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Energy Costs Eliminated By Satellite System

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Abstract

Successfully implementing a Solar Power Satellite Program will take a multi-discipline, multi-national, geopolitical effort. Planning for that level of complexity must begin now. This article gives the principal reasons for going to space for "free power," and seeks to illustrate some of that complexity. Solar energy is "free", just like the water in a hydroelectric system. There is no cost for fuel.

The sun delivers energy to earth at the rate of 1.37 kilowatts per square meter during daylight hours. This amounts to 174 petawatts (one petawatt is 10 to the fifteenth power). About 89 petawatts reach the earth's surface. A satellite positioned in geosynchronous orbit at approximately 22,300 miles above earth (with an area of solar cells of 10 kilometers squared) will be bombarded by 13.7 gigawatts with only brief blackouts twice a year. With cell conversion efficiencies of only 10%, the electricity potentially produced will be 10 gigawatts delivered to the space-based microwave transmitter; somewhat less will be delivered to the receiver and relayed into the modified power distribution networks located near the user on earth.

Not one but several gigawatt-satellites will be required to generate the power needed over the next twenty to twenty five years. The continuing degradation of the environment accelerated by population growth, our inadequate efforts to balance carbon-based fuels with those from "green" sources and the increasing worldwide gross national product is good reason to get started with a program of energy from space.

The U.S. Electrical Power Industry

Implementation of Solar Power Satellites requires a careful look at the economics of the space technology proposed and its comparative advantages to the alternatives that exist today. The existing electrical power system of the United States is fraught with problems. The main population centers are not near the oil fields, coal mining areas, or natural gas fields; therefore, fuels must be transported to the generation plants or the generation plants must be moved to the fuel sources. There are either fuel transportation costs or electrical transmission costs, usually there are both. To argue the merits of going into space for "free power," a detailed analysis of the cost elements of the current electrical systems should be done.

The U.S. consumes approximately 25 percent of the world's energy at 29,000 terawatt hours per year. The user categories are industrial, transportation, residential and commercial users, as defined by the Energy Information Administration of the U.S. Department of Energy. Coal, oil, natural gas and nuclear fuel, in that order, dominate among the electricity production industries. The following Table presents the 2009 data, as extracted from the EIA total electrical power industry summary for June of 2009. The values are given in thousand megawatt hours.

Sectors	Electric Producers	Public Utilities	Independents	Other Producers	Number of Producers
Coal #1	149,156	113,180	34,363	90	1,243
Natural Gas #3	84,098	32,438	45,180	322	6,157
Nuclear	69,435	36,633	32,801	0	0
Hydroelectric	28,866	26,386	2,291	10	180
Other Renewables	10,667	965	7,424	143	3,136
Wind	4,957	620	4,337	0	0
Wood & Wood Derived #5	3,027	145	782	2	2,099
Petroleum Liquids #2	2,092	1,662	296	10	125
Other Biomass #6	1,420	101	1,141	141	37
Geothermal	1,170	99	1,071	0	0
Petroleum Coke	1,159	478	567	0	114
Other Sources #8	958	48	553	67	312
Other Gases #4	864	7	243	0	615
Solar Thermal, Photovoltaic	94	2	92	0	0
Hydro Pumped Storage	-226	-139	-87	0	0
TOTAL	**347,069**	**211,656**	**123,690**	**642**	**10,881**

Table 1. Net Generation, June 2009 (click image for larger view)

From these sources, the total electricity output in the U.S. appears to be over 45 trillion kilowatt hours. At only 10 cents per kilowatt hour, this would suggest that the existing income of the electric power companies is over 4.5 trillion dollars per year.

What Comprises the Electrical Power Industry

The existing power system consists of the following major components:

1. The fuel energy needed for conversion to electrical power;

2. The transport systems needed to move that fuel to the generators;
3. The power generators needed to produce the electricity;
4. The high power transmission lines needed to transport the power;
5. The distribution lines needed to deliver the power to the users; and
6. The end users.

Let's look at steps one through four of these components and outline the deficiencies and existing problem areas.

Fuel Sources: Amounts and Transport Costs

The major fuels used in the production of electrical power are coal, oil, natural gas, nuclear power and hydropower (U.S. Coal Supply and Demand, 2008 Review).

1. The majority of U.S. electricity comes from coal steaming generators. The coal fields are typically in the Midwest or West as much as 1500 miles away from the generation plants. The cost of the delivery of the coal is at 40-50 dollars per short ton and the many mile-long trains required to deliver the coal are clogging the rail systems. The disposition of the coal ash and debris is a major expense.

The 1,460 coal-fired boiler plants operating at 30.9% capacity consume 121.7 million short tons of coal to yield 171,683 megawatt hours of electricity. The average delivered price is $41.23 per short ton. Most of this coal is mined in Appalachia (389 million short tons), in the interior states (146.7 million short tons), and in the western states (633.6 million short tons). This fuel cost totals over 5 billion dollars. The average mileage of the rail transportation lies in the vicinity of 100 to 500 miles from the mines to the power generation sites.

While the coal derived electricity cost is at 3 to 4 cents per kilowatt hour, there are unaccounted costs:

- These plants are large producers of greenhouse gases, a principal driver of planetary warming;
- These plants are extremely wasteful of energy, converting only about a third of the available energy into electrical power;
- These plants leave significant residue in the ash (and airborne contaminants such as mercury) that further contaminate the soil;
- The mile-long trains required to deliver the coal are clogging the rail systems; and
- The disposition of the coal ashes and debris is a major expense.

2. The second largest producers of electrical power are those using petroleum or petroleum-derived products. In 2008, there were 3,524 power plants producing 7,020 terawatt hours while burning 3,624,000 barrels at a cost near 100 dollars a barrel. The amount spent at this price amounted to about 362 billion dollars. The

cost of electricity produced from petroleum was approximately 5 cents per kilowatt hour (EIA, 2008).

3. The third largest producers are the 1,686 combined natural gas plants, which in 2008 delivered 505 billion kilowatt hours, and the 776 natural gas-fueled boilers, which delivered 159 billion kilowatt hours to the system. (Reference). These 2,462 plants produced 664 billion kilowatt hours, some 16.3% of the electricity in the country. During the month of July 2009, 775,046 million cubic feet of natural gas was used by U.S. electric power plants. This was roughly 55% of the total natural gas consumed in that month. The wellhead price of that gas was 3.43 dollars per 100 cubic feet, at a fuel expense of 26.6 billion dollars. The average cost, if we recognize that half of the gas supply was imported, was one and a half times the 26.6 billion dollars. Calculating the cost as 5.1 dollars per thousand cubic feet, the cost to produce 664 billion kilowatt hours of electricity was 40 billion dollars. This amounts to 12.5 cents/kilowatt hour (EIA).

4. The fourth largest contributors were the 114 nuclear reactor plants yielding 703,199 megawatt hours of electricity. World wide, in 2007, there were 439 reactors generating 16% of the world's energy supply. The 114 reactors operating in the U.S. produced 70,319 million terawatt hours. The fears here are: "more Chernobyls" and "where does the radioactive waste go?" These 114 nuclear plants produced 10 % of U.S. electric power in 2006. These plants are large, expensive, and require large water supplies. Attendant are security problems and nuclear waste disposal requirements which drive up the costs. (What is the kwatt hour cost of nuclear?)

Except for Canada, there are no more places left for locating hydroelectric plants. The locations of the major plants in the U.S., such as the Columbia River complex, require high-voltage transmission systems. (What are the Kwatt hour costs of hydro-power?)

In summary, the fuel costs for producing electricity in the U.S. are exorbitant: over $50 billion for coal; $30 billion for oil; another $39 billion for natural gas. These alone put the fuel costs for U.S. electric power at well over $119 billion per year. (An October news release in the Seattle Times quotes the Natural Academy of Sciences as giving the value at over 120 billion dollars per year for all carbon gas consumers?)

Complexity of System and Costs

I would add government to the category of bulk users of electrical power, in addition to those identified by the DOE Energy Information Administration: industrial, transportation, commercial and residential.

The electric power system is over 100 years old. As it stands today, it is a classic hierarchy that has grown out of the changing requirements of the public and the increasing capabilities of industry. Electricity uses have grown in scope, quantity, and location diversity. Meeting industry and public demands have resulted in the development of several types of generators. The diversity and variability of the categories of end users have required that the output of the power generators be distributed, creating the need for transmission networks of different sizes that could handle DC or AC power at varying voltages. This has resulted in the rise of the 500 or so commercial operators who design, monitor, control and manage the transmission networks. The distances over which the power must be delivered requires interconnection of U.S. and Canadian AC power supplies. Power is lost in transit. Efficiency in transfer of power is relevant to the amount of generated, and the voltages that can be used in the transmission must be taken into consideration.

The complexity, the limitations, and the diversity of requirements have resulted in three distinct transfer stations where the interconnections between the eastern states, the western, and the independent Texas transmission grids can take place. The independent grids are not really independent and are subject to blackouts or to planned rolling blackouts as the power loads vary. There are over 300,000 miles of lines operated by multiple companies. Transmission can add at least one cent a kilowatt hour to the power charges for the 150 billion kilowatt hours or more moving through the grid.

Satellite Costs and Financing Conclusions

In the preceding paragraphs, I have shown a few of the areas within the electric power system that might undergo drastic change with a new source of energy from the satellite power system. Upon implementation, the majority of the terrestrial cross-linking power transmission networks will never be used. Satellite power will be delivered to receiving antennas located close to the distribution network, eliminating the need for most of the high power transmission lines. This should reduce the cost per kilowatt hour by at least 10%, since at least 30-40 percent is due to the fuel burned. The present rates average about 10 cents per kilowatt hour; that rate will drop to 5 cents per kilowatt hour, or less. Society will see a reduction in some of the unaccounted costs due to reductions in green house gas emissions not showing up in the power costs today. Those costs will be further lowered by greater efficiencies and implementation of advance technologies and mass production in the designing, developing, deploying and operating satellite and rectenna systems. Such cost reductions can be estimated as part of an early solar satellite definition program. That program should be started as soon as possible -- Now.

Solar Power Satellite costs are calculable if we make reasonable assumptions. We must lay out goals and plans for a fleet structure that are relatively complete. At this time, we anticipate that 20 to 30 billion dollars could be required in the next five years.

We need first to convince the present administration that this effort is of prime importance, far exceeding the demands of any other efforts in space. President Obama in a speech at the Florida Power and Light utility on October 6, 2009, made reference to the Federal Government funding of efforts of this nature. Government participation is necessary. In my opinion, the Department of Energy should establish at the undersecretary level an office of Solar Power. It should be financed with sufficient funds and talent to initiate the following efforts.

1. Establish an advisory group consisting of civilian space advisors, representatives from NASA, DOE, and the State Department. This group would sponsor participation and guide the efforts to identify relevant policies, national and international limitations and to fund competitive well-defined tasks selected to move along a path to the full development and placement of operational solar power satellites in space.

Recommendations concerning these tasks were established by the first solar power satellite teams in the 1977-1980 era, and have been to a large extent described in Ralph Nansen's book ENERGY CRISIS: Solution from Space.

2. The first operational task should be the design, placement, and operation of a ground test station that can be used throughout the program for testing components of the satellite and rectennas as well as the microwave beam divergence transmission. Several years ago, I estimated that such a station would cost 25 million dollars. Today, I suspect that for the first two years the ground test would require 100 million dollars to staff with 20-30 people. This would include the locating and leasing of a site, the designing and building of a 50-to-100 kilowatt bank of solar cells, and the designing and building of both transmitting and receiving antennas.

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