FLOATING SOLAR CHIMNEY TECHNOLOGY- A SOLAR PROPOSAL FOR CHINA

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ABSTRACT

The Floating Solar Chimney (FSC) Technology Power Plants, are made of three major components:

- A large solar collector with a transparent roof that warms the air below it, due to the solar irradiation.
- A tall lighter-than-air hollow cylinder placed in the center of the solar collector that is up-drafting the warm air, through its open top to the upper atmosphere (the Floating Solar Chimney).
- A series of air turbines, placed in the path of moving and up-drafting stream of warm air, geared to appropriate electric generators, that transform part of the thermodynamic energy of the moving stream of air to electricity.

In the present paper the large scale application of FSC Technology in China is examined with the conclusion that this technology could cost-effectively meet, much of China's electricity demand, promoting China's sustainable development and eliminating greenhouse gas emissions.

1. INTRODUCTION

By 2030, China's total electricity consumption is projected to be 6000 to7500 TWh. This figure is based on an estimate future population of 1.5 billion and per capita electricity consumption of 4000 to 5000 Kwh/year. This estimate is reasonable considering the estimated future (in the year 2030) per capita electricity consumption rates in Western Europe (8400 Kwh/year), North America (18000 Kwh/year) and Japan- Pacific (11600 Kwh/year).

Without cost effective renewable electricity production it is most likely that most of China's power will come from coal-fired power plants due to the availability of coal reserves in China. This will make China (that today is the second, after USA, producer of CO_2) the world's leading emitter of CO_2, at a time of growing threat of global warming of our planet.

The Floating Solar Chimney Technology is a viable solar technology that can generate electricity in Solar Aero Electric Power Plants (SAEPPs), named due to their similarity to hydroelectric power plants. SAEPPs are operating 24 hours per day and thus can replace baseload coal-fired power plants with a competitive cost per produced KWh.

The lighter than air Floating Solar Chimneys of the SAEPPs can reach heights up to 1300 m, and thus achieving efficiencies up to 1.5% on the solar irradiation on horizontal surface.

Taking into consideration that the best area for a large-scale installation of SAEPPs is the Xinjiang region where the annual solar irradiation on horizontal surface exceeds 1700 Kwh/m^2, the amount of land required to operate a SAEPP producing 100 GWh/year is not more than 4 Km^2. Thus China in order to generate 4000 TWh (up to year 2030), or most of its electricity, a desert or semi desert land area of 160000 Km^2 (400 Km x 400 Km) in this region or similar desert areas elsewhere, is required.

This constitutes less than half of the Taklamakan desert of Xinjiang region.

As it will be shown this can be achieved with investments on SAEPPs that will not exceed the investments in equivalent electrical energy producing coal fired power plants, while the used material and equipment used for the construction of these power plants can be produced locally in China.

2. FLOATING SOLAR CHIMNEY TECHNOLOGY

2.1 FSC Technology presentation

Floating Solar Chimney (FSC) Technology is a cost effective version of solar chimney technology, see http://www.peswiki.com/index.php/Directory:Floating_Solar_Chimney .

The main parts of the respective power plants (SAEPPs) are:

- A large solar collector open in its perimeter with a transparent roof (glass is the best option). Below of this large greenhouse the air is warming, due to the solar irradiation (the greenhouse).
- A tall lighter than air hollow cylinder placed in the center of the solar collector that is up-drafting the warm air, through its open top to the upper atmosphere (the Floating Solar Chimney FSC).
- A series of air turbines, placed with horizontal axis around the solar chimney in the paths of moving warm air from the open perimeter of the solar collector towards the bottom of the FSC and up-drafting through it. These air turbines geared to appropriate electric generators are transforming part of the thermodynamic energy of the moving stream of warm air to electrical energy.

A SAEPP with Floating Solar Chimney under external winds is shown in fig.1

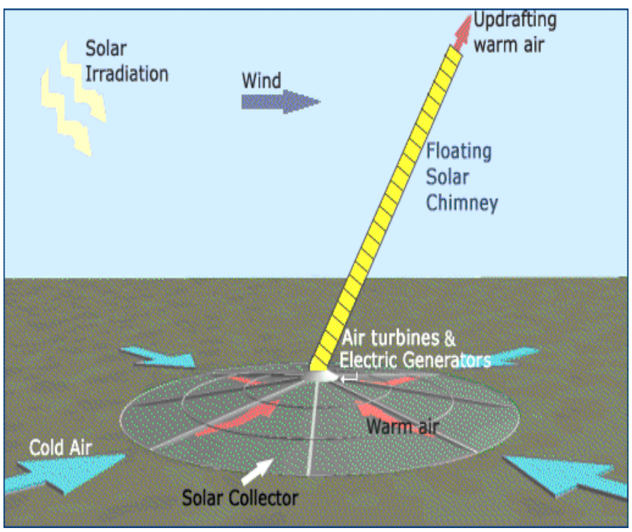

Fig 1: Indicative presentation of a SAEPP with FSC under external winds.

The operation of SAEPPs is similar to the operation of the hydroelectric power plants. The SAEPPs are using the dynamic energy of up-drafting buoyant warm air. Hydroelectric power plants use the dynamic energy of falling water due its gravity. Both are using turbines in order to transform part of their fluid's dynamic energy to rotational energy and through their geared electric generators to produce electric energy. The efficiency of the SAEPPs is proportional to their solar chimney's height, as the efficiency of the hydroelectric power plant is proportional to the dam height.

In fig2 the efficiency of SAEPPs (defined as the ratio of annually generated electricity to the solar energy arriving on the land of the SAEPP) with floating solar chimneys of height H and internal diameter 60m as function of H is shown. The SAEPPs are assumed to be installed in areas where the average annual solar irradiation is 1700 Kw/m^2 and their solar collectors have areas of 4 Km^2, which for example is an optimum design for the Taklamakan desert.

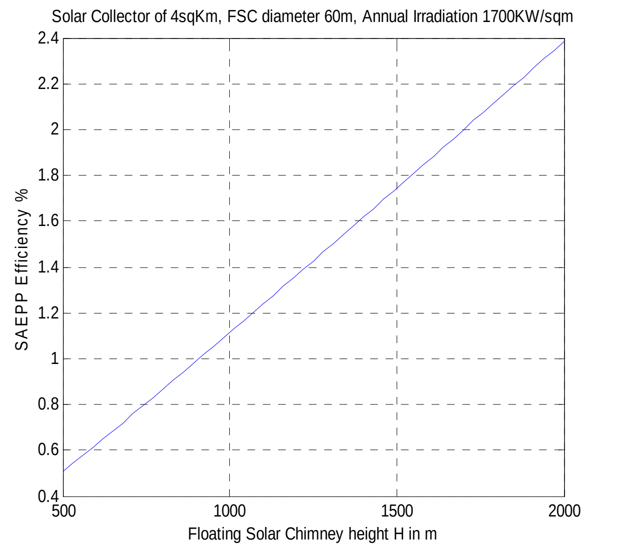

Fig. 2: Efficiency of a SAEPP as function of its FSC height

Solar Chimney Technology has been successfully tested several years ago in Spain where a small power plant of 50 KW with a steel solar chimney of 200m with 10m internal diameter was operating and tested for several years by Prof. Jorg Schlaigh and his team. Prof. Jorg Schlaigh proposed in his book [1], the construction of SAEPPs with enormous reinforced concrete solar chimneys. However the proposed concrete solar chimneys are expensive constructions and have a height limit up to 600m, due to concrete and steel specific weights and strength. For such heights the efficiencies of their respective SAEPPs are limited, and in order to generate a defined amount of electric energy, the solar collectors must be very large and thus expensive.

In order to increase the efficiency of solar chimney power plants and to decrease their cost, taller solar chimneys as lighter-than-air inflated fabric structures, named Floating Solar Chimneys (FSCs), were proposed and studied by the author [2,3,4]. A recent estimation [5] gives a figure of 5 to 6 times less investment cost, for the same rating power, of Floating Solar Chimney SAEPPs compared to concrete solar chimney SAEPPs.

A major advantage of SAEPPs in comparison to other renewable power generation methods (wind, solar concentrators, solar photo-voltaics) is the ability of their SAEPPs, due to ground thermal storage , to generate a guaranteed profile of baseload power for 24h/day, 365days/year. In fig3 the produced electric power % by a SAEPP in a typical day is shown.

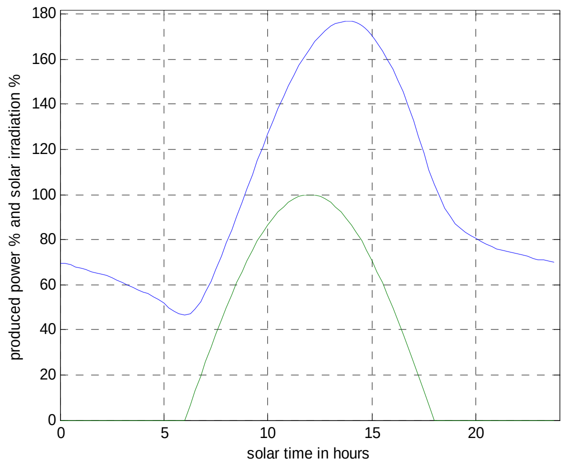

Fig. 3: A typical daily variation of power production of a SAEPP with the respective solar irradiance.

Several institutions have built small demonstration models of SAEPPs, such as Huazhong University of Science and Technology in China [6] or they have publish experimental or theoretical work on various aspects of this technology [7,8,9]. As scientific research on solar chimney technology and engineering know-how on the construction of the SAEPPs are accumulated I believe that soon a successful model of a SAEPP of several MW will be financed and realized proving not only the viability of the FSC Technology but also its cost competitiveness in comparison to conventional fuel consuming power plants (coal, natural gas, nuclear etc.).

2.2 <u>Power production and cost of FSC Technology in comparison to coal fired power plants</u>

According to initial design estimations an optimum SAEPP with a Floating Solar Chimney appropriate for Taklamakan desert area with a minimum annual solar irradiation of 1700 Kw/m^2 should have the following characteristics:

- An annual electricity production approximately of 100 GWh
- A Floating Solar Chimney with a maintainable height of 1300m, and a reasonably proportional external diameter (of 1 to 20), define its internal diameter approximately to 60m
- The previous decisions can define approximately the area of the solar collector of the SAEPP in order to produce 100 GWh/year to 4 Km^2
- Taking into consideration that the hours of operation for the rating power of the SAEPP are not less than 3000 hours, the rating power of air turbines gear boxes and electric generators is approximately 32 MW. The rating power of the SAEPP is defined as the maximum electric power produced at maximum irradiance on horizontal surface (as is the noon of a summer day).

A solar farm of 16 identical SAEPPs with an overall rating power of 512 MW will be an electricity generating plant with an annual production of 1600 GWh. This SAEPP solar farm can be operated and maintained by a team of properly trained personnel, not bigger than the number required for the operation and maintenance of a coal-fired power plant producing the same annual amount of electrical energy, which would have approximately a rating power of 200 MW.

Taking into consideration prices in China for glass, fabric and power equipment (air turbines, gearboxes, electric generators), the SAEPP of 32 MW it is estimated that will have a construction cost, in China, of approximately 32 million USD (~1000 USD/KW). The investment cost for the SAEPP solar farm, operating 24 hours per day following the fig 3 production curve, which is an approximation of the demand curve for a baseload coal-fired power plant, is 512 million USD. This investment cost is comparable to the investment cost in China for a 200 MW coal-fired power plant.

Although the amount of land for the SAEPP solar farm (64 Km^2) is great, the land cost is negligible, since is desertified and largely unused arid or semi-arid land.

Taking into consideration that the SAEPP solar farm demands no fuel, the production cost of an electrical KWh by the SAEPP solar farm is lower than the production cost of a KWh by the coal-fired power plant.

The decision of choosing SAEPP solar farms instead of coal fired power plants will be a reasonable investment financial decision as soon as the viability and the investment cost of the FSC Technology will be evaluated. The best way for this evaluation is the construction of a model SAEPP of several MW, installed in the Taklamakan desert for example.

However the decision of replacing the future coal-fired power plants in China with SAEPP solar farms is not only an optimum investment financial decision but has also other major environmental positive results as:

- The SAEPP solar farms do not produce any CO_2 emissions
- The SAEPP solar farm demands no water for its operation, while the coal fired power plant spends a lot of this valuable resource.
- The SAEPP solar farm can be used as a rain collecting water system with its large solar collectors' roofs.

The prospect for a solar China producing up to year 2030, 4000 TWh by SAEPP solar farms installed in appropriate areas of unused land of its various desert or semi desert areas in its northwestern regions is a very reasonable proposal.

The necessary investment cost for this decision it is not higher than the investment cost for the generation of the same electricity by coal-fired or nuclear power plants. The investment, on SAEPP solar farms, annual cost is estimated to 60 billion USD for the years 2010 to 2030, and will secure China's sustainable development for ever. Simultaneously China will lead the world race towards the road for elimination of CO_2 emissions that are creating the threatening global warming effect, and thus securing the safety of our planet.

There are also complimentary strong arguments supporting the decision of a SAEPP solar future for China the most important of which are:

- China's land availability with appropriate solar irradiation (mid-latitude desert climate areas like Taklamakan are the best for FSC technology application having low wind potential and low precipitation).
- China's availability, in reasonable prices, of the basic material used in the construction of the SAEPPs (like glass, fabric etc.)
- China's engineering and industrial ability to design and produce in, reasonable prices and excellent quality, the basic equipment for this technology (like air turbines, gear boxes, electric generators etc.)

3. CONCLUSIONS

China's mid-latitude deserts (as Taklamakan), have proper meteorological conditions and large areas of unused land for a large scale application of Floating Solar Chimney Technology. A Solar Aero Electric farm producing 1600 GWh/year, operating due to ground thermal storage 24h/day, can replace a coal fired power plant of 200 MW. The investment, operation and maintenance cost of both power plants are almost the same, but SAEPPs is a zero fuel power plant with no CO_2 emissions. Although personally I have no doubt about the effectiveness of the FSC Technology, I consider that a decision for a large scale application on FSC Technology in China's lands will demand the results by an operating model SAEPP of several MW with a Floating Solar Chimney of at least several hundred meters.

4. REFERENCES

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