ID: 2016-ISFT-401

A Review on Untapped Technologies and Possibilities in the Field of Renewable Energy

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Abstract: *Energy is that inseparable part of our lives that has not only enabled us to create modern marvels of science and technology but also sustain lives and work for ages. It is that property of a substance which makes it suitable for the harnessing of work. However over time the conventional and exhaustible sources of energy i.e. fossil fuels and such others have dwindled which give way to the worldwide campaign for the development of renewable sources of energy. This paper reviews some of such largely untapped sources which are currently undergoing research and optimization phase, namely kitewind generator, Google-funded EGS working to tap geothermal energy, fuel cells, solar satellites, tornado based power plant and other such technologies that are establishing their feet in the bid to end global power crisis, that so often dictates economies and governments.*

Kitewind generator is an innovative project that tries to convert the upper troposphere's wind energy into viable electrical energy using kites that drive turbines on ground. Geothermal energy is the procurement of heat from the earth that is further used to drive steam turbines. Compressed air energy is derived from compressed air from a high pressure source filled generally using electrical power. These sources are the alternatives for energy security and independence from exhaustion, also reducing pollution and other hazards. This paper will review all such technologies, their methods and theory of operation, feasibility, failings and future course of action.

Keywords: *Atmospheric Vortex Engine (AVE), Enhanced Geothermal Systems (EGS), Fenton Hill Project, Fuel Cells, Fuel Cell Technologies Program (FCTP), Kitewind Generator, Makani Power, Solar Powered Satellites (SPS).*

1. INTRODUCTION

The increasing prices of crude oil and conventional energy resources, their fast depletion and the accompanying environmental pollution have called for the need for alternative sources of energy. Energy is required in all sectors from transportation, production, defence, processing, telecommunication, space endeavours, engineering to any other thinkable fields. The peak oil theory predicts a decline in production by 10% owing to the depletion of crude oil by 2020. [1] Oil constitutes about 29% of our energy supply. [2] Also this supply drop is not predicted to be gradual but rather drastic that calls for the development of sources that tackle this problem at the earliest. [1] Coal supply (currently 29% of world energy needs) is estimated to be halved by 2047. [3] Only natural gas, which is 25% of our energy supply, will peak after 2020. [4]

This paper aims at reviewing such technologies that are being studied and are under the developmental face to provide emission-free low-cost energy supply to the world. This paper first reviews Atmospheric Vortex Engine (AVE), which harnesses mechanical energy due to convection of heated air by the formation of a vortex. This vortex acts as a virtual draft chimney and the removal of heat at lower temperatures improves the efficiency of the plant greatly. This is followed by Enhanced Geothermal Systems (EGS) which harness the geothermal energy of the subsurface rocks by artificially fracturing the surface due to the injection of a fluid. The energy is then returned in the form of heated working fluid via the production wells.

Fuel Cells are another way to combat energy crisis where electrochemical means are used to make use fuel energy in a clean and efficient manner. The fuel is oxidised at the anode and the electron flow ensure current supply.Kitewind generators are used to harness the energy of winds in upper troposphere where the winds are steadier and possess higher velocities. Solar powered satellites (SPS) are currently under consideration to make use of solar energy in space and transmit it back to earth using microwave or laser techniques. These technologies are the way to a safe future without compromising the needs of today. General understanding and exposure to them is of the utmost importance to understand the crisis world is facing today.

2. DESCRIPTION OF EMERGING TECHNOLOGIES

2.1.1 ATMOSPHERIC VORTEX ENGINE (AVE)

Atmospheric Vortex engine is the technology that has created many expectations around its feasibility and future potential. An AVE is used to harness mechanical energy which is developed due to natural convection of air, which

can be heated by waste heat from industries, ground solar-energy or naturally heated seawater. The technology does not call for any modifications to the ground to collect heat as in conventional solar renewable energy sources. [5]

In 1982, in Manzanares, South-Central Spain, a 600-foot high experimental setup tried to harness the energy of rising air in a natural draft chimney by using plastic panels at the bottom to heat the air. The air rose in the chimney and it was found that 50 KW energy was developed. However in such an experiment, the cost of obtaining the ground area and construction are a major bottleneck. Thus natural draft is not to be relied upon and instead an AVE tries to generate a vortex to overcome this problem. [5]

Naturally occurring "dust devils" is a phenomenon that occur globally due to heated ground surface. This phenomenon is the base for the research in the field of AVE where instead of dust devils vortices are created by converting the gravitational potential energy to solar-induced kinetic energy of the wind. These vortices are confined in a converging chimney with vanes placed azimuthally for imparting tangential velocity to the entering air to form self-sustaining vortices. These vortices can be tapped to obtain carbon-free energy and without using fossil fuels.

A cooling tower of an existing thermal power plant dumps waste heat at ambient environment conditions with a temperature between 0 to 30 C, however with a vortex rising thousands of feet in the atmosphere, it is possible to dump heat in the tropopause at a temperature of -60C, which greatly improves the Carnot efficiency of the cycle. The sink temperature is a lot lower than the lower atmosphere temperature and thus vortex formation to the higher heights is critical to improvement of Carnot efficiency. The diameter of the vortex is regulatory in itself as the air particles move in their tangential velocity increases to conserve angular momentum. This increased velocity is marked by an enhancement in the value of centripetal force acting on the air particles. Thus the vortex is resistant to the ambient cooler air outside and heat loss is prevented. Also this ensures the laminar flow in a vortex instead of a turbulent one and also explains the smooth outer appearance of the vortex. [6]

Thermodynamic analysis predicts that the work done per kg of the air is equal to the change in its enthalpy during its rise minus the change in potential energy of the fluid. This value is estimated to be in the order of 1000 to 2000 J/Kg. [5] Temperatures of about 26 C are enough to sustain the vortex, although it is to be noted that temperatures near 31 C can be obtained in tropical climates. This is a significant difference as a mere rise of 3 C can lead to an increased production of energy by 1000 J/Kg. Furthermore, the temperature of industrial waste heat is in the range of 50-60 C which provides an exciting potential. It was further calculated that in a 1500 MW facility, rejecting heat to tropopause instead of the lower atmosphere can lead to a saving of 200 MW power. [5]

The energy production can be increased by increasing the temperature and humidity of the air. The humidity can be increased by bringing air and water in equilibrium in a wet cooling tower. The temperature of unsaturated air falls quicker than that of saturated air with fall of pressure as the condensation heat increases the temperature of air. It arrives into the picture at around heights of 500-3000m.A prototype was tested which was 12 feet diameter in which the air was heated by four 20KW propane heaters to heat the air upstream of tangential entry. As initially expected, a vortex 1 to 2 feet across was obtained which stretched as much as 60 feet in the sky. [5]

The vortices are used to drive turbines and can also be coupled to existing thermal power plants by using the waste heat of the cooling towers. As the vortex reaches many miles into the air, artificial sources are not required to heat the air and solar energy on ground or seawater can suffice. The low-heat and low-airflow models can easily drive turbines and prove a cost-effective measure of producing clean electricity.

2.1.2 CONSTRUCTION

The plan of an AVE is similar to that of a naturally draft chimney as shown in the fig.1. [6] The design proposed by L Michaud consists of a tapering tower with base diameter of 200m and can extend up to 120m in height. The vortex is rooted at the base and has a base diameter of about 30m. Turbo generators are installed at the periphery to tap the energy of rotating air into mechanical energy and subsequently electrical energy. The plume can extend up to 15km. This setup can produce energy in the order of 200MW. [6-7]

Heat exchangers can be installed at the periphery in case of combined cycle operations (as shown in fig. 1), the hot air thus produced enters the base of the tower in a direction perpendicular to the plane, to restrict the backflow of the air restrictors and guide vanes are installed throughout the passage. The air enters the central area called the arena. This air gets converged subsequently due to the presence of an opening in the annular roof of the structure. The diameter of the vortex is smaller than the annular roof. [8]

The vortex can be initiated or cut off by controlling the airflow in the setup. This can be done by incorporating air dampers and quenching systems to allow for quick shutdown of the plant in case of an emergency. [9] The figure 2 [9] shows the advantage of the heights used in an atmospheric vortex engine.

An AVE can also reduce the occurrence of natural storms by reducing the heat content of the nearby areas. Protective screens can be placed on the upstream side of the turbines to prevent the entry of the birds and bats. Also the airplanes

can easily avoid the vortex as they are highly visible. The other advantages of AVE include the reduction in global warming, causing precipitation and the cleaning of polluted surface air. Developing AVE requires a new approach and people who can develop new solutions to problems that arise during the course of development. Also the selection of sites and technologies to implement present a major issue that has to be resolved to obtain clean and sustainable energy. [9]

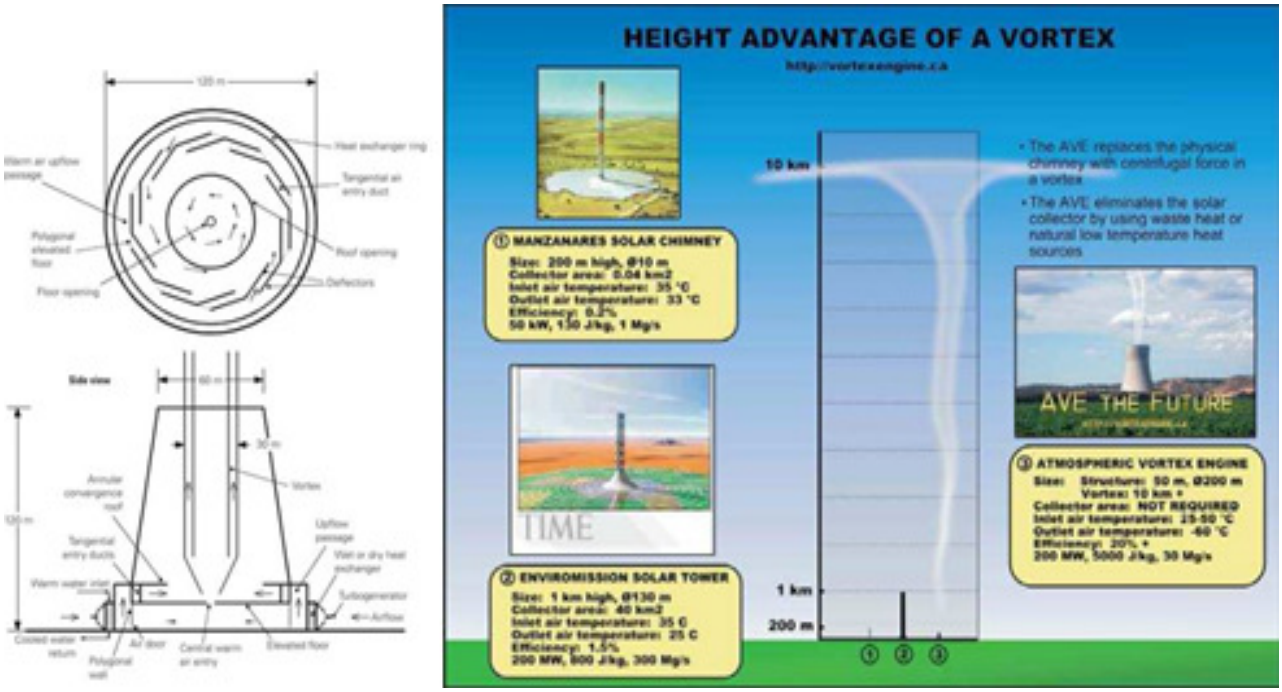

Fig. 1.

2.2 ENHANCED GEOTHERMAL SYSTEMS (EGS)

The United States Department of Energy definesenhanced geothermal systems as engineered reservoirs fabricated to obtain feasible amount of energy from porous and less permeable geothermal resources. These geothermal resources include all those which are inactive commercially and also require a certain extent of stimulation or enhancement. This thus excludes high grade hydrothermal projects however magma and low permeability formations in sedimentary formations are a component.[10]There are other definitions also such as those by the Australian Geothermal Reporting Code Committee which considers EGS as 'a bodyof rock containing useful energy, the recoverability of which has been increased byartificial means such as fracturing'. [11] Other definitions include sources as varied as hot wet rock, hot fracture rock and deep heat mining. [12-13]

These Geothermal systems have a small footprintand little emissions of carbon dioxide. EGS has high base-loadpotential, requires little storage, and, thus, it goes along well with other renewable energy sources – solar, wind, hydropower – in a lower-carbon energy future. [10] The project tries to harness the energy contained in subsurface rocks by creating artificial fractures in which water or gel is injected and heated steam returns to the surface via production wells.

The initial proposals for EGS came from Los Alamos, Fenton Hill, USA in 1970 and the work was started in 1973. This was world's first EGS project and did not produce power.The aim of the EGS project was the development of methods suitable for the extraction of energy economically from theHot Dry Rock (HDR) systems which were located in crystalline, granitic/metamorphic basement rocks of adequately high temperature. The first well dug to a height 2, 042 m and a series of hydraulic fracturing tests was run. Another well was dug to a depth of 3, 064 m and then it was found out the reservoir that connected the wells was not enough. It was then attempted to drill one of the wells into the fracture system of the other well to establish a high permeability flow path between the two.The project was terminated due to a lack of support and because further drilling and wellbore repairs became unfeasible.

The results of the test indicated that wells as deep as 5 km could be dug into hard, abrasive rocks by using traditional drilling methods so that hydraulic pressurization methods could create an open network of hydraulically conductive fractures. This also led to the foundation of equipments and technologies necessary for future EGR work. It was found that the best way for production is the creation of a hot

reservoir by preliminary boreholes and then connecting them with the production boreholes. [14]

In Hunter Valley, Australia, an EGS project was started in 1999 due to huge area of granite base, which is a promoter of heat flow due to radioactive decay and large amount of data available. The radiogenic and uranium-rich rocks facilitate the achievement of higher temperatures at relatively lower heights. The results of the project were encouraging and Geodynamics Ltd. Was formed in 2002, which is currently funded by Google.The Basel project in Switzerland however had some repercussions involved in it. As the water flow rate was increased, earthquakes at a Richter scale of 3 were observed during water injection due to a change in the stress patterns in reservoir rocks. This created widespread outcry and led to the abandoning of project.The well was bled off and the project was halted as a result. [15]

Another point of concern in EGS is the formation of hazardous scale as the hydraulic fluids and the radionuclide come in contact. However worker safety can be ensured by using proper equipments and also long lived radionuclide are not releases as the plant operates and the fluid is re-injected to the reservoir. [13, 16] Also it is estimated that the total radioactivity occurring in such a plant is lesser than that in conventional energy production. [17]The current challenges include the achievement of economic flow rates at productive depths and temperature, maintaining acceptable or minimal seismic activity and the exploration of possible geothermal sites at minimal risk and cost.

2.3 FUEL CELLS

A fuel cell is a device working on the electromechanical principle that on supply of fuel and oxidant converts the chemical energy of the fuel into electrical and heat energy using an anode, cathode and electrolyte. The fuel supply is to the anode and the oxidant is supplied to the cathode. The fuel is oxidised at anode that involves the emission of electrons that travel to the cathode via the outer circuit and thus electricity is generated. The electrolyte can be of various types.

$2H_2(g)+O_2(g)\rightarrow 2H_2O+energy$

Hydrogen+oxygen→water+(electrical power+heat)

A single fuel cell may develop power less than 1 Watt at an operating voltage of less than 1 Volt. Thus a number of fuel cells are connected in series or parallel to provide energy. This serves as a stumbling block as managing a microstructure is more complicated as compared to a macro power plant. However fuel cells are not governed by the Carnot cycle and thus have a much higher efficiency. Also the emissions are lower owing to the lack of a high pressure and temperature combustion chamber and due to the presence of air and fuel in separate chambers. [18]

Direct Carbon Fuel cells oxidise carbon particles from high quality sources by electrochemical means at high temperatures to give high quality CO_2. The fuel and CO_2 are in different phases and thus separation is easier and efficiency of fuel utilization is also very high.

The US Department of Energy tested the feasibility of fuel cell vehicles and developed theFuel Cell Technologies Program (FCTP) in 2009. The fuel cell operated from hydrogen produced using anaerobic digestion of municipal waste water. The research focus was the study of over 400 materials for storing hydrogen, and to improve the volumetric efficiency. The project deployed over 1000 fuel cells as of December 2011. The well-to-wheel analyses shows that petroleum usage and greenhouse emissions from the fuel cell vehicles was considerably lower than that from conventional and hybrid vehicles. [19]Another study by DOE in collaboration with National Renewable Energy Laboratory (NREL), FCTP, DOE biomass and others estimated that the cost of running vehicles for around 400 miles was highest for the battery operated vehicles. [20]

A Malaysian research project [21] indicated that phosphoric acid fuel cells could give a Combined Heat and Power (CHP) efficiency of over 85%, closely followed by alkaline fuel cells (80%), solid oxide (85%) and molten carbonate (80%). In terms of power efficiency alkaline (PEM) fuel cells(60%) ranked the highest, followed by Polymer electrolyte membrane (58%) and molten carbonate (47%). The specific costs for CHP plants equipped with commercial fuel cellswas in the order:

Solid Oxide fuel cells > Molten carbonate fuel cells > Phosphoric Acid fuel cells

PEMFC were found to be most suitable for automobile applications. Comparison with conventional sources show higher initial costs but the costs were somewhat offset in the operation life. [21] These fuel cells may also be used to derive electrical energy to compress air into high pressure cylinders which can then be used to drive automotive engines.

The current challenges in front of the researchers are not only the evaluation of the upfront cost but also life cycle estimation and analysis.A focus is suggested on DMFCs (direct methanol fuel cells) in the consumer electronics market, PEMFCs in the automotivesector, and high-temperature fuel cells for the distributed CHP market. [22] IPHE (International Partnership for Hydrogen and Fuel Cells in the Economy) suggests that the highest costs encountered are at low volumes and in developing the cell stack, which deserves more R&D focus. [23]

2.4 KITE WIND GENERATOR

Wind energy has been a frontrunner as a clean renewable energy source since decades. Most contemporary wind turbines operate at about 100 m from ground level. As we move upwards the quality of winds becomes steadier and its velocity increase substantially owing to the reduced friction

between air and ground, but moving the rotor upwards require high structural strength of the supporting columns and also increased induced maintenance costs. Thus, a potentially promising source of clean energy is untapped [24-25]. This prospect is being explored by two types of mechanisms. One relies on generator carried aircrafts (Makani Power). [26] The electrical energy produced is transmitted to the ground by a conductive tether which in turn supports the structure of the turbine. The other method separated the wind harnessing and generator components. The wind harnessing can be engineered to operate at higher altitudes while high performance fragile generators could be installed on the ground. Laddermill [27] of Delft University of Technology (Netherlands) gave the idea of harnessing energy generated due to motion up and down motion, like a ferris wheel, of vertically stacked "kites".

2.4.1 MODELLING

A widely used relation between height from ground (H) and velocity of air(V(H)) can be given by [28] :
Power equation (during high temperatures i.e. midday) :
$V(H) = V_g(H/H_m)^a$
Logarithmic equation (during low-medium temperatures i.e. evening and early mornings) :
$V(H) = k_g V_g \ln(H/H_m)$

Here a, k_g are constants and V_g and H_g are reference velocities and heights respectively. Physical modelling of kite motion can be done while assuming it to be a combination of a number of flat airfoils. The modelling differs from that of traditional airplane wings as kites are designed to operate at higher angle of attacks than the critical angle of attack. The incoming air can be broken into both horizontal and vertical components, the horizontal component would provide Lift force (L) and also skin friction and viscous pressure drag (D), while the vertical component could be imagined to produce a push force P in the direction of net force (Pull).The flow over the kite can be laminar, turbulent or transitional depending upon the angle of attack which in turn equals the angle made by the tether axis and the z-axis [1](figure 3). It is observed that at angles of attacks greater than the critical angle, the ratio of drag force to the Pull force is less than 2 %. Thus, the tension present in the tether could be assumed to equal to the lift and push forces acting perpendicular to the chord plane, as weight of kite can be neglected, thus we can arrive at a relationship between tension in tether and angle of attack (figure 4).As this tension would drive the generator through gearbox, higher value of the same would result in more power. It is observed that tension rises monotonically until the kite reaches zenith, i.e. till a certain critical angle and decreases henceforth due to reduction in wind speeds.

The power produced with angle can be subdivided into 4 zones namely red, green, blue andblack. The red and green zones are fit for energy generation, i.e. the tension in the tether is sufficient to support kite motion and drive the generator. The blue zone denotes very high and very low angle of attacks and is unfit for power generation, the reduced tension no longer supports kite weight. The black zone is area where although the kite can flow but tension is significantly reduced (figure 5). Yo-Yo mechanism of motion can be achieved in this zone and subsequently pumps can be powered.

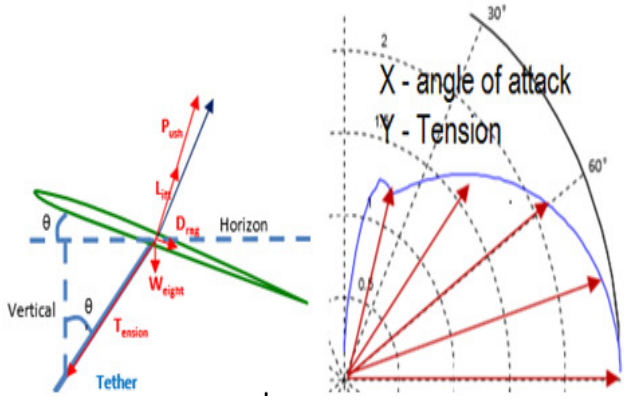

Fig. 2.

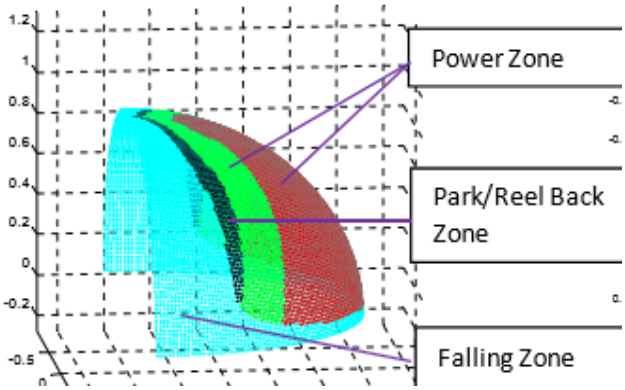

Fig. 3.

2.4.2 MAKANI POWER

Makani power has prototyped a device which is a hybrid of a model aircraft and traditional windmill[29]. The model aircraft weighs 56kg and has the capacity to reach 1500ft, here winds are more stabilized and with a wingspan of 8m power upto 20KW can be easily extracted.This energy can be tethered back to ground.

2.5 SOLAR POWERED SATELLITES (SPS)

Photo-voltaic cells are used for generating power on Earth and also for powering low energy and geosynchronous orbiting spacecraft and satellites. On earth sunshine is subject to various climatic phenomenons and is hence, unreliable, but the Sun shines constantly in space and our challenge there is to transmit the harnessed solar power to Earth [30].SPS can receive sunlight for entirety of an year bearing few hours during equinoxes, also it receives 450% more energy than Earth based solar plants. This coupled by

recent research in metamorphic solar panels can lead to an efficiency exceeding the theoretical limit [31].

The initial idea was proposed by Dr.Peter Glaser [32] in 1968, his plan was to transmit the solar power via radio frequency beams. Subsequently he patented his ideas in 1973 and the technology was put to economical, technological studies by NASA. During the 1980s extensive work was done in the satellite receiver and transmitting modules, means to beam energy back to Earth [30]. The infrastructural challenge is two-fold, i.e. economical challenge to deploy SPS to orbit and the cost of constructing receiving system whose diameter is theoretically kilometres long. In the transmitting end the proposed ideas consist of radio frequencies, microwave both suffer noise and attenuation losses due to ionospheric interactions. Currently these technological obstacles are being engineered with by various companies like Solaren INC., POWERSAT. Some proposed solutions are as follows:

1. GEO Sun Tower- It proposes installing a 15 km long structure of 340 pairs of panels at the geostationary orbit. At the lower end a 340m transmitter would be installed. Due to large distance from Earth the damage due to debris is negligible.

2. Clipper Ship- The installation is proposed in solar synchronous orbit which would rotate along its axis to track Sun, but the scanning loses are enhanced in this mechanism.

3. GEO Concentrator- Itconsists of a system of mirrors which can reflect the sunlight in the transmitter/generator unit, eliminating the extravagant size of Sun Tower.

2.5.2 TRANSMISSION PROPOSALS

The proposed solutions are laser and microwave. The loses are two-fold, one due to conversion of Solar to either of Solar / Microwave and the other due to attenuation, diffraction etc .The system has transmitter, beam controller and rectifying antenna . The units have a larger area in microwave than laser although conversion and transmitting losses are lesser. Presently the project is in its initial stages and would require extensive research and a substantial decrement in launching costs before the project can achieve its genesis. The project has potential to satisfy entire energy demands of the planet.

3. CONCLUSION

It can be concluded that the above mentioned technologies have a huge potential in terms of power output, efficiency, controlling emissions and development costs on a mass scale. However these technologies and methods have knocked very recently on our doors and their experimentation and implementation suffers severe technological, economic, socio-political and other barriers. Promoting these low-cost low-emission feasible methods of producing energy is a solution to our problems of energy scarcity, pollution and environmental degradation. R&D in these technologies in the current day will pave the path for further development in the same.

This requires concentrated efforts and discussions between the communities and the research world and total support from the political entities. The aim should also be the development of these technologies in specific fields at minimal costs at an aggressive rate.

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