Making President Trump the Needed Champion of GEO Space Solar Power

By Mike Snead[1]

Abstract
Today's worldwide substantial dependence on fossil fuels for industrialized prosperity has created general energy insecurity, brought widespread energy impoverishment, and increased the risk of warfare to secure vital fossil fuel resources. This use of fossil fuels has also created a significant environmental security threat due to reasonable uncertainty that the now abnormally high and rising atmospheric carbon dioxide concentration could harm the environment and, consequently, civilization. Space-based solar power platforms, built in geostationary Earth orbit (GEO), were identified in 1968 as a means of providing sustainable electrical power to ground receiving stations distributed around the world. President Trump's focus on achieving American energy independence and on creating a new international agreement to address anthropogenic carbon dioxide emissions has created the political circumstances where President Trump could champion undertaking GEO space solar power as a major initiative of his administration.

Key words: President Trump, United Nations Framework Convention on Climate Change, Paris Agreement, carbon dioxide, CO_2, sustainable energy, fossil fuels, GEO space solar power, energy impoverishment, sustainable development.

Introduction

> *In the midst of chaos, there is also opportunity.*
> *—Sun-Tzu*

For the first time ever—yes, ever—the political, technological, and economic opportunities to create an American-led spacefaring industrial revolution, accompanied by large-scale human space settlement, now exist. The need for this revolution is to open O'Neill's "high frontier" to build thousands of space solar power platforms in geostationary Earth orbit (GEO) to transmit (nearly) continuous, pollution-free electrical power to receiving stations all over the Earth. I refer to the space-based component of this worldwide, sustainable energy infrastructure as GEO space solar power.

Humanity has run out of excuses for not adopting space-based sustainable energy to power our civilization. The political opportunity to undertake GEO space solar power is at hand provided we convince President Trump to champion GEO space solar power. Without his strong support, GEO space solar power and this vitally needed transformation of our civilization will most likely not happen. The purpose of this article is to explain why convincing President Trump to be the champion is consistent with his stated views on energy and environmental security—views that most Americans probably share—as well as his apparent openness to undertaking big, bold ideas to make America great again.

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The Sustainable Energy Security Challenge

Almost everyone in the world wishes to live well. By this I mean having, at least, what Americans think of as a middle-class standard of living. What is preventing this from happening is the lack of a worldwide sustainable energy infrastructure providing the affordable per capita energy supply needed to have a middle-class standard of living. That this is not happening, including in the United States, is due to our substantial reliance on fossil fuels for energy. The limited supply of non-sustainable fossil fuels automatically creates “haves” and “have nots” because the marketplace seeks to balance limited supplies with a price-dominated distribution of these limited resources. As a result, most industrialized and industrializing nations, including the United States, suffer fossil fuel energy insecurity that is addressed through, at times, awkward political/economic alliances and the threat of warfare, if not actual warfare. Peacefully resolving this fossil fuel energy insecurity, by transitioning to plentiful space-based sustainable energy, is the energy security challenge America must lead the world in addressing.

The Opportunity for a Champion

While identifying the need for sustainable energy security is not new, what has changed is that a real opportunity to begin the changes necessary to achieve this security is now at hand with President Trump. To achieve true energy security worldwide, the world must fundamentally change to adopt sustainable development powered by, obviously, sustainable energy. Reasonable people understand the need for this to happen including, we must assume, President Trump and key members of his administration. Run-of-the-mill politics over the last half-century have not put the United States or the world on a practical path to eliminating energy impoverishment and achieving true energy security. President Trump is, certainly, a counter-establishment president. He approaches solving problems differently, making this a key personal attribute during his campaign. He reemphasized this point, at the end of his inauguration speech, by saying, “Finally, we must think big and dream even bigger.”

President Trump appears to have carried his openness to “big ideas” into the White House. Unlike any time since GEO space solar power was conceived in the late 1960s, the opportunity to sell this remarkable “big idea” to the president of the United States now exists. If adopted and initiated effectively, it would certainly become an acknowledged successful legacy of his administration. The opportunity to get President Trump to champion GEO space solar power must not be ignored.

GEO Space Solar Power

About a century ago, the idea of using GEO to locate transmitters to broadcast to the Earth first emerged. A GEO satellite moves around that orbit at the same angular rate as the Earth rotates each day (Figure 1). Thus, to an observer on the ground, a visible GEO satellite remains constantly in view with its position stationary. This feature has been used since the 1960s to relay telephone, radio, and TV broadcasts to receivers located within the broad swath of ground that can “see” the GEO communication satellite.

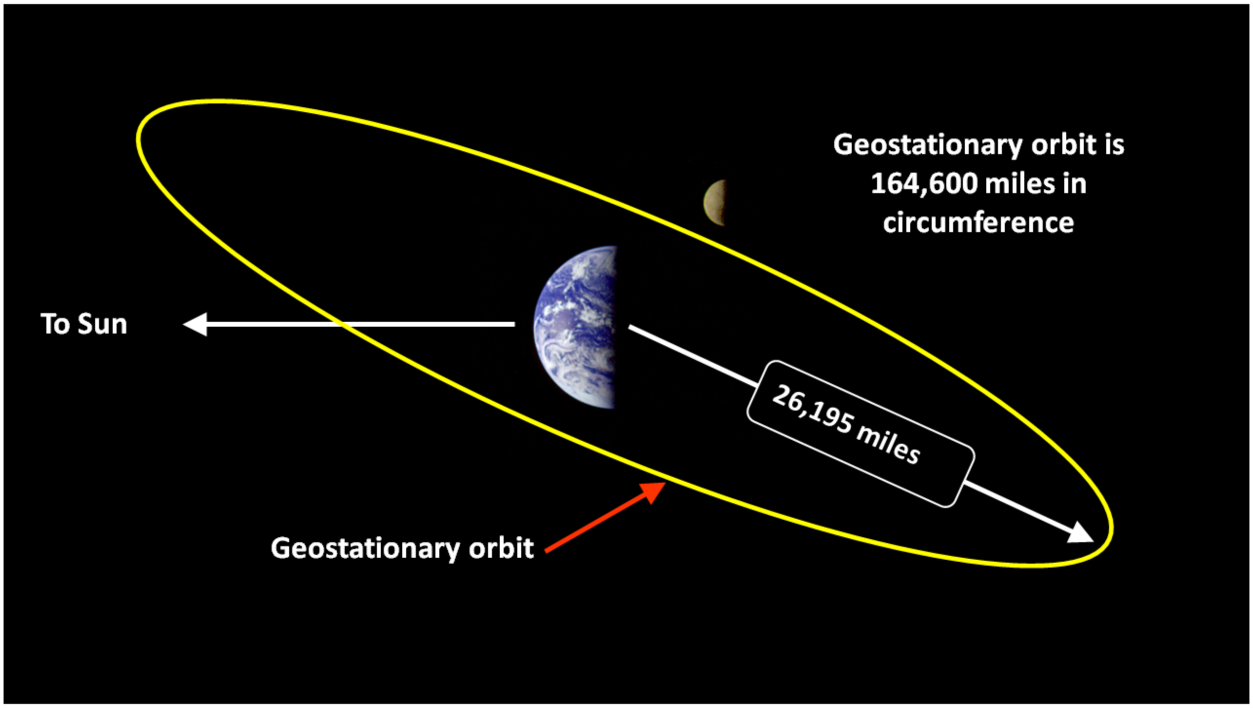

Figure 1. Illustration of geostationary Earth orbit.

In the 1940s, a science fiction story told of converting sunlight into electrical power and transmitting this power through space via high-power radio waves. Dr. Peter Glaser linked this idea with that of GEO communication satellites to originate the GEO space solar power satellite (platform) concept in a 1968 *Science* article followed by a patent in 1973. While fundamentally similar, there are two primary differences between a GEO communications satellite and a space solar power platform. The first is that the communication satellite's transmission power level is modest to meet the needs of transmitting information. Obviously, a power platform will need to transmit at a much higher power level. The second difference is that the communication satellite's signal is broadcast over a large area of the ground to enable widespread reception. The power platform's signal is, instead, tailored to match up with an antenna at a ground receiving station to establish a continuous transfer of power specifically to this ground site (Figure 2).

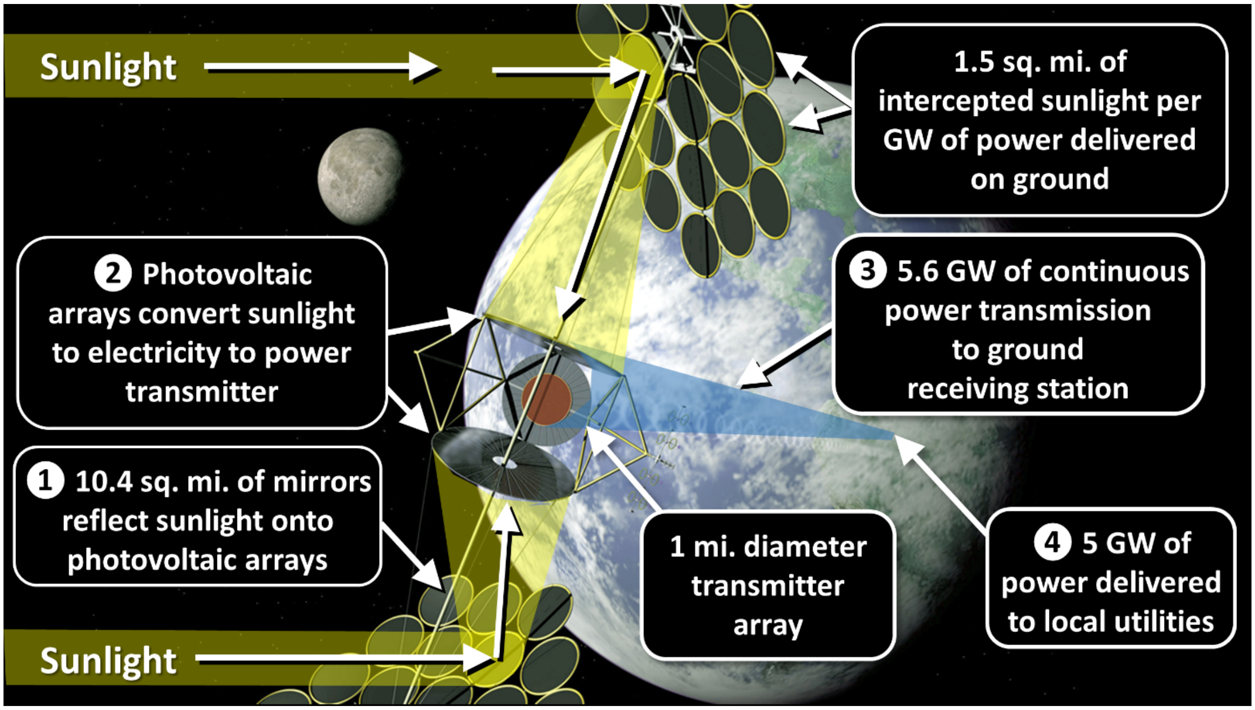

Figure 2. Illustration of a possible GEO space solar power platform capturing sunlight and converting this into electrical power transmitted to a ground receiving station (original illustration credit: NASA).

Figure 2 highlights the basic features of a generic space solar power platform. Mylar mirrors intercept sunlight, reflecting this sunlight to photovoltaic arrays where the solar power is converted into electrical power. (Some designs focus the sunlight to create high temperatures to generate electrical power.) The electrical power is carried by power cables to the transmitter array, where the power is converted into a radio signal. Using the large transmitter array, the signal is directed to a particular ground receiving station on the Earth's surface—one of thousands that will be built all around the world.

As water vapor and the other gases making up the atmosphere absorb some frequencies (wavelengths) of radio signals, the baseline NASA design selected a radio signal frequency of 2.45 gigahertz (GHZ). This is in what is referred to as the "microwave" band of the spectrum—a part of the spectrum widely used for industrial processes. At this frequency, very little of the power in the radio signal is absorbed in the atmosphere, creating an "electromagnetic window" to transmit power efficiently through the atmosphere to the ground receiver. However, as this frequency is very close to that used in microwave ovens, NASA took great care in defining a baseline system design that provides needed public safety (Figure 3).

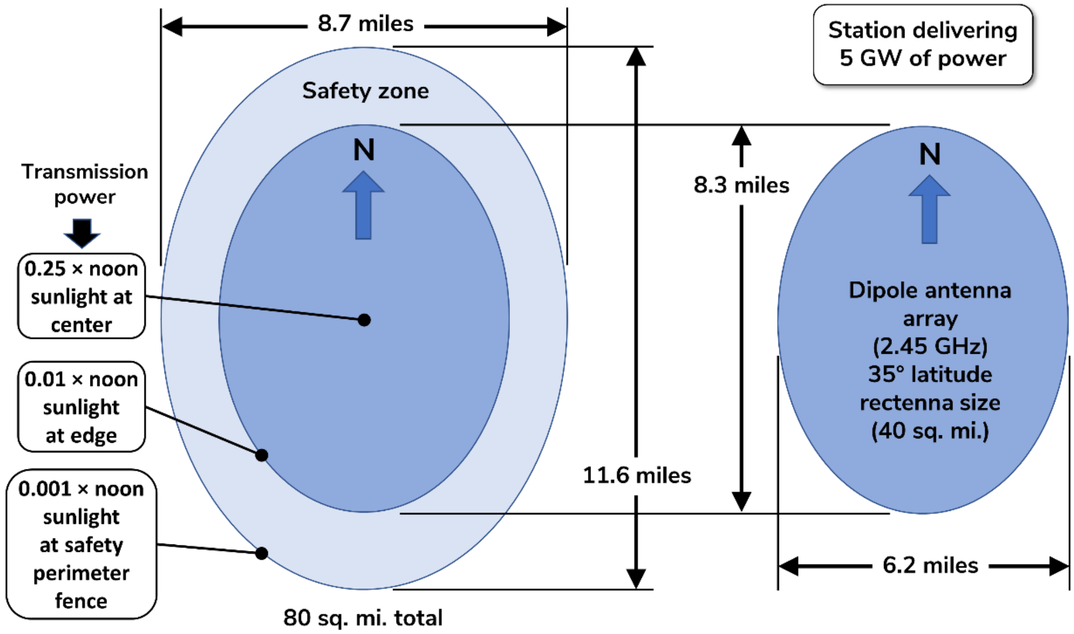

Figure 3. Space solar power ground receiving station layout based on the 1980s baseline design in the NASA report. The shape is for a receiving station located at a latitude of 35°. The elliptical shape is due to the signal striking the ground at an angle. If the station was located at the equator, it would be circular.

Figure 3 shows the configuration and size of a ground receiving station tailored for the 2.45 GHz signal frequency. Besides the choice of the frequency, the size of the transmitting array, the long distance to the ground, and the physics of radio transmission establish the needed size of the receiving array as well as the distribution of power within the signal when it reaches the ground. The strength of the signal is highest in the middle and falls off away from the center. As seen in Figure 3, with a proper design, the peak power level in the signal is 25% of sunlight at noon at the equator. At the edge of the actual receiving antenna array, the power level is only 1% of noon sunlight, while at the safety perimeter fence, it is only 0.1%.

The antenna array receives the power signal, converts this into alternating current (AC) power, and sends this power to local utilities and end-users using the standard electricity transmission and distribution system. Each ground receiving station would provide (nearly) continuous electrical power equal to five nuclear power plants or 2.5 Hoover Dams. This power is continuous except for brief periods in the couple of weeks before and after the spring and fall equinoxes when the space solar power platform briefly enters the Earth's shadow at local midnight as the platform orbits the Earth. Backup power generators would meet demand during these times. Space-based sustainable power would be continuously supplied over 99% of the year.

The total land area needed for a 5-GW receiving station in the central United States is about 80 square miles, or about 16 square miles per GW. The 2-GW Hoover Dam uses

Lake Mead to store the water used to provide hydroelectricity. Lake Mead covers about 250 square miles or about 125 square miles per GW of nameplate generation capacity. The baseline ground receiving station design is more economical in land use than hydroelectricity using reservoirs or, as discussed later, ground solar energy or wind energy.

GEO space solar power has the scalable potential to meet the world's energy needs. The circumference of GEO is about 165,000 miles. With a spacing of 10 miles, 16,500 5-GW space solar power platforms, providing 82,500 GW of continuous electrical power, could feasibly be built. If these platforms are doubled-up to generate 10 GW each, this would increase the GEO sustainable power potential to 165,000 GW.

American and World Power Needs in 2100

In a sustainable energy infrastructure, electricity is the primary form of energy. Electrical power, measured in watts, is how the electricity generated is measured. Electrical energy, expressed in watt-hours, is how the total amount of electrical power used is metered. When discussing electrical power, "kilo" (k) is used for 1 thousand, "mega" (M) is used for 1 million, and "giga" (G) is used for 1 billion.

A typical countertop microwave oven uses 1,000 watts or 1 kilowatt (kW) of electrical power. If this operated continuously for one day, it would use 24 kW-hours (kWh) of electrical energy. If it were to run continuously for one year, it would consume 8,760 kWh or 8.76 megawatt-hours (MWh) of electrical energy.

As the world's transition to sustainable energy will take time, I use the year 2100 as the target for completion. This is consistent with the Paris Climate Agreement's general timeline for ending the use of fossil fuels worldwide. The goal would be to ready the world for the 22nd century in terms of having achieved worldwide sustainable development powered by sufficient sustainable energy.

The future power needs of a nation or the world require only two inputs: the population size and the per capita energy need.

From a population of about 320 million currently, the American Statistical Association projects that the US population will likely grow to 450 million by 2100. For the world, with a current population around 7.5 billion, the population may grow to over 10 billion by 2100. We will use a world population of 10 billion in 2100 for this discussion.

The historic peak per capita energy use in the United States occurred in 1979, just prior to the long, severe economic recession resulting from sharp oil price increases in the aftermath of the Iranian Revolution. Since 1979, the annual per capita energy use has been declining, but at a very slow pace. For example, in 2000 when the economy was prosperous, per capita energy use had only declined a total of 2.6% from the 1979 peak twenty-one years earlier. When averaged over this period, the annual reduction was only 0.12% per year. To project the US total energy need in 2100, I assume that the American per capita energy need will have declined 20% from the 1979 peak.

When America's transition to sustainable energy is completed by 2100, its energy infrastructure will produce primarily electrical power. I have estimated that Americans will need a per capita continuous electrical power supply of 10,000 watts or 10 kW in 2100 to provide the energy used directly and to provide the goods and services consumed, including synthetic fuels.[2] Thus, each gigawatt—1 billion watts—of continuous power would meet the total needs of 100,000 Americans in 2100. From this estimate, 450 million Americans in 2100 would need a continuous power supply of 4,500 billion watts or 4,500 GW. For comparison, America today has an equivalent continuous generation capacity of about 472 GW—1.5 kW per capita—of which only one third, or 157 GW, is not generated using fossil fuels. Thus, by 2100, America needs to build nearly 4,500 GW of new sustainable generation capacity. Only GEO space solar power has this potential.

To estimate the world's sustainable energy need in 2100, I base my estimate on the per capita energy needs of Germany and Japan. Not having America's fossil fuel resources, they have a more frugal style of living with a higher population density. They have, however, a very high standard of living which makes their per capita energy use suitable for use as a target for setting worldwide sustainable development goals. Hence, for 2100, I assume a worldwide per capita continuous sustainable power supply of 5,000 watts or 5 kW to provide for sustainable development achieving broad middle-class prosperity. This is an average, of course. Those living in warm climates may use less on average, while those living in colder or hotter climates may use more. Thus, by 2100, a world with 10 billion people will need in the ballpark of 50,000 GW of sustainable generation capacity to enable most people to have a middle-class standard of living. Again, only GEO space solar power has the potential to meet this need.

As noted in the above illustration of a 5-GW GEO space solar power platform, 10.4 square miles of space mirrors will be used to reflect the sunlight onto the photovoltaic arrays. These mirrors will likely be lightweight, aluminized plastic film like that used to make shiny helium balloons. As mentioned above, each gigawatt of continuous power delivered would meet the needs of 100,000 Americans. This means that it only takes about 600 square feet of mirror to supply an American with the sustainable power necessary for a prosperous, middle-class standard of living. Think about this for a moment. America's sustainable energy independence can be realized by deploying the equivalent of a 24-foot by 24-foot aluminized plastic film mirror into GEO for each American. This is about the floor area of a typical two-car garage.

[2] Currently, the United States has the equivalent of 1.5 kW of continuous electrical power generating capacity per capita from all sources. Today, combustible fuels used by the end-consumers almost entirely come from fossil fuels. Even with a sustainable energy infrastructure, combustible fuels will still be needed for transportation, industrial processing, and, most likely, home heating and cooking. When estimating sustainable energy needs, hydrogen produced from water using electrolysis is assumed to be used to replace combustible fossil fuels. Producing hydrogen in this manner is quite energy intensive. This is why a total need for 10 kW per capita of continuous sustainable power is needed in 2100—to provide both the electricity used directly and that needed to produce hydrogen fuel.

Terrestrial Renewable or Nuclear Energy Sources Are Not Practical

While there are many terrestrial alternatives to fossil fuels, only three could possibly be scaled up to replace fossil fuels: wind power, ground solar power, and nuclear power. For the following reasons, none of these terrestrial alternatives are practical for America.

- Wind farms are not dispatchable, like coal-fired or nuclear power plants, but are a variable electrical power source. It is not unusual for wind farms to produce little power at times, especially in the hot summer months when the demand for electricity is usually the greatest. This variability introduces significant complexity when trying to use wind electricity as an assured national energy source. In addition to this variability, wind power is also a diffuse power source. Thus, even when using modern 500-foot-tall wind turbines, each wind turbine would, on average, supply the annual energy needs of about only 50 Americans in 2100. For optimum power generation, about four turbines would be located per square mile of commercial wind farms. Thus, each square mile would meet the annual energy needs of only about 200 Americans in 2100. To meet the needs of 450 million Americans, 2.25 million square miles—about 75% of the contiguous United States—would need to be converted into wind farms. The scale of the necessary wind farms is shown in Figure 4. This is not a practical political or environmentally-friendly solution.

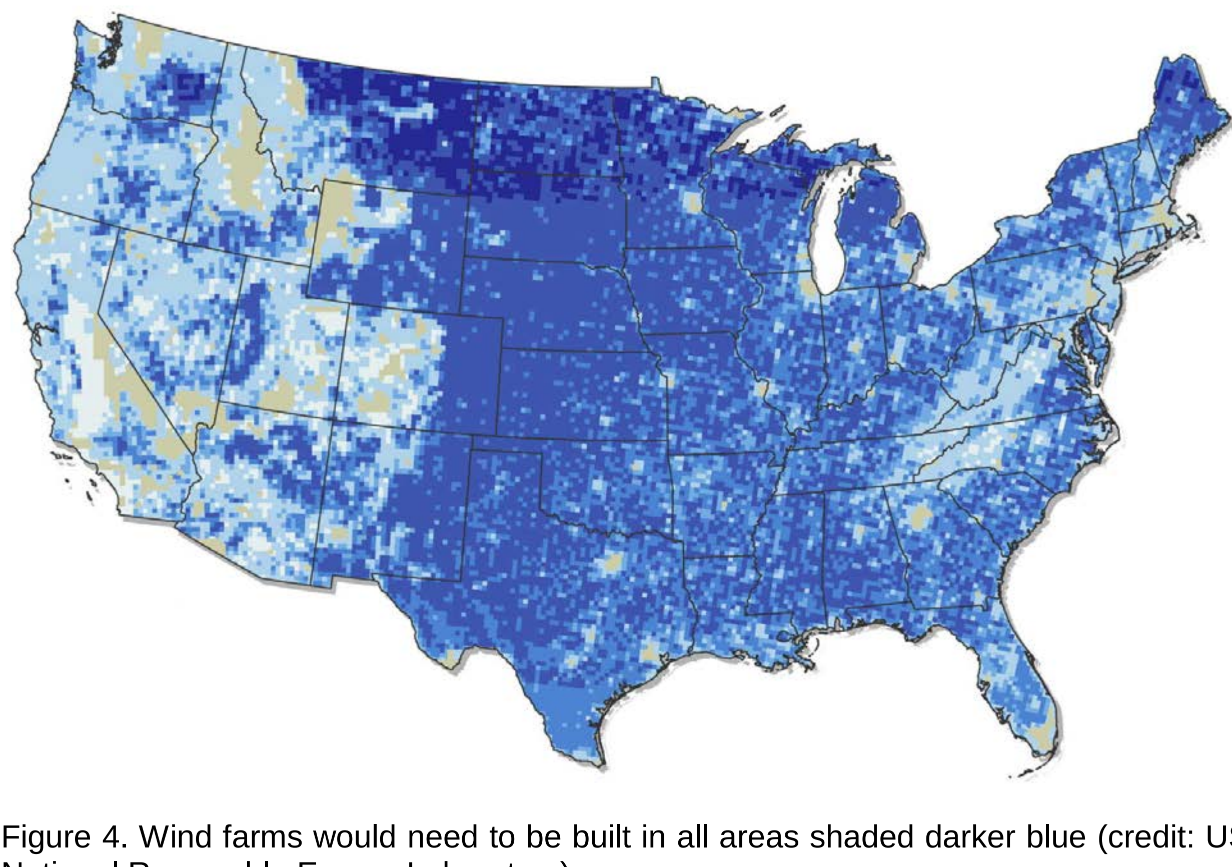

Figure 4. Wind farms would need to be built in all areas shaded darker blue (credit: US National Renewable Energy Laboratory).

- Commercial ground solar farms are also a variable electrical power source requiring a complex system to turn variable ground solar-electricity into an assured national energy supply. Due to the day-night cycle and the impact of weather, a typical solar farm will produce its nameplate power only about 20% of the time. Commercial solar farms would, per square mile, supply sufficient variable electrical energy to meet the annual energy needs of about 2,000 Americans in 2100. Thus, 225,000 square miles of actual solar farms would be needed in 2100 to meet the total energy needs of 450 million Americans. The best place to locate commercial solar farms is in the American Southwest—southern California, New Mexico, Arizona, Nevada, Utah, Colorado, and western Texas. The National Renewable Energy Laboratory has found that only about 87,000 square miles of land in these states is suitable for commercial solar farms without major grading to level the landscape. This is not a practical political or environmentally friendly solution.

- While it would be appropriate for the United States to replace its current nuclear power plants with updated designs with improved safety and lower operational costs, these total only about 100 GW of generating capacity. A new nuclear power plant is expected to operate for 120 years. Thus, each new plant needs a 120-year supply of natural uranium to fuel the plant. The most optimistic estimate of the available domestic uranium supply would meet the lifetime needs of only about 100-150 1-GW nuclear power plants. To expand the fuel supply would require breeding plutonium or the uranium U-233 isotope—both capable of being used for nuclear weapons or dirty bombs. Each plant will need about one metric ton (tonne) of plutonium or U-233 each year. The 4,500 GW of power needed in 2100 would require the annual production of 4,500 tonnes of plutonium or U-233. To meet the world's energy needs in 2100, this would expand to roughly 50,000 tonnes per year. If the United States adopts a program of fuel breeding, much of the rest of the world will likely follow suit. This would create significant nuclear weapon proliferation threats and would generate large quantities of nuclear waste each year. This is not a practical solution for many reasons.

As mentioned previously, a 5-GW ground receiving station would require about 80 square miles of land area. Providing 4,500 GW of space power would require 900 ground receiving stations utilizing a total of 72,000 square miles. This compares quite favorably with the 2.25 million square miles needed for wind farms or the 225,000 square miles needed for ground solar farms.

Ending World Energy Impoverishment

Impoverishment breeds discontent and fuels hostilities between peoples. Billions of people lack the fossil fuel resources or the economic wherewithal to escape energy impoverishment. Modern forms of energy are the lifeblood of modern agriculture and industrialization—the foundations of a middle-class standard of living. Thus, billions are excluded from having a modern style and standard of living because of energy impoverishment.

Energy impoverishment cannot be ended using fossil fuels. The fossil fuel marketplace is all about selling inherently limited supplies of a non-sustainable commodity. Eliminating energy impoverishment requires a sustainable energy solution. Doing this with GEO space solar power will involve building 10,000 5-GW GEO platforms and an equal number of ground receiving stations almost all over the world. As noted, each 5-GW receiving station would be equivalent to 2.5 Hoover Dams operating continuously. Thus, the equivalent of 25,000 Hoover Dams would be built all around the world during the transition to sustainable energy. Considering what a single Hoover Dam did electrifying the American Southwest in the 1930s, the thought of the sustainable development potential of 25,000 Hoover Dams being built by 2100 is staggering. With each ground receiving station supporting 1 million people, hundreds, if not thousands of modern cities, embracing sustainable development and housing upwards of 10 billion people, could be built, readying the world for the 22nd century. As indicated—but worth repeating—only GEO space solar power has this potential.

Achieving True American Energy Independence

President Trump made making American energy independent an important campaign promise. As president, he has expanded on this promise to include achieving American dominance of the energy marketplace. Noteworthy is that in his remarks, President Trump reiterated his openness to big, bold ideas—ideas tied to achieving energy independence and dominance.

> With these incredible resources, my administration will seek not only American energy independence that we've been looking for so long, but American energy dominance.… When it comes to the future of America's energy needs, we will find it, we will dream it, and we will build it. (President Trump, June 30, 2017)

Informed Americans understand that the value of any short-term energy independence, achieved through increased domestic fossil fuel production, will be fleeting as it will be based on non-sustainable energy sources. Eventually, discoveries of new oil and natural gas fields will fall, soon to be followed by decreases in production. This is what happened with conventional oil and natural gas production from 1970 up until the start of the fracking revolution in 2008. Growing dependence on imports forced America's involvement in the Middle East at great sacrifice. At some point later this century, just as happened in the 1970s, the need for increasing oil and natural gas imports will return, casting our children and grandchildren back into the quagmire of securing sufficient affordable oil and natural gas imports to keep America prosperous. Today's Americans have a moral obligation to enable our future generations to avoid what we most certainly know will be a disastrous future.

For President Trump's goal of America becoming energy independent to be achieved, the need to transition to sustainable energy is obvious. The fracking revolution has, quite simply, bought America precious time to undertake this transition in an orderly manner that does not harm the economy. Building roughly 4,500 GW of sustainable electrical power generation capacity, plus the new infrastructure to produce hydrogen or synthetic carbon fuels, will not happen in short order—this will be the work of several generations. The increase in technically recoverable oil and natural gas achieved through improved technologies and reduced regulations will enable America to make this transition by 2100 while maintaining affordable energy supplies. America is now "fat" with oil, natural gas, and coal, making this exactly the right time to begin the needed transition to true energy independence with sustainable energy.

Some will argue for delay—as some protectors of the status quo always do. Imagine that a solid engineering plan came forth to transition America to sustainable hydroelectricity in an environmentally acceptable way. Starting now, America would undertake building 4,500 GW of new hydroelectric facilities, making America energy secure with clean sustainable energy by 2100. Would there be any likely political or business opposition to supporting this plan? No, certainly not, as it would relieve America of the costly burden of relying on energy imports. However, had such a plan arisen in the 1890s, forty years before the first major dams were built, this plan would have been met with strong skepticism. In the 1890s, the industrial mastery to build large concrete dams did not exist. Yet, by the 1930s—two generations later—America had this capability, producing the Hoover Dam, the Grand Coulee Dam, the Bonneville Dam, etc.

Today, skepticism of America's ability to undertake GEO space solar power is without merit. It has now been nearly forty years since NASA—the NASA that undertook the Apollo program—conducted a thorough, $50 million (then-year dollars) evaluation of the GEO space solar power concept, finding that the American aerospace industry had the industrial mastery to build the GEO space solar power platforms. What was lacking was the enabling spacefaring logistics infrastructure. This was two generations ago—before there were even personal computers. Today, America's aerospace industry can build the spacefaring logistics infrastructure necessary to create the new American space mining, space manufacturing, and space power industries that will build up to 4,500 GW of American GEO space solar power by 2100. What this means is that proceeding with GEO space solar power is, now, a political decision—a big idea that will bring America true energy independence while beginning an American-led human spacefaring industrial revolution.

President Trump is not, however, content with achieving energy independence; he wishes for American dominance in world energy markets. Dominance can happen in many ways. The fracking revolution is providing, at least for a short period, American dominance of world oil and natural gas prices as America reduces its imports and becomes a net energy exporter.

An American-led spacefaring industrial revolution will put America in a dominant position for providing the world with much of the 50,000 GW of GEO space solar power needed to eradicate energy impoverishment and to enable worldwide sustainable development. Of course, this will be undertaken through commercial contracts of American space mining, space manufacturing, space power, and spacefaring logistics industries working with partners around the world. But, through the early development of key intellectual property, space industrial capabilities, employee experience and expertise, and key spacefaring operational capabilities, American dominance of these industries for generations can be achieved. America has done this in military and commercial aviation for several generations. Under President Trump, America has relearned the lesson of not giving away industrial and intellectual leadership. There is no reason why America cannot dominate an emerging world energy market using GEO space solar power. America builds and sells nuclear power plants and gas turbine generators to other countries. There is no reason why this cannot be done with GEO space solar power platforms.

Each 5-GW ground receiving station will provide about 8,760 million kWh of electricity per year. Today, the electricity from a coal-fired power plant sells for about four cents per kWh. At $0.04 per kWh, each 5-GW system will generate $438 million in revenue per year. The 900 GEO space solar power systems for the United States would bring in nearly $400 billion a year from wholesale electricity sales. The 10,000 systems needed for the world would generate nearly $5 trillion in annual revenue. Today, a new 1-GW nuclear power plant costs about $5 billion. The purchase price of 50,000 GW of space power would be expected to be at least $250 trillion. These back-of-the-envelope estimates indicate the immense new world market for space power that will start this century. President Trump's energy independence and dominance goals can make the United States a leader in this new emerging market.

Resolving the Carbon Dioxide Emissions Environmental Security Threat

A controversial decision by President Trump was to withdraw the United States from the 2015 Paris Climate Agreement. This agreement was the latest attempt to define a protocol responsive to the United Nations Framework Convention on Climate Change (UNFCCC) treaty's objective. Here is the treaty's objective with the key phrase in italics:

> The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt [such as the Paris Agreement] is to achieve, in accordance with the relevant provisions of the Convention, *stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system*. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Using measurements of ancient air trapped in tiny air bubbles in glacial ice in Antarctica and Greenland, scientists have determined the general range of the atmospheric carbon dioxide (CO_2) concentration over the last 800,000 years (Figure 5). Measured in parts per million by volume (PPM), the variation in the concentration is shown in the figure below. During eight cycles of natural global warming and cooling, the maximum natural CO_2 concentration has been in the range of 242-299 PPM. For reasons that are unclear, nature has held this upper limit at least eight times. Hence, a reasonable person would likely conclude that the upper side of this range—about 300 PPM—defines the maximum safe CO_2 concentration that would not cause "dangerous anthropogenic interference with the climate system."

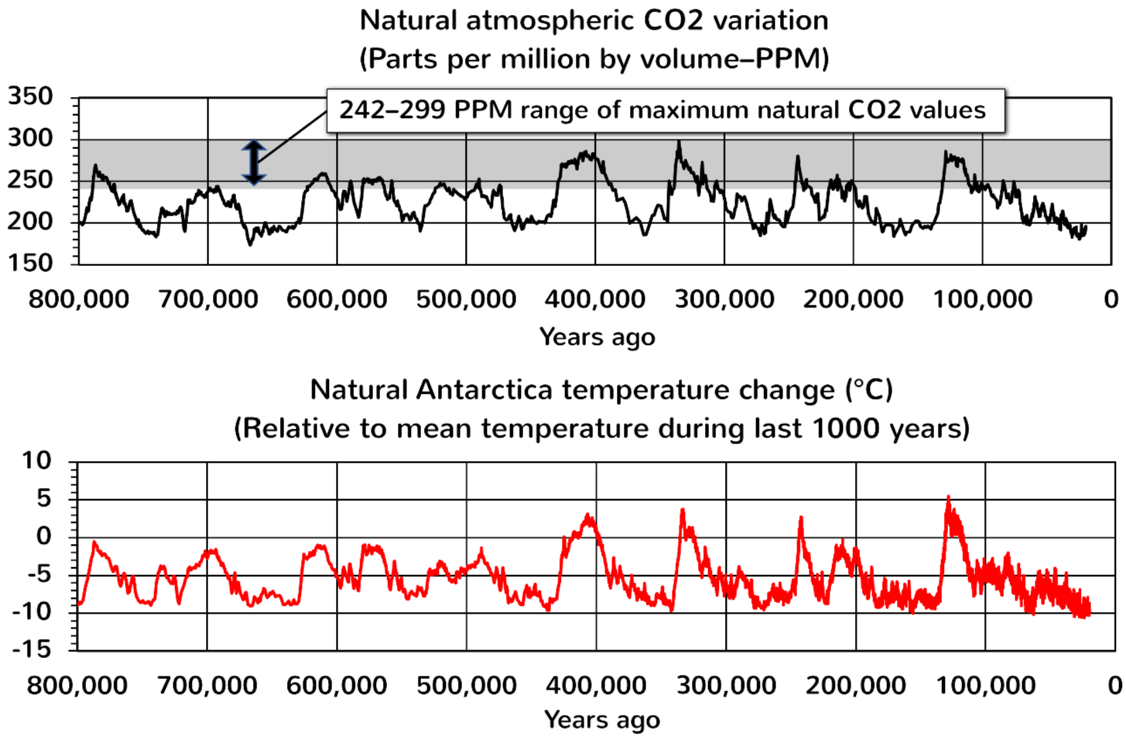

Figure 5. Atmospheric CO_2 concentration (PPM) and Antarctica temperature change (°C) from 800,000 to 20,000 years ago using ice core measurements (data source: World Data Center for Paleoclimatology, Bolder, and NOAA Paleoclimatology Program, retrieved 2016 and 2017).

As a matter of interest, the scientists were also able to estimate the temperature changes in central Antarctica using different measurement methods. Using the average temperature over the last 1,000 years as the baseline, the temperature changes over the last 800,000 years are also shown in the figure above. The average time between CO_2 data points is 420 years, while the average time between temperature data points is 138 years. Further, the temperature data do not necessarily reflect global temperature changes. While these temperature estimates show general climate warming and cooling, the lack of precision in the CO_2 and temperature data does not enable a cause-effect relationship to be established with scientific certainty. The lack of certainty means that our focus should be on the atmospheric CO_2 concentration—something that can be measured directly without ambiguity.

The abnormal rise in the CO_2 concentration began in the industrial age. With industrialization, the world's standard of living improved, leading to an increasing population and an increasing use of energy per capita. As seen in Figure 6, the atmospheric CO_2 concentration climbed as the world's population and the total fossil fuel carbon emissions increased. About a century ago, the CO_2 level broke through the 300 PPM natural ceiling. It has now climbed to around 405 PPM, and it is still increasing 2–3 PPM each year.

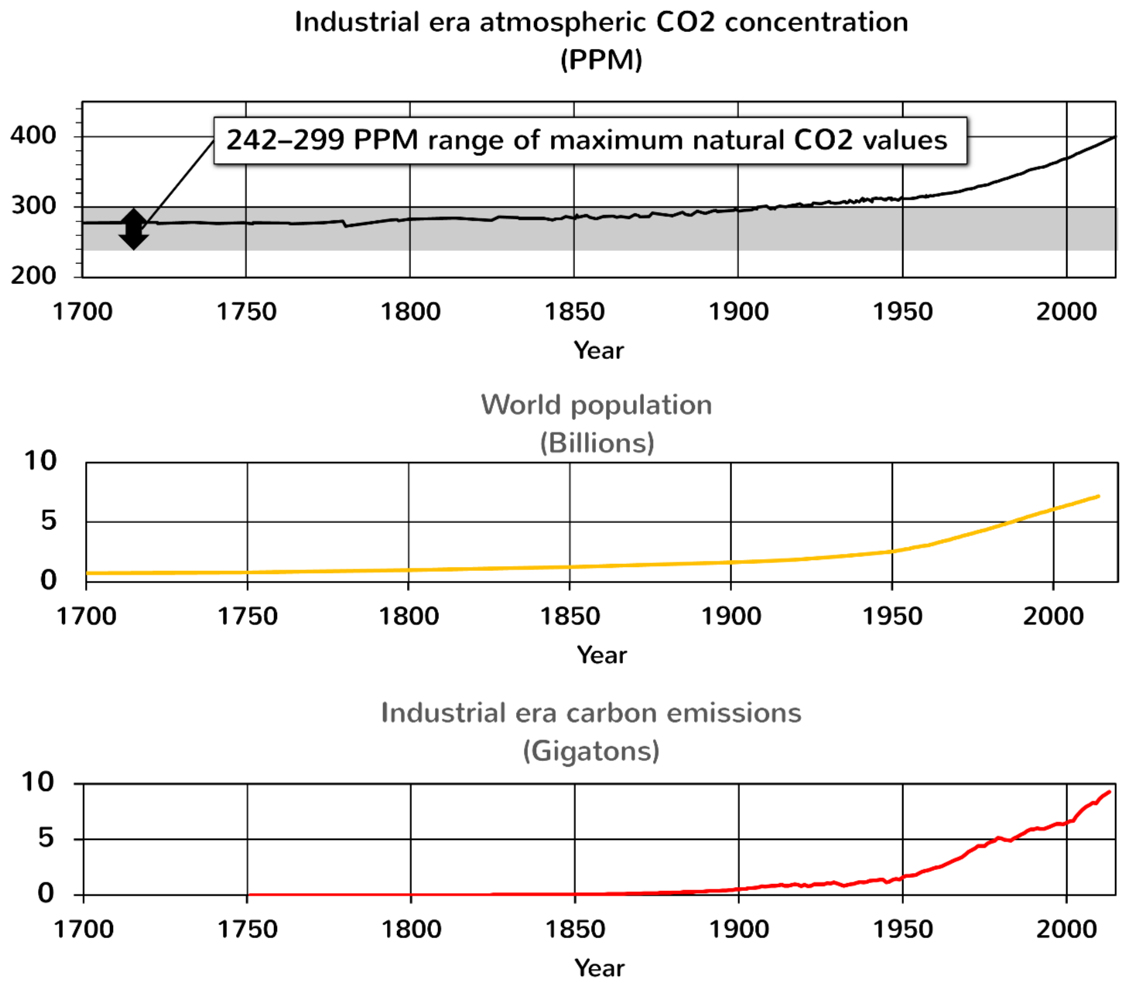

Figure 6. Industrial era atmospheric CO_2 concentration, 1700-2015 (climate data source: World Data Center for Paleoclimatology, Bolder, and NOAA Paleoclimatology Program, 1700–1958, retrieved 2015 and 2016; NOAA/Mauna Loa, Hawaii, 1959-2015, retrieved 2016). World population estimate (data source: US Census Bureau). Carbon emissions from fossil fuels (data source: US Department of Energy's Carbon Dioxide Information Analysis Center and BP's Statistical Review of World Energy as compiled by the Earth Policy Institute).

From the ice core data, we know that the current atmospheric CO_2 concentration is now abnormally high. The CO_2 concentration increase over the last 300 years is, most likely, due to large human and domesticated animal population increases, land use changes for agriculture and pasture, and growing fossil fuel carbon emissions due to industrialization. Measurements of changes in the ratio of the carbon isotopes making up the CO_2 suggest that fossil fuel carbon emissions are the primary cause for the increase.

Since the 1970s, the rising CO_2 concentration has raised questions about whether this is safe for the environment. While some approach this from a point of view of requiring evidence of harm, a reasonable person approaches this from the point of view of assuming potential harm absent evidence to the contrary. Today, there is no scientific evidence that the current abnormally high CO_2 concentration is safe for the environment and, hence, for our civilization. Essentially, humanity is overdosing the environment with CO_2 without a good understanding of the impact. Clearly, now that we are aware of what is happening, it is unwise to take no action. The UNFCCC treaty established a widely accepted need for action to "prevent dangerous anthropogenic interference with the climate system." As a party to the treaty, the United States acknowledges this need for preventive action.

An examination of the Paris Agreement finds that it does not effectively address concerns with the rising atmospheric CO_2 concentration. For example, it does not identify what CO_2 concentration is safe—something that common sense indicates should be done. Further, the agreement does not even mention CO_2 and it gives scant attention to replacing fossil fuels with sustainable energy. What it does do is demand reductions in the use of fossil fuels in developed nations, such as the United States, while permitting continued growth in their use in developing nations. It also uses changes in the global average temperature as the key metric for determining success when there is no scientifically established cause-effect relationship that an increasing CO_2 concentration correlates, over a period of years to decades, with global average temperature increases. In other words, measuring temperature is not a good metric for assessing success of the Paris Agreement actions. Thus, the Paris Agreement is not an effective technological approach to address the environmental security threat created by the uncertainty due to the increasing atmospheric CO_2 concentration.

On June 1, 2017, President Trump acted on his campaign promise to withdraw the United States from the Paris Agreement. Formal action was initiated on August 4, 2017 through notification of the United Nations. That he did not act to withdraw the United States from the UNFCCC treaty is noteworthy. Besides keeping a legal focus in US law to prevent "dangerous anthropogenic interference with the climate system," this also provides the basis for US foreign policy, as indicated in the objective statement, "to enable economic development to proceed in a sustainable manner."

After listing the reasons for his decision, President Trump indicated a willingness to work in a bipartisan manner to revise the Paris Agreement or negotiate a new agreement. Here is a key part of his remarks:

> I will work to ensure that America remains the world's leader on environmental issues, but under a framework that is fair and where the burdens and responsibilities are equally shared among the many nations all around the world.

After announcing President Trump's America First Energy Plan later in June, the White House released the following statement that ties these two policy decisions together:

> Lastly, our need for energy must go hand in hand with responsible stewardship of the environment. Protecting clean air and clean water, conserving our natural habitats, and preserving our natural reserves and

> resources will remain a high priority. President Trump will refocus the EPA on its essential mission of protecting our air and water.
>
> A brighter future depends on energy policies that stimulate our economy, ensure our security, and protect our health. Under the Trump Administration's energy policies, that future can become a reality.[3]

Common sense indicates there is only one path forward that will provide America and the world with true energy security, while addressing the environmental security threat posed by rising CO_2 levels and enabling worldwide sustainable development. This is GEO space solar power. President Trump's call for American energy independence and his justified rejection of the faulty Paris Agreement have created the political opportunity to pursue GEO space solar power.

GEO Space Solar Power Needs to Be an American Big Idea

GEO space solar power was originated in 1968—nearly a half century ago. During this time, America has suffered through two major imported oil shortages, seen periods of extreme energy price increases bringing major recessions, fought or is still fighting several major land wars in a part of the world most Americans have little interest in, expended considerable national treasure on these wars or for securing imported Middle East energy, and suffered substantial domestic political turmoil largely because of America's oil and natural gas insecurity.

During this same period, American and worldwide environmental awareness grew. Concerns about the rising atmospheric CO_2 concentration were first identified in the 1970s, in part leading to the establishment of the Environmental Protection Agency. These concerns then led to the UNFCCC treaty, which a Republican president signed and the US Senate overwhelmingly concurred with in 1992. In the subsequent quarter century, no president has led an effort to resolve the potential threat of environmental harm due to the rising CO_2 level effectively. The most recent attempt—the Paris Agreement—failed, as did the two previous attempts, because it did not define and implement an achievable technological path for the world to transition from fossil fuels to sustainable energy while enabling continued worldwide economic development. It is especially worth noting that while the previous administration was aware of the GEO space solar power approach, it did not pursue this when negotiating the Paris Agreement despite the common sense need to identify a practical technological solution to end fossil fuel carbon emissions.

For over a half century, traditional American politicians, from across the political spectrum, have failed to recognize and champion GEO space solar power. The traditional path to American political leadership has not yielded politicians now open to big ideas of the type that built the transcontinental railroads, the Panama Canal, or the Interstate Highway System—the type of ideas that made America great.

[3] Retrieved July 11, 2017

GEO space solar power is a BIG idea that President Trump is the ideal president to champion. Championing GEO space solar power will cross the political divide and effectively engage America in addressing key world energy and environmental security concerns. Undertaking GEO space solar power will:

- make the United States energy secure with sustainable energy by 2100;

- enable the United States to end its fossil fuel carbon emissions later this century in accordance with the general goals of the Paris Agreement;

- provide for an orderly transition from fossil fuels to sustainable energy with a solution that, unlike wind, ground solar, or nuclear power, is practical to implement in the United States without unacceptable environmental consequences;

- maintain a robust domestic fossil fuel industry for, at least, several generations, because America will still need to produce, during this transition, nearly as much fossil fuels as it has produced in the last 160 years;

- expand the natural gas industry to make use of synthetic methane—produced using sustainable space power and CO_2 from the atmosphere—as the general sustainable fuel of choice going into the future;

- enable most of the remaining coal and America’s oil shale resources to be kept as emergency energy supplies should the transition run into difficulties;

- enable the United States to initiate a spacefaring industrial revolution to establish the space mining, space manufacturing, space power, and spacefaring logistics industries needed to undertake GEO space solar power;

- provide NASA with the mission of being the human and robotic pathfinder to identify the extraterrestrial resources needed for large-scale GEO space solar power construction and, in partnership with universities and industry, undertake the key American technological development efforts and demonstrations needed to jumpstart this spacefaring industrial revolution;

- enable the United States to lead the large-scale human settlement of Earth-space, the Moon, the LaGrangian Points, and, eventually, the central solar system as part of an American commercial spacefaring industrial revolution;

- transition space transportation from outdated chemical propulsion to advanced electric propulsion using beamed power to shorten travel times dramatically and to increase the safety and comfort of commercial human travel within space;

- enable the United States to build upwards of 900 5-GW ground receiving stations—the equivalent of 2,250 Hoover Dams—across the United States to provide dispersed sustainable energy to enable America's transition from fossil fuels;

- enable the United States to build hundreds of new sustainable cities, near many of the ground receiving stations, to begin America's transition into a sustainable nation ready for the 22nd century;

- enable a broad expansion of American STEM, manufacturing, and construction career jobs all around the United States—an Apollo program on steroids, so to speak—as America begins to undertake this spacefaring industrial revolution, build the ground receiving stations, and to design and build the hundreds of new sustainable cities.

- enable the world to adopt a true technological solution to ending global fossil fuel carbon emissions through an orderly transition to sustainable energy;

- end the nation-on-nation conflict for the control of now vital fossil fuel resources that have characterized much of the warfare in the last 100 years;

- enable the world to avoid having to build nuclear fission power plants in the tens of thousands that would be necessary to replace fossil fuels;

- enable the world to avoid having to rely on the breeding of plutonium or U-233 to fuel terrestrial nuclear power plants once affordable supplies of fossil fuels become scarce;

- enable building upwards of 10,000 5-GW ground receiving stations—the equivalent of 25,000 Hoover Dams—all around the world to eradicate energy impoverishment;

- enable thousands of new sustainable cities to be built all around the world, turning the UNFCCC's objective of sustainable development into reality and enabling the world's population to enter the 22nd century with a middle-class standard of living;

- enable the use of additional sustainable space power to remove excess CO_2 from the atmosphere permanently, returning the carbon to geological storage as synthetic oil and methane and providing the world with a permanent energy reserve should this be needed in the future;

- provide 50,000 GW of sustainable energy that, in combination with robotic manufacturing, construction, servicing, and recycling, will fundamentally transform human culture much as the agricultural revolution did 11,000 years ago; and,

- transform humanity into a true spacefaring civilization.

The above describes how GEO space solar power will enable humanity to undertake a true paradigm shift through plentiful sustainable energy and robotic construction, manufacturing, servicing, and resource recycling. Understanding what can now technologically be made to happen makes remaining in today's paradigm of intensive fossil fuel insecurity, energy impoverishment, and environmental CO_2 uncertainty simply unacceptable. What is now needed is for the president of the United States to champion this paradigm shift.

Turning O'Neill's GEO Space Solar Power Vision into Reality

I first became aware of the idea of space solar power in the 1970s when Princeton Professor Gerard K. O'Neill founded the space settlement movement with his transformational vision of implementing GEO space solar power. While the technical concept of space solar power originated with Dr. Peter Glaser's paper in 1968, Professor O'Neill stoked the imagination of the Apollo generation to define a spacefaring future where humans settled Earth-Moon space to build GEO space solar power systems.

In 1970, Professor O'Neill conceived of utilizing lunar resources and zero-g space manufacturing to build Glaser's GEO space solar power platforms. O'Neill wrote his first paper, "The Colonization of Space," on the topic in 1970, but it took four years—with multiple rejections by leading scientific publications, such as *Scientific American* and *Science*—before it was published in *Physics Today* in 1974.[4] The American pro-space movement's interest in space colonization and industrialization embraced his new paradigm of a spacefaring civilization. He held his first conference on space manufacturing in 1975. The L-5 Society and the Space Studies Institute were founded to promote this vision. In 1976, he published his vision in the now famous book, *The High Frontier: Human Colonies in Space*,[5] putting the idea before the general public (Figure 7). However, with no prominent American politician giving any attention to these transformational ideas, enthusiasm faded. The Space Studies Institute diminished after O'Neill's death in 1992. The L-5 Society merged with the National Space Institute to create the National Space Society, focusing on NASA's efforts with the Space Shuttle and the International Space Station. Dreamers of a true American commercial spacefaring future went into political hibernation.

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[4] Gerald K. O'Neill, "The Colonization of Space," *Physics Today* 27, no. 9 (1974): 32-40.
[5] Gerald K. O'Neill, *The High Frontier: Human Colonies in Space* (New York: Morrow, 1976).

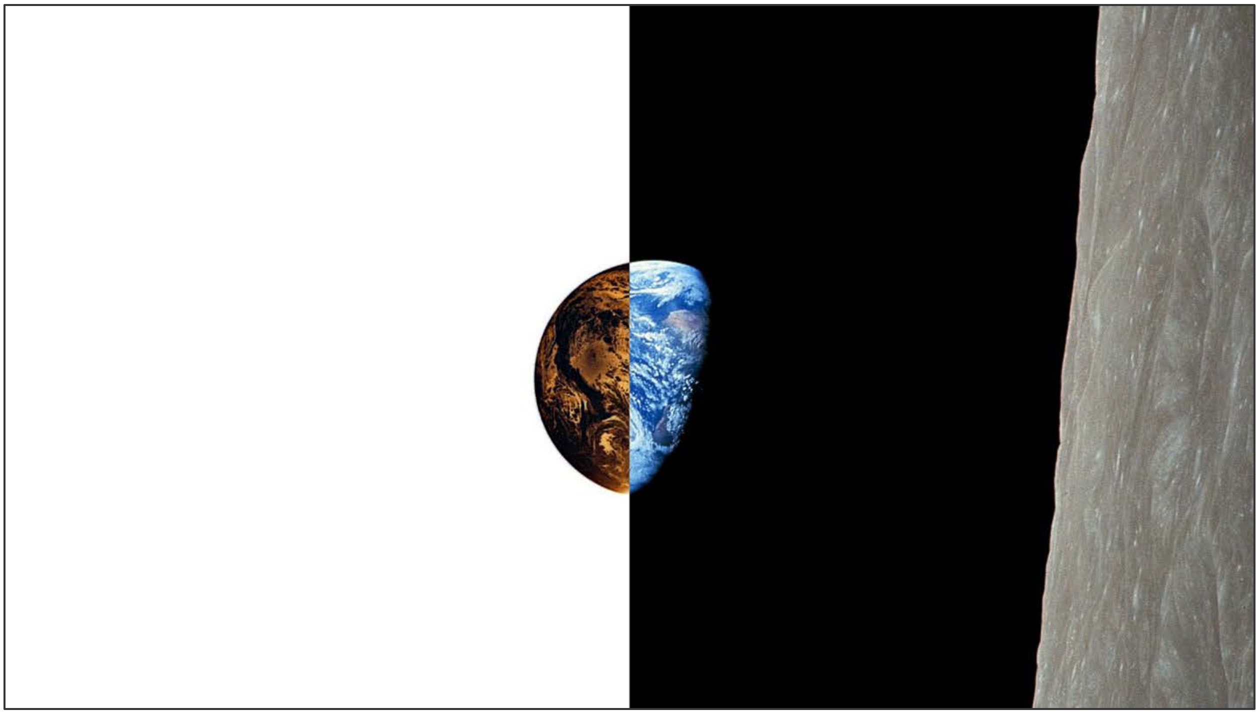

Figure 7. This is the Apollo 8 photograph of the Earth from lunar orbit. While the right side of the image depicts space as seen with the human eye, the inverted left side of the image illustrates that the Earth is surrounded by continuous solar energy, invisible to our eyes, but sufficient to power our civilization through GEO space solar power (original photograph credit: NASA).

To convince President Trump to champion GEO space solar power, O'Neill's "High Frontier" vision must be brought to the forefront of American politics as a problem-solving, opportunity-enabling idea whose time has come. A nation intensely divided politically needs unifying higher aspirational goals to overcome political divisions. Many of today's political and social divisions are directly related to areas that undertaking GEO space solar power will address—removing anthropogenic CO_2 fossil fuel emissions, providing real energy security, avoiding a political war with the fossil fuel industry, creating solid career jobs in STEM and construction, remaking America under the banner of sustainable development, avoiding foreign entanglements or war brought about by oil insecurity, increasing American prosperity, enabling the world to achieve individual and national prosperity through sustainable development, etc.

America's pro-spacefaring community now needs a modern version of the L-5 Society to build a social movement to promote GEO space solar power within America. New tools, such as social media and crowd sourcing, can enable this movement to have a tremendous positive influence on American politics and, of course, on President Trump by focusing America's attention on a remarkably positive future for the nation. Further, through the creation of the National Space Council under Vice President Pence, the means of bringing GEO space solar power to the attention of President Trump now exists.

The need, the means, and the opportunity to make President Trump the champion of GEO space solar power is now at hand. As Sun Tzu said long ago, "In the midst of chaos, there is also opportunity." We dare not let this opportunity to undertake GEO space solar power slip by.

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About the Author: James M. (Mike) Snead has wide-ranging systems and structural engineering experience from a variety of significant projects including the X-30 National Aerospace Plane, Delta Clipper Experimental (DC-X), and USAF Transatmospheric Vehicle (TAV). He holds an MS in Aerospace Engineering from the US Air Force Institute of Technology and a BS in Aerospace Engineering from the University of Cincinnati. He is a registered professional engineer in the State of Ohio and a graduate of the Department of Defense's Advanced Program Management program (in residence). He has chaired the AIAA Space Logistics Technical Committee and is an Associate Fellow of the AIAA.

Mike was the Project Engineer for the Air Force TAV Project Office where he led the technology readiness assessment for a fully-reusable, manned, space access system. Following establishment of the National Aerospace Plane Program (X-30), he was the Chief Flight Systems Engineer (Phase I) and Lead Structures Engineer (Phase II) in the X-30 Joint Program Office Systems Engineering Division. Later, he was a name-requested Government Technical Consultant for the DC-X Program – supporting this program through the fourth flight test – and served on the X-33 source selection. He developed systems engineering concepts for an integrated spacefaring logistics infrastructure focusing on fully reusable to-space and in-space transportation capable of achieving the equivalent of airworthiness certification for safety. His primary efforts were developing fully reusable, rocket-powered, TSTO system concepts using current technologies as well as concepts using advanced airbreathing propulsion.

Prior to his focus on space systems, Mike worked in the Air Force Aeronautical Systems Center's Engineering Directorate doing both original engineering and contractor structural engineering oversight on a diverse range of aircraft including the F-4, F-111, C-141, and Saudi AWACS. He served on the Executive Independent Review Team assessing first flight readiness for the YF-22 and YF-23 Advanced Tactical Fighters and on the F-22 independent cost team. While working in the Air Force Research Laboratory, He served as Lead for Agile Combat Support where, in addition to focusing on future space logistics, he co-developed the Configurable Air Transport (CAT) tanker and air mobility concept. He also initiated and led a wide-ranging futures wargaming effort, reporting to the Air Force Chief Scientist, focusing on advanced military weapons system conceptualization.

In addition, he established and leads the Spacefaring Institute LLC with a special focus on space solar power and the integrated spacefaring logistics capabilities needed to make space solar power a primary sustainable energy supply capability. In this effort, Mike has published several papers and a YouTube video on space solar power and the enabling spacefaring logistics capabilities.

Editors' Notes: Engineer Mike Snead has been a leading Space Solar Power engineer and advocate for decades. He frequently publishes in the *Journal of Space Philosophy,* and was a panel member in the KSI sponsored session on "*Space Abundance for Humankind's Needs"* at ISDC-2017 (see Article 17, following) where he presented the following critically important points:

> Each space solar power system will provide the equivalent of 2.5 Hoover Dams almost anywhere on the Earth.
>
> No other form of sustainable energy offers the world this opportunity for transformational sustainable development.

In this article, he aims his knowledge and expertise at the US President by elaborating on those conclusions. *Bob Krone and Gordon Arthur*.