Carbon Emissions and Floating Solar Chimney Technology

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1. INTRODUCTION

This is an energy and global economy transient period. The end of Fossil fuels (oil and natural gas) is not too far. Climate change indications due to global warming threat are accelerating. Climate change policies should be agreed upon and urgent measures should be taken. Global warming due to greenhouse gases emissions (CO_2, CH_4 etc.) is a reality scientifically documented.

For an estimated average cost of 20-30 EURO/tCO_2, the carbon emissions cost in Greece for the minimum projected fossil fueled electricity of 50000 GWh/year, even for a 50% to 50% share between coal and natural gas, it will reach 750-1000 million EURO per year after 2012. Thus for Greek electricity producers (ΔEH etc.) the Kyoto protocol penalty cost is very heavy.

Floating Solar Chimney (FSC) technology is a low cost version of solar chimney technology. The power plants of the FSC technology do not demand water, operate continuously (24X365) and their average daily electricity production is proportional to the daily horizontal irradiation. A large scale application of the FSC technology in Greece, or in MENA area for Greece, is feasible and can be implemented in a few years. Applying this cost efficient solar technology as well as other renewable technologies, Greece can fulfill its Kyoto protocol obligations and its CO_2 emissions cost could be minimized.

2. THE CO_2 EMISSIONS COST FOR FOSSIL FUELED POWER PLANTS

The energy sector is the major contributor of the green house gases due to fossil fuelled technologies in electricity generation, transport, industry etc. For year 2010 an estimated quantity of 29,000 Mt of carbon dioxide will be spread to the environment by fossil fuels of which:

- 36.4 % for electricity generation
- 20.8 % for the industry
- 18.8 % for transport and
- 14.2 % for household, service and agriculture and
- 9.8 % in international bunkers

The mechanism of Kyoto protocol aims to make “objective” the external cost at least for the threatening carbon dioxide (CO_2) emissions through trading their rights.

The cost of the emitted CO_2, sooner or later it will reach at prices 20-30 EURO per ton of CO_2 and after the year 2012 the fossil fuelled PPs should pay for every ton of CO_2 emitted by them. Taking into consideration that 1 Kg of coal has a thermal energy of ~8.14 KWh, thus a modern coal fired power plant with efficiency ~45% will generate by this ~ 3.66 KWh and will emitt to the environment 3.667 Kg of CO_2. Thus in a modern coal fired plant approximately 1.0 Kg of CO_2 is emitted per generated KWh. For the existing in Greece lignite coal fired power plants this figure is 50% higher and for modern combined cycle natural gas power plants could be 50% smaller.

Thus for an estimated average cost of 20-30 EURO/tCO_2, the carbon emissions cost, after the year 2012, for the minimum projected fossil fueled electricity generated in Greece of 50000 GWh/year, and for a 50% to 50% share between coal and natural gas, will reach the amount of 750-1000 million EURO per year. In case of CO_2 prices rise to 50 EURO/ton, the carbon emissions cost for Greek electricity generating companies it will be extremely heavy even beyond 2 billion EURO/year. In this case the electricity tariffs for the consumers could be increased by 50% only for carbon emissions penalties. Thus urgent measures by the Greek state and electricity producers are necessary.
The investments in renewable electricity technologies should be encouraged and should be increased, however with the existing status of technology the wind and solar technologies without storage systems can enter to the electric grid up to 20 % of the power of the system.
Taking into consideration a projected maximum power demand of 12 GW for the Greek electricity system, the maximum power by all renewable producers can not be more than 2.2 GW. For an estimated maximum annual production (by wind turbines) of 2500 KWh per KW, the annual energy offer to the Greek electric grid will not be more than 5.5 TWh, that is approximately 10% of the projected fossil fueled generated electricity. Thus the decision for the investment increase in classic renewable technologies is necessary but not enough.
The other two options are the nuclear power plants and the coal fired power plants with carbon capture and storage. Even if the decisions for such technologies could be magically supported by the majority of the political parties, the public opinion and the local communities in the places of their installation, due to complicated technological and legal matters that should arise, their implementation it could last decades beyond the year 2012. Thus another approach is necessary. My proposal is related to a low cost alternative of solar updraft tower technology named Floating Solar Chimney technology.

3. FLOATING SOLAR CHIMNEY (FSC) TECHNOLOGY PRESENTATION

The solar chimney power plants are usually referred as solar updraft power plants http://en.wikipedia.org/wiki/Solar_updraft_tower and their proposed solar chimneys are reinforced concrete structures. A low cost alternative of the concrete solar chimney is the Floating Solar Chimney (FSC) www.floatingsolarchimney.gr .
The solar chimney technology was experimentally tested in Manzanares of Spain, where a small prototype of 50 KW was built in 1982 and successfully tested for 6 years, by the team of Prof J. Schlaich. Part of the results by the operation of this small demo is appearing in the book [1] and in the reference [2] .
A thermodynamic cycle analysis of the solar chimney power plant operation was given by Prof Backstrom and his associates the paper [3].
Floating solar chimney technology was presented by the author in a series of papers [4,5,6,and 7]. Most recently the author presented a paper [8] for the application of the FSC technology in desert areas of China with adequate horizontal irradiation. Similar desert areas, even with higher solar irradiation, exist in USA, South America, Australia, south and North Africa and India. It is estimating that with FSC technology, operating on 1% efficiency and using a 2-3% of the existing unused desert or semi desert areas, we can generate at least 50% of the world electricity demand.
There are places in Europe of adequate solar horizontal irradiation but in general the land is very expensive and there are no desert or semi desert areas. However in the nearby to Europe Middle East and North Africa (MENA) countries, there are huge unused desert or semi desert areas with appropriate solar characteristics that can be used for solar

electricity generation. This solar electricity can be transmitted to the European electric grid through appropriate HVDC or UHVDC electric lines.
A Floating Solar Chimney (FSC) power plant is made of three basic parts:

- A large solar collector with a transparent roof supported a few meters above the ground, open at its perimeter (the greenhouse).
- A tall lighter than air cylinder in the center of the solar collector (the Floating Solar Chimney)
- A set of air turbines geared to appropriate electric generators placed in a circular path around the FSC (the turbo-generators)

The solar irradiation warms the ground below the roof of the greenhouse and the air inside it. The warm air becomes lighter than the ambient air and tends to escape though the solar chimney, up drafting to the upper atmospheric layers. New ambient air is entering in the Greenhouse through its open periphery that, as is moving towards the FSC, becomes warm by the solar irradiation and is also up drafting through the FSC etc. In the path of the airflow of the warm air are placed appropriate air turbines, with inlet guiding vanes, geared to electric generators that transform to electricity a part of the thermodynamic energy of the moving air mass.
The FSCs can easily be constructed to heights up to 1 Km. The figure (1) is representing the FSC power plant and its operation.

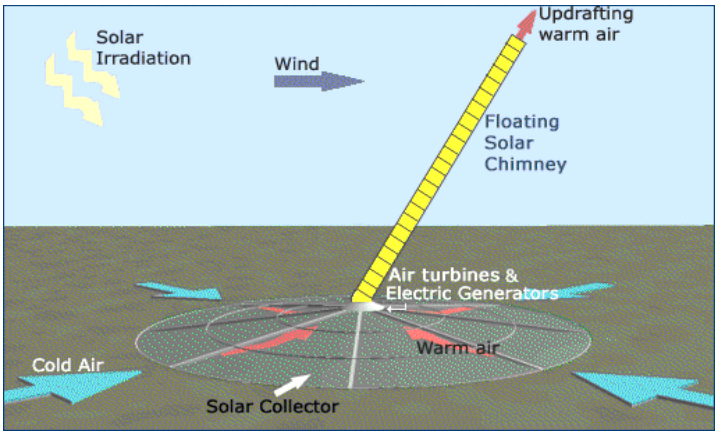

Figure1.Floating Solar Chimney Power Plant in operation

The FSC is made by a series of successive tubular balloon rings made of fabric.
The polyester fabric of the tubular rings and the rest parts of the FSC, is similar to the polyester fabric already used for the construction of air balloons or airships. These tubular balloon rings can become lighter than air containing special balloons filled with lighter than air gas (He or NH_3). In order to keep the rigidity of the structure the balloon tubular rings should be over pressed with ambient air. Thus the whole fabric cylinder can not be deformed by external winds or by the operational sub pressure and can be a free standing lighter than air structure. Through this free standing cylinder the warm air of the greenhouse is up drafting. When external winds appear the structure is bending due to its inclining special patented heavy base but its up drafting operation it is not interrupted.

4. SOLAR AERO ELECTRIC POWER PLANTS MAIN CHARACTERISTICS

The FSC power plants named by the author as Solar Aero Electric power plants (SAEPPs) are similar to hydroelectric power plants. In hydroelectric power plants the dynamic energy of the falling water, due to gravity, is transformed to electricity through water turbines geared to appropriate electric generators. In the SAEPPs the dynamic energy of the warm air, due to buoyancy, is partly transformed to electricity through their air turbines geared to their appropriate electric generators. The annual efficiency defined as the ratio of the produced electricity in KWh to the annual solar irradiation arriving on the greenhouse roof is proportional to the height of the FSC as shown in Fig(2).

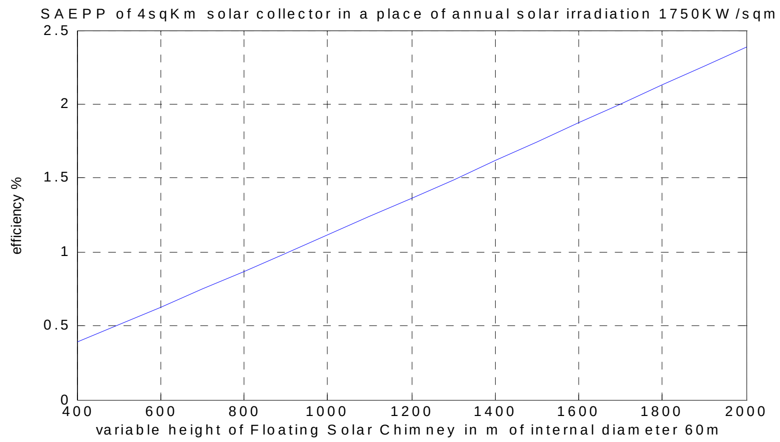

Figure 2. Annual efficiency of a typical SAEPP as function of its FSC height

Due to the ground thermal storage Bernades [9] and Pretorius [10] have shown that the SAEPP can operate all year round 24 hours per day. Typical daily operation curves for an average day of the year is shown in the fig.(3), with and without artificial thermal storage

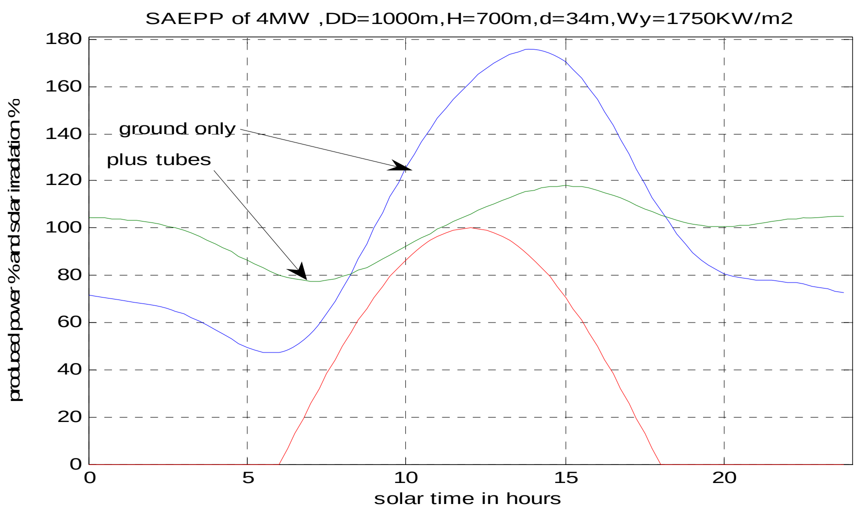

Figure 3. Typical daily production curves of the SAEPP

In ref. [4] the author has proposed an algorithm through which the produced average electric power by the SAEPP can be calculated, as function of its mass flow, given the dimensions of the SAEPP and the annual solar irradiation of its place of installation.

5. SAEPP FARMS IN GREECE OR MENA COUNTRIES

Due to 24x365 operation electricity by SAEPPs can enter to the grid up to 75% thus for Greek electric grid the maximum (rating) power by SAEPPs could reach up to 8 GW, for annual electricity production 4000 KWh/KW by SAEPPs, an annual electricity of 32 TWh can be offered to the electric grid (60% of the fossil fuelled electricity). The maximum power by SAEPPs is achieved during the summer noon hours when is more

appropriate. The proper way of applying the FSC technology is by large farms made by a series of adjacent SAEPPs. For 1% efficiency (900 m FSC) in an average Greece area of 1600 KW/m^2 annual horizontal irradiation, a land of 4 Km^2 can generate electricity up to 64 GWh/year. The necessary land for the 32 TWh/year, supplied by 500 SAEPPs of 4 Km^2 land, is 2000 Km^2 i.e. a square land of 45 Km x 45 Km. In MENA countries there are huge unused lands of annual solar horizontal irradiation above 2000 KW/m^2. Thus each SAEPP of 4 Km^2 will generate annually at least 80 GWh. Thus in MENA area the necessary SAEPPs are 400 and the necessary land is1600 Km^2, or a square of 40 Km x 40 Km. Estimating the construction cost for the basic unit SAEPP, of 4 Km^2 greenhouse and of a FSC of height 900m and internal diameter 64m, in 40-45 million EURO the investment in MENA area of the farms of 400 SAEPPs it will be in the range of 16-18 billion EURO, including the investment for the UHVDC lines for the transmission of the generated electricity to the Greek electric grid. As it is obvious the required investment for this project can be repaid almost by the CO_2 penalties.
However the FSC technology should be tested by a small demo of 1MW, with a greenhouse of 500000m^2 and a FSC of 450m height and 24m internal diameter. The cost of this demo it will be less than 5 million EURO and will produce 4 GWh/year. I hope that the proposal demo SAEPP project will be supported by the market and the Greek state, taking into consideration that there is an urgent demand for renewable energy in order Greece to meet the demands of KYOTO protocol.

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