Re: Attn: Mr. Mook

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Mök Energy Innovations Increasing Solar Energy Efficiency

1. Panel Design to Maximize Energy Capture
a. Concentrators
i. All concentrating photovoltaic (CPV) systems seek to reduce costs by focusing sunlight to a small point and devising a PV device to work with that small intense point of sunlight efficiently. In this way costly PV material is used more efficiently and PV costs are reduced as a consequence. The Mök system operates at 1,100x solar intensity dramatically reducing the cost of PV materials. This method of operation introduces a number of challenges adding to balance of system costs. All these challenges have been efficiently addressed including the following factors;
1. Concentrator benefits   low PV cost − the high efficiency multi− junction PV materials we use are 38% efficient and cost $11,000 per square meter. By concentrating sunlight 1,100x we only use $10 of material per square meter. By generating 380 watts per square meter our PV costs are less than $0.03 per peak watt.
2. Concentrator Costs   mirrors, glass lenses, fresnel lenses and holograms all cost in excess of $100 per square meter. While contributing only $0.26 per watt, this cost is still higher than we d like to pay. For this reason we use precision hot press molded PET films that have an array of molded lens shapes. Two or more PET sheets, each 200 microns thick, are joined together in a fluid bath to create an extremely low cost liquid filled optical cavity that efficiently focuses light to high intensity at a cost of less than $1 per square meter, adding a fraction of a cent to the cost of generating each watt of electrical output.
3. Thermal management   at 1,100x solar intensity energy arrives at the PV cell at a rate of 110 watts per square centimeter. This rate of energy influx if far too high to be cooled conventionally. There are a number of innovations, that are used to manage heat in the Mök system and do so at very low added cost per watt.;
a. Spectral Cooling   as taught in one of my patents on this subject, using dichroic mirrors on the face of the PV cells to create an optical band−pass filter, allows only effective light to strike the PV material, limiting heating of the material. Added cost is nil for the giant−bi−refingent optical (GBO) films we use.
b. Limiting Current   by operating six or more junctions efficiently

in series current is reduced, and parasitic i−squared−R heating is reduced by a factor of 30 or more at no added cost to the system.
c. Total Immersion in Optical Medium the fluid filled lens cavities focus light inside the lens medium. Locating the PV cells inside these cavities allow the lens fluid to circulate and efficiently carry away heat by fluid convection at a rate of 50 watts per square cm per side at no added cost to the system.
d. Efficient Loading continuous operation at the peak power point for each cell means that over 1/3 the energy arriving at the cell in the form of optical energy, is efficiently carried away from the cell by as electrical output, reducing the heat load of the cell at no added cost to the system..

2. Eliminate Mechanical Tracking
a. Entendue in optical systems has been compared to entropy in heat engines. Just as entropic considerations explain the ultimate limitations of all heat engines, such as Carnot efficiency, entendue provides a powerful argument for similar limitations in all optical concentrators namely the clear relation between field of regard and concentration ratio. Legendary workers such as Wilson in the 20th century used in his optical calculations much of the same mathematical machinery, the continuity of complex spaces, that legends such as Botzmann used in their work on heat engines in the 19th century. As mentioned a critically important finding is the relation between field of regard and concentration ratio. This finding seems to require that highly concentrating systems such as the Mök system possess a mechanical tracker that accurately maintains orientation toward the solar disk with an accuracy of a few degrees. Through a clever approach to optics, this requirement is met without the use of moving systems or mechanical trackers and is a central feature of the Mök system.
b. The easiest way to see how the Mök system works is to consider various types of tracking systems all of which have been built and studied by Mök;
i. Bulk mechanical motion a lens projects the image of the sky onto an image plane. A PV cell is located at the center of that image and the lens is moved mechanically to maintain the image of the solar disk on that PV cell.
ii. Internal mechanical motion the same lens as above projects the image of the sky as before, but as the sun moves through the sky, the PV cell is moved inside the lens system within the image plane to maintain the image of the solar disk on the PV cell
iii. Compound internal mechanical motion in this system a secondary lens is located on the image plane to redirect the solar disk to a stationary PV cell located beyond the image plane.
iv. Stationary Compound lens array in this system an array of stationary secondary lenses is located on the image plane to redirect the solar disk to a stationary PV cell located beyond the image plane.
c. The compound lens array described in item IV above has no moving parts and is the method Mök uses in its most advanced systems. This system is implemented using very low cost synthetic hologons similar

to those used to secure credit cards and consumer goods like CD cases. A sheet of holographically imprinted plastic material is placed between the precision molded PET films at an added cost of fractions of a cent per peak watt.

d. The wide field of view of the fisheye primary lens combined with relative insensitivity to orientation allow Mök CPV panels to operate as a flat panel PV collector regardless of panel orientation or concentration ratio. This feature dramatically reduced installation and maintenance costs.

e. It is easy to see that a casual analysis might conclude the system described appears to exceed entendue limits. A careful analysis reveals it does not! By merely observing that the primary lens is reused thousands of times by each of the secondary lenses in the array and that each pair constitutes a separate system each with its own field of regard, overlapping other pair s field of regard. Another important point is that each system is discontinuous with all others while following continuity limits itself.

f. No other CPV system uses this approach, and this is subject of current patent activity.

3. Minimize Solar Cell Size

a. Our solar panels consist therefore of

i. A top sheet of precision molded PET film 200 microns thick

ii. A redirector cover sheet of PET film 25 microns thick.

iii. A holographically molded sheet of PET 25 microns thick with 5 micron surface deformations produced by a heated nickel form to implement a holographically formed redirector lens array.

iv. The redirector cover sheet and holographically molded sheet are bound together creating 5 micron thick voids where joined creating a permanent holographic lens array.

v. A bottom sheet of precision molded PET film 200 microns thick to complete the liquid filled optical cavity.

vi. A base top sheet of molded ABS plastic

vii. A base bottom sheet of molded ABS plastic

1. The base bottom sheet has copper foil impressed upon it to implement a power capture circuit.

2. An array of PV cells each 750 microns square are cleaved from a 300 mm wafer and joined to the foil pattern already described.

viii. The base bottom sheet is joined to the base top sheet to create an optical die array that is electrically insulated, but has a window to expose the PV cell.

ix. The optical die array is molded to form fingers that hold each PV cell at the focal point within each lens in the lens array forming the base assembly.

x. The base assembly is joined to the bottom sheet described above.

xi. The bottom sheet,, holographic lens array, and top sheet are all joined in a fluid bath to create a finished lens array joined by ultrasonic welding.

b. Each PV cell consists of a germanium over silicon base layer that operates at 1,600 nm. To that is added through chemical vapor deposition three or more layers of gallium−arsenide, each layer is doped to operate as slightly different bandgap energy. Finally a layer of indium−phosphide is added to capture shortwave energy. In this way 38% of the energy contained in the solar spectrum is converted to electrical energy. PV cells are coated with glass by a CVD process to isolate the cells from the fluids used..

c. Each lens array consists of 4,608 lenses in a 4 foot by 8 foot array ¾ inch thick. Each lens focuses light onto one of 4,608 multi−junction PV cells . Each cell is joined in parallel to 96 others in columns. 48 columns are joined in series to create a panel producing approximately 300 volts at 3 amperes in full sunlight at a total cost of less than $40 per panel   a cost of less than $0.05 per peak watt.

4. Minimize Manufacture/Assembly/Shipping/Installation Cost/Unit

a. The Portland Oregon based company, CH2MHill, was retained to design a 1.2 million square foot factory capable of producing 188 acres of panels per hour and a field based system to install panels at this rate while maintaining very low production and installation costs. Selling rights to various markets allow construction of this plant.

b. Panels are produced as part of continuous strings 1,100 panels long. They are wired together the same way Christmas tree lights are wired, at the factory, to present two 9,000 Volt circuits at either end of a 4,400 foot long 8 foot wide string. There are only two electrical connections in the field, for each string minimizing cost per watt.

c. Panels have a water drainage system molded into their back side so they may be installed directly on graded earth held in place by netting molded along with the panels that is continuously buried in trenches continuously dug by special tractors designed to install the panels.

d. Panels are z−folded together into easily shipped blocks that are 8 ft x 12 ft x 53 ft in size. These blocks are handled by special tractors that unfold and install them in 4,400 ft strips 8 ft wide. In this way a crew of five installs a square mile per eight hour shift. Six crews totaling 30 workers working around the clock with two tractors install 7 square miles every 24 hours   the output of each plant. Mök has plans to create backorders of panels sufficient to keep 14 plants busy when at full capacity. .

e. Total cost of the completed systems, without electrolyzers, is $0.05 per peak watt installed. This translates to an energy cost of less than 1/5th cent per kilowatt−hour.

f. Very low cost alkaline electrolyzer systems costing an added $0.02 per peak watt is installed at either end of each strip. These are made of PET film vapor coated with metal to form very efficient and low cost electrodes operating within PET containers Fed with water laced with potassium hydroxide at 200 psi these systems produce hydrogen and oxygen at a rate proportional to lighting conditions. Oxygen is blown down through a turbo pump to reduce water compression costs. Hydrogen is withdrawn at 200 psi into a low pressure gathering system and transmitted to point of use by pipeline.

5. Efficiencies in Energy Storage by Use of Hydrogen

a. The Mök system uses solar derived DC power to make hydrogen in the field as a way to maintain efficient operation.

b. A major difficulty of any solar powered system is low capital

utilization. There are 8,766 hours in a year. Even in sunny areas sun is available 20% of the time.
c. This means that solar powered systems stand idle 80% or more of the time. So, low capital cost is of paramount importance to maintain low operating costs.
d. It is unreasonable to demand that the entire chain of industrial equipment operate at such low capital efficiency. So, in order to use solar energy on a large scale some system of storing solar energy must be developed so that industrial equipment attached to the solar primary source may be operated continuously.
e. DC electricity produced by solar panels must be fed into a balanced load that requires no more or no less than the solar panel produces under the lighting conditions it finds itself. Since lighting conditions change throughout the day this means that any load attached to a solar panel must be equipped with some sort of intertie to maintain this balance. These intertie systems alone cost in excess of $0.30 per watt which is far larger than our low cost system described here.
f. Batteries cost nearly $1 per watt, and far more per watt hour. Batteries may only be charged and discharged a few thousand times and then must be replaced. As a consequence, available batteries are impractical on an industrial scale at low cost. Batteries also self−discharge in a matter of days, reducing efficiency.
g. Low cost electrolytic hydrogen production is the best way to connect low cost solar panels to industrial loads.
i. Electrolytic production of hydrogen naturally uses the DC output of solar panels
ii. Hydrogen may be stored indefinitely in tanks or pipes
iii. Hydrogen burns under the same conditions as all other fuels, and may also be used in fuel cells and other advanced systems, without creating a carbon footprint, or creating an issue with solid waste as battery disposal does.
6. Hydrogen Production, Variable Load Electrolyzer
a. The Nernst Equation describes in detail the physical operation of electrochemical systems such as alkaline electrolyzers. Mök has devised a means to efficiently and reliably tie together arrays of PV cells at high voltage in a way that maintains efficient PV operation under variable lighting conditions when driving variable geometry electrolytic cells designed as part of a single circuit. This approach makes natural use of the physical processes involved to vary hydrogen production rates as lighting conditions vary. By varying electrode geometry the peak power point of the PV cells are maintained even while their operation changes throughout the day. The result is a system that varies hydrogen production and water flow to keep balance with available lighting. This innovation, when combined with other production innovations allow Mök to create a system that produces hydrogen from water at less than $110 per metric ton from 9 metric tons of distilled water using 56 mega−watt−hours of DC electricity. Heat released burning that ton of hydrogen is equivalent to burning 6.2 tons of coal, or 24.3 barrels of crude oil. Unlike these other fuels, hydrogen combustion produces no CO_2. The heat from

this hydrogen is used to boil (through multi−stage distillation) 2,000 tons of sea water producing 2,000 kiloliters of distilled water,and 35 tons of salt solids, both of which are saleable. Hydrogen made through sunlit hours is used continuously to drive evaporators efficiently, even when there is no sunlight.

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Dec 13th Economist pg 56 & pg 57:

Energy security is a major concern of governments, businesses and increasingly, consumers. While oil−producing countries are becoming more politically assertive, those who depend on them are becoming increasingly unsettled by the rise of resource nationalism. Risk of terrorist threat to key infrastructure, increased demand from developing nations and the voltility of oil prices have also pushed the issue to the top of the agenda in every region of the world. With this in mind, Economists Conferences gathered influential thinkers and prominent business figures to debate the issues.

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This is a powerful argument for the US to engage in its own resource imperialism to restore its economic strength.

The first step is to carry out my program to cover 25,000 sq km with solar panels make 277 million tons of hydrogen per year displace 1.14 billion tons of coal in US' 1,032 coal fired power plants using a national hydrogen pipeline and create 7 billion barrels of liquid fuels each year from the stranded coal exporting 2 billion barrels when this production is combined with conventional US production. This program is completed in 7 years at a cost of $200 billion per year. The bulk of this is borrowed aganst government purchases of syncrude at $35 per barrel which is paid at time of delivery and sold by gov't at market rates. The production infrastructure once underway reverts back to market once established. In addition to providing energy security this program also cuts our carbon footprint in half.

The next step is to fill greater and greater parts of our energy need directly with hydrogen. Since the US economy doubles every 20 years this provides a natural transition to an all hydrogen economy. The beginnings of a hydrogen infrastructure are in place at this time. Tthat hydrogen component is expanded while the hydro−carbon is fixed or declines through natural depletion. Since depletion raises prices this provides a natural transition to a lower cost hydrogen alternative created in the first step. As technology develops public private partnerships develop core hydrogen tech − just as NACA developed air travel tech in the first half of the 20th century these partnerships with adequate solar hydrogen at low cost begin to make sense. In this second phase as the US develops its own hydrogen infrastructure it exports ever larger shares of its synfuel production overseas. This has two beneficial effects; it lowers oil prices undermining foreign oil profits; and undermines the development of foreign hydrogen tech allowing US to excel in this tech.

Phase three involves US export of hydrogen overseas and older hydogen tech

Phase four export of advanced hydrogen tech along with increasing amounts of hydrogen.

This program especially when combined with more speculative advanced tech developments will maintain US economic a geopolitical leadership for two generations or more while capturing foreign revenues that equals then exceeds the entire economic output of the USA today.

Cheers
Bill
Sent from my Verizon Wireless BlackBerry
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