# Floating Solar Chimney Technology

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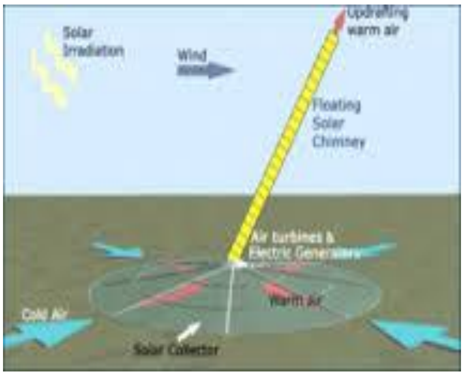
**Abstract: The Floating Solar Chimney (FSC) Technology Power Plants, are made of three major components:**

- **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.**

## I. INTRODUCTION:




The Floating Solar Chimney Power Plant, named by the author as **Solar Aero-Electric Power Plant (SAEP)** due to its similarity to the Hydro-Electric power plant, is a set of three major components:

- **The Solar Collector (greenhouse)**

It is a large greenhouse open at its periphery with a transparent roof supported a few meters above the ground.

- **The Floating Solar Chimney (FSC).**

It is a tall fabric cylinder placed at the centre of the solar collector through which the warm air of the greenhouse, due to its relative buoyancy to the ambient air, is up-drafting. Floating Solar Chimney is patented by the author in USA and several other countries.

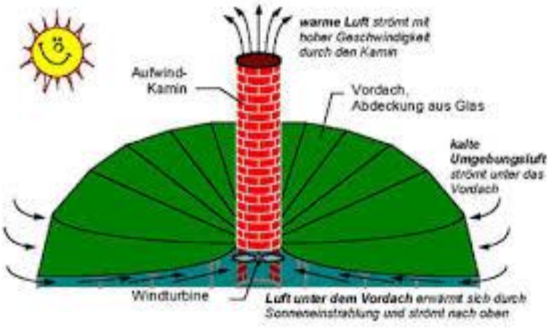
- **The Electric Power Unit**.

It is a set of air turbines geared to appropriate electric generators in the path of up-drafting warm air flow that are forced to rotate generating electricity. The gear boxes are adjusting the rotation speed of the air turbines to the generator rotation speed defined by the grid frequency and their pole pairs. The energy source, for the rotation of the air turbines and the electricity generation, is the horizontal solar irradiation passing through the transparent roof of the greenhouse and heating the ground beneath it. The ground thermal energy is partly transferred to the air stream, entering the greenhouse and moving towards the FSC bottom entrance.

Thus the first two components of the floating solar chimney power plants form a huge thermodynamic device, up-drafting the groundambient air towards the upper atmosphere layers and the thirdcomponent is the electricity generating device operating by the up-drafting warm air mass.

**Principles of operation of the solar chimney technology and its annual efficiency Information:**

**Short description and principles of operation:**




A floating solar chimney power plant (SAEP) is made of three major components:

• A large solar collector, usually circular, which is made of a transparent roof supported a few meters above the ground (the greenhouse). The transparent roof can be made of glass or crystal clear plastic. A second cover made of thin crystal clear plastic is suggested to be hanged just underneath the roof in order to increase its thermal efficiency. The periphery of the solar collector is open in order that the ambient air can move freely into it.

• A tall fabric free standing lighter than air cylinder (the floating solar chimney) placed in the center of the greenhouse which is up drafting the warm air of the greenhouse, due to its buoyancy, to the upper atmospheric layers.

• A set of air turbines geared to appropriate electric generators (the turbo generators), placed with a horizontal axis in a circular path around the base of the FSC or with a vertical axis inside the entrance of the solar chimney. The air turbines are caged and can be just a rotor with several blades or a two stage machine (i.e. with a set of inlet guiding vanes and a rotor of several blades). The gear boxes are adjusting the rotation frequency of the air turbines to the electric generator rotation frequency defined by the grid frequency and the electric generator pole pairs.

The horizontal solar irradiation passing through the transparent roof of the solar collector is heating the ground beneath it. The air beneath the solar collector is becoming warm through a heat transfer process from the ground area to the air. This heat transfer is increased due to the greenhouse effect of the transparent roof.

This warm air becomes lighter than the ambient air. The buoyancy of the warm air is forcing the warm air to escape through the solar chimney. As the warm air is up drafting through the chimney, fresh ambient air is entering from the open periphery of the greenhouse. This fresh air becomes gradually warm, while moving towards the bottom of the solar chimney, and it is also up-drafting.

Thus a large quantity of air mass is continuously circulating from ground to the upper layers of the atmosphere. This circulating air mass flow is offering a part of its thermodynamic energy to the air turbines which rotate and force the geared electric generators also to rotate. Thus the rotational mechanical power of the air turbines is transformed to electrical power.

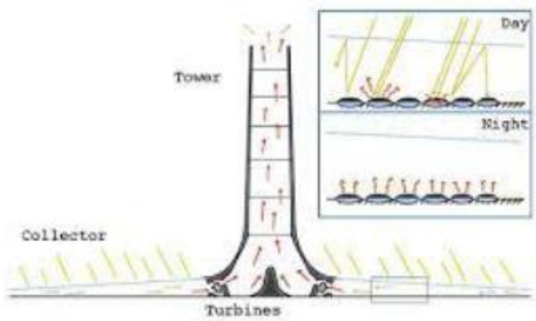
Thus the first two parts of the SAEPs form a huge thermodynamic device up drafting the ground ambient air to the upper atmosphere layers and the third part of the SAEP is the electricity generating unit.

The solar energy arriving on the horizontal surface area Ac of the greenhouse of the SAEP is given by EIR=Ac·Wy, where Wy is the annual horizontal solar irradiation in KWh/m2, at the place of installation of the SAEP and is given by the meteorological data nearly everywhere.

The average annual horizontal solar irradiance is given by Gav=Wy/Ac. The horizontal solar irradiation is offering thermal power PTh= m□·cp· (T03-T02) to the up drafting air mass flow m□of the ambient air, cp≈1005 and T02 is equal to the average ambient temperature T0 plus ~ 0.5 0K, in order that it is taken into account the outer air stream increased inlet temperature due to its proximity to the ground on its entrance inside the solar collector.

**Energy storage in the collector:**

The ground under the collector roof behaves as a storage medium, and can even heat up the air for a significant time after sunset. The efficiency of the solar chimney power plant is below 2% and depends mainly on the height of the tower. As a result, these power plants can only be constructed on land that is very cheap or free. Such areas are usually situated in desert regions. However, this approach is not without other uses, as the outer area under the collector roof can also be utilized as a greenhouse for agricultural purposes.




Water filled black tubes are laid down side by side on the black sheeted or sprayed soil under the glass roof collector. They are filled with water once and remain closed thereafter, so that no evaporation can take place. The volume of water in the tubes is selected to correspond to a water layer with a depth of 5 to 20 cm depending on the desired power output.

Since the heat transfer between black tubes and water is much larger than that between the black sheet and the soil, even at low water flow speed in the tubes, and since the heat capacity of water (4.2 kJ/kg) is much higher than that of soil (0.75 - 0.85 kJ/kg) the water inside the tubes stores a part of the solar heat and releases it during the night, when the air in the collector cools down.

Kreetz (1997), also furnished with ground water storage systems of solar chimney examined the effect of the power of time, depending (Bernardes, 2004) [35].His calculations showed the possibility of a continuous day and night operation of the solar chimney. Hedderwickand Pretorius et al. (2004) studied and discussed the temperature distributions in the ground below the collector are also presented and discussed.

It is thus found that the ground plays an important role in the energy consumption. Pretorius et al. compared the power outputs of six different ground types: sandstone, granite, limestone, and sand, wet soil and water. They found that the SCPPs employing the wet soil and the sand have the lowest and highest power outputs respectively, and different materials lead to varying power outputs during the daytime and at night. Pretorius also concluded that increased ground absorptivity holds positive effects on annual solar chimney power output. Hammadi (2008) have developed a mathematical model for a solar updraft tower with water storage system. This study studied the effect of thermal storage system on the power production of the plant. the obtained results showed that The thickness of the water storage layer is shifted the peak value of the output power far away from mid-day and more smoothing the output curve.

Ming et al (2009) analyzed the characteristics of heat transfer and air flow in the solar chimney power plant system with energy storage layer. Different mathematical models for the energy storage layer have been developed, and the effect of solar radiation on the heat storage characteristic of the energy storage layer has been analyzed. Simulation results show that the heat storage ratio of the energy storage layer decreases firstly and then increases with the solar radiation increasing from 200 W/m2 to 800W/m2 and that the average temperature of the chimney outlet and the energy storage layer may increase significantly with the increase of the solar radiation. An experimental study was conducted in Baghdad by Chaichan focusing on chimney's basements kind effect on collected air temperatures. The objective of this study was to examine the effect of basement types on the air temperatures of a prototype solar chimney designed and constructed for this purpose. Three basements were used: concrete, black concrete and black pebbles basements. The results show that the highest temperature difference reached was with the pebble ground. The effects of storage parameter, such as the solar radiation, the ambient temperature, and the heat storage capacity for ground materials on the power plant operation time were also investigated.

To analyze the performance of a solar chimney with energy storage layer Zheng et al (2010) have carried out a numerical study. The response of different energy storage materials to the solar radiation and their effect on the power output were analyzed. This study has shown that soil and gravel could be used as energy storage material for solar chimney system. Ming et al performed unsteady numerical simulations to analyze the characteristics of heat transfer and air flow in the solar chimney power plant system with energy storage layer. The authors established mathematical models of the different parts of the system. They have studied the effect of solar radiation on the heat storage characteristics of the energy storage layer. The numerical simulations showed that it is beneficial for the utilization of soil, with comparatively higher heat capacity, as the material of energy storage layer, which could effectively modulate the temperature and power output difference of the solar chimney power plant between the daytime and night. The simulation results showed that the larger the conductivity of the energy storage layer, the lower the surface temperature of the energy storage layer.

Fanlong et al (2011) adopted in their research the hybrid energy storage system with water and soil to decrease the fluctuation of solar chimney power generating systems. The authors established mathematical models of fluid flow, heat transfer and power output features of solar chimney including an energy storage layer. Also the influence of the material and depth of energy storage medium upon power output has been analyzed. The simulation results demonstrate that hybrid energy storage system with water and soil can effectively decrease the power output fluctuation.

Najmi et al (2012) have chosen Paraffin as the material of energy storage layer. In this study, an unsteady conjugate numerical simulation of the system was done by FLUENT software. The operation condition of the system was simulated when the solar radiation value was changed with time according to the actual situation. Due to the energy storage effect of phase change materials, the system had output power of 1.3W at night. Moreover because of the continuous work of the heat storage layer, in the same condition of solar radiation, the air velocity and maximum output power increased with the system operation days extended.

Xu et al. (2011) performed a numerical simulation of a solar chimney with an energy storage layer similar to the Spanish prototype. An experimental investigation of the effect of ground temperature changes on the solar chimney system were carried out by Buğutekin.

## ADVANTAGES AND DISADVANTAGES:

Advantages of industrial chimney are:

- Wastage flue gasses is used to generate electricity
- This plant helps to provide electricity for increasing demand in future. Disadvantages of industrial chimney are:
- Flue gasses affect the turbine blades.
- Finally, with installation of a turbine in a chimney there will be a loss of total up-drafting energy of

flue gases which would further affect the draught produced by the chimney.

So, further study would be needed to assess the effect on the entire system and do the necessary constant analysis.

## CONCLUSION:

The purpose of this paper is to give initial information for the technological feasibility construction of the FSC, and to present preliminary results of such a construction with ordinary low cost materials.

The existing materials plastic and Al etc used to made FCS.

Using such materials and design techniques, the FSCs can be constructed with a bigger height and much lower cost compared to a solar chimney by reinforced concrete. The FSCs' construction techniques with any appropriate diameter and height, for the STPSs of given power output, could accelerate the use of solar chimney power stations.

It is worthwhile to mention that special studies of experts could be proved important especially in the following subjects:

- Study of solar collector in order to maximize its efficiency around the point of maximum power output.
- Study of supporting ring structure, for achieving the maximum strength under given sub pressure. This can be achieved using a combination of special or composite material, and appropriate design.
- Study of dynamical behavior of the FSC under external winds of variable speed with altitude.
- Study and design of an appropriate type of stepped-pressure ducted air turbine. also in case of industrial chimney some of the important points to be considered are:
- Effect of particulate matter in flue gases on the turbine blades;
- Cost analysis of amount of energy produced in a given time frame vs. actual cost of installation and maintenance;
- Effect on draught produced by using a turbine in the chimney.

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