A Trump Administration Path to advance commercial space solar power

By Mike Snead

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America's space enterprise was not a topic of discussion during the Trump presidential campaign beyond vague mentions of general support when campaigning in Florida. While NASA's supporters can be expected to push for returning NASA astronauts to the Moon or going to Mars, the better alternative is to focus on informing the incoming Trump Administration how America's commercial human space enterprise can be used as an economic tool to strengthen and secure America.

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President-elect Trump is now setting the policy and legislative agenda for his administration to fulfill his campaign promises. Three very important topics that will likely receive attention are national energy independence, global atmospheric environmental protection, and the Paris Climate Agreement. An invigorated American commercial human spacefaring enterprise, focused on space-based sustainable energy, provides the means to strengthen America's future energy security, address the political hot potato of atmospheric carbon dioxide buildup, and provide the basis for renegotiating the Paris Climate Agreement—and to do all of this with likely strong bipartisan support. As a consequence, the White House National Space Council, under the direction of the vice president, could be reinstated to establish clear interdepartmental and congressional coordination of these efforts. As part of this, NASA's human space exploration program would also be strengthened to provide American private enterprise with the exploration and technological pathfinding needed to establish the coming space-based energy, space mining, and space manufacturing industries.

## National energy security

National energy security is essential for the United States to remain a great power this century. Fossil fuels, which provide 80 percent of the energy Americans use, are the foundation of America's current energy security. Most Americans incorrectly assume that America has an inexhaustible domestic supply of coal, oil, and natural gas because inaccurate news reports and misleading TV advertisements create this impression.

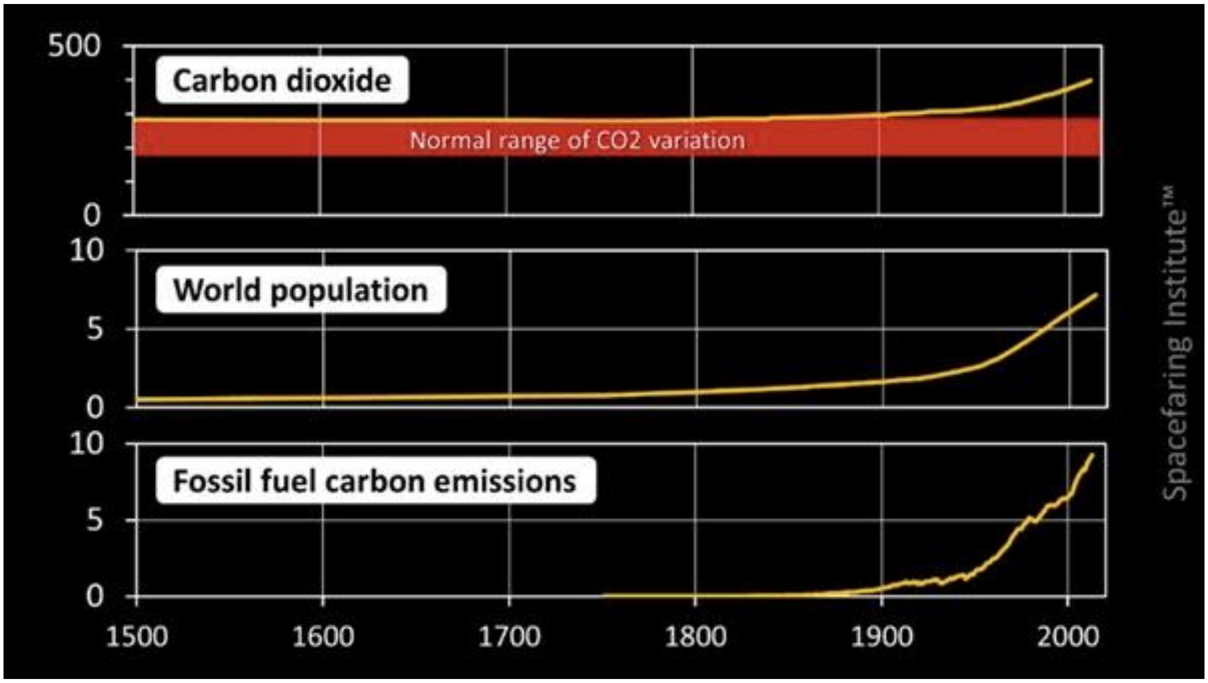
While everyone understands that fossil fuels are non-renewable, the belief in an inexhaustible supply has led to false conclusions about America's fossil fuel energy security. Consequently, the public has concluded that no policy or action to secure America's post-fossil fuel energy security is now warranted. They have no idea of what it will take to replace fossil fuels or how soon this will be needed.

Energy security is all about numbers: the population, the per-capita energy supply needed for the nation to be prosperous, and how much remaining domestic fossil fuels can be recovered. The US Geological Survey (USGS) provides formal estimates of how much fossil fuels remain that can be recovered using available technologies. Referred to as the technically recoverable endowment, it includes known reserves as well as expert estimates of yet to be discovered extractable resources in known geological formations. The size and composition of this endowment is appropriate for use in assessing America's fossil fuel energy security.

| Fuel | Technically Recoverable Fossil Fuels (Billion BOE) | Consumption (Billion BOE/yr) | Resource Life (Years) |
|---|---|---|---|
| Oil | 259.8 | 6.1 | 43 |
| Natural Gas | 403.4 | 4.9 | 82 |
| Coal | 882.5 | ~18 (with coal → oil) | ~49 |
| **Total** | **1,545.7** | | Spacefaring Institute™ |

The above table lists the USGS endowment estimates for US coal, oil, and natural gas. Also shown is the current US annual consumption and the life of each fuel's endowment at current consumption rates. The value for coal shows about how long coal would last after coal, in addition to being used for electricity generation, begins to be used to produce a synthetic oil after conventional oil is exhausted. It is quite likely that the entire endowment will be gone—or, at least, no longer affordable—within two or three generations. Of course, these are rough estimates, but they make the point that the United States does not have an inexhaustible affordable fossil fuel supply. The time to begin planning for the post-fossil fuel future is here at the beginning of the Trump Administration because for a US population of 320 million, likely growing to 500 million by 2100, it will take generations to complete the transition.

**Global atmospheric carbon dioxide level**




The above chart plots the atmospheric carbon dioxide level, the size of the human population, and the discharge of carbon emissions from fossil fuels since 1500, well before coal came into common use. The red band in the top plot is the range of variation of the atmospheric carbon dioxide level over the last 800,000 years. The higher value corresponds to the warmer interglacial periods, such as we are now experiencing, while the lower value corresponds to the depths of the much colder glacial period when ice sheets covered much of the northern hemisphere. The maximum and minimum carbon dioxide values during these wide variations in global climate conditions are surprisingly consistent indicating that the current value is abnormally high.

These plots led me to conclude that humans began to impact the atmospheric carbon dioxide level in the 1700s as the population grew above about one billion. The level increased sharply, beginning in the mid-1800s, as coal came into widespread use to replace wood fuel and the steam-powered industrial revolution, driving the demand for coal, increased the standard of living, boosting the human population size. While there is considerable public and scientific debate about the related issue of "global warming," the primary focus should be on the fact that the atmospheric carbon dioxide level is now about 40 percent higher than the prior "natural" maximum and continues to rise each year.

**A better approach is to renegotiate the Paris Agreement to emphasize the technological solutions that will halt, and then reverse, the rise in atmospheric carbon dioxide while providing the world with sustainable energy needed to replace fossil fuels and elevate the standard of living in energy impoverished nations.**

**Paris Climate Agreement**

In 1992, the US Senate approved, and President George H. W. Bush signed, the United Nations Framework Convention on Climate Change (UNFCCC). The objective of this treaty is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." Carbon dioxide is one of these greenhouse gases.

The Paris Climate Agreement was the most recent attempt to reach a global consensus on how to implement the objective of the treaty with respect to carbon dioxide. The agreement entered into force on November 4, 2016. Treating the agreement as an "executive agreement," rather than a treaty requiring Senate consent, the United States submitted ratification documents on September 4, 2016. However, the Obama Administration stated, "The targets are not binding; the elements that are binding are consistent with already approved previous agreements."

In several aspects, the agreement is flawed. One example is its focus on global temperature increases, believed to be substantially due to the rising carbon dioxide level, instead of focusing on how to eliminate the need for fossil fuels by transitioning, in an orderly manner, to sustainable energy. Another example is the creation of a class of nations that are self-defined victims of "climate change" that can expect, per the agreement, to receive collective economic payment of not less than $100 billion per year as compensation.

While there has been some discussion of scrapping the agreement, legally this may be difficult to do. The legal authority of a prior president's executive agreement appears to be murky, and subject to case-by-case legal decisions. Some federal judges may accept arguments that the public good is better served with the agreement than without it. One result could be that regulatory restrictions on carbon dioxide emissions, issued by the Obama Administration, may be upheld in court while a Senate filibuster prevents any quick legislative fix.

**America needs another sustainable energy solution. As remarkable as this now sounds, the new solution that is needed is space-based sustainable energy because there are no other remaining choices.**

Federal lawsuits involving environmental issues have proved to be tricky and lengthy. Using the courts to keep this agreement alive as a political thorn in the side of the Trump Administration may become a political agenda item for some. While I am not a lawyer, it is also possible that an attempt to ignore the agreement could be challenged in some international court and become a foreign policy headache for President Trump whenever he travels abroad, especially to developing nations expecting compensation.

A better approach is to renegotiate the agreement to emphasize the technological solutions that will halt, and then reverse, the rise in atmospheric carbon dioxide while providing the world with sustainable energy needed to replace fossil fuels and elevate the standard of living in energy impoverished nations. Of course, I'm talking about space-based sustainable energy. The renegotiated agreement would maintain the same timeline, completing the transition from fossil fuels by 2100. The renegotiated agreement would become a simple statement setting 2100 as the target to complete the transition and listing the sustainable energy approaches that can be used, with space-based sustainable energy being among these. Each nation would be free to select the combination of approaches that best meet its needs. Such a short agreement would be in the best interests of the United States to sign and would likely obtain strong bipartisan support in Congress. This would provide the Trump Administration with a significant tool for foreign policy negotiations as all nations need energy and most wish that this be sustainable energy.

**America's need for space-based sustainable energy**

Many people do not yet acknowledge the need for America to undertake space-based sustainable energy. Having written about this previously in The Space Review, here is a summary of my findings:

- Fossil fuels now supply 80 percent of America's energy. With a likely 2100 population of 500 million, 80 percent, or 400 million, would need new sustainable energy supplies for electricity and fuels. The other 20 percent would be supplied by hydroelectricity, geothermal electricity, nuclear, wind, ground solar, and biofuels as they are today.

- For wind energy, the total annual energy needs of only about 77 Americans can be met by each square kilometer of commercial wind farms. Thus, 5.2 million square kilometers of commercial wind farms, requiring about 5 million 150-meter tall wind turbines, would be needed by 2100 to replace fossil fuels.

- For ground solar energy, the total annual energy needs of only about 580 Americans can be met by each square kilometer of commercial solar farms. About 700,000 square kilometers would be needed for solar farms in the sunny American Southwest to replace fossil fuels. Due to the generally rugged terrain, most of the flat land in New Mexico, Arizona, Nevada, Utah, western Texas, and southern California would need to be used. If built elsewhere, where cloud cover increases, the total area needed also correspondingly increases.

- For nuclear energy, a one-gigawatt (GW) plant can meet the energy needs of about 100,000 Americans. Hence, by 2100, 4,000 1-GW nuclear power plants would be needed to replace fossil fuels. Besides the issues of nuclear waste disposal safety, nuclear plant safety, limited uranium supplies, and the foreign policy difficulties related to nuclear fuel breeding, the continental United States only has sufficient locations with adequate cooling water to support a modest expansion of nuclear power.

Clearly, wind, ground solar, and terrestrial nuclear power do not offer practical replacements for fossil fuels for America. Neither does expanded hydroelectricity, geothermal electricity, or biofuels. Obviously, America needs another sustainable energy solution. As remarkable as this now sounds, the new solution that is needed is space-based sustainable energy because there are no other remaining choices. Just as in the mid-1800s, the United States was forced to transition to coal to replace diminishing wood fuel supplies, the United States is now forced to transition to space-based energy to replace diminishing fossil fuel supplies and meet legal and moral obligations with respect to the increase of the atmospheric carbon dioxide level. Space solar power will likely be the primary form of space-based sustainable energy.

**Space solar power and potential revenues**

Invented in the 1960s, space-based solar energy moves the ground solar farms to geostationary Earth orbit. From this orbit, the power is transmitted to ground receiving stations and, then, distributed to local utilities. By doing this, the needed solar array (or mirror) size shrinks to about 15,500 square kilometers to provide 4,000 GW of baseload electrical power to the utilities. The difference in size is because the space-based arrays are in sunshine about 100 percent of the time, versus only 20 percent for ground arrays; the sunlight is about 50 percent stronger above the atmosphere; the solar arrays always point at the sun, and, the lack of ground obstacles, roads, and so on enables more compact solar arrays. Geostationary Earth orbit is about 265,000 kilometers in circumference, providing ample room for locating the platforms.

A combination of a renegotiated Paris Climate Agreement, a new National Energy Security Policy, and an updated National Space Policy will make it clear to American private enterprise that the United States will require a new space-based sustainable energy industry capable of providing roughly 4,000 gigawatts of baseload electrical power by 2100. Further, the agreement offers the potential of a world market demand for 50,000 gigawatts with, perhaps, an additional 20,000 gigawatts needed to extract excess carbon dioxide from the atmosphere, over many decades, to return the atmospheric level to normal. (Yes, we are now becoming planetary engineers.)

**Getting this ball rolling will require robust, effective leadership within the Trump Administration. A reinvigorated White House National Space Council, under the vice president, may be ideal for the broad, interdepartmental planning that will be needed to put America on the path to become a true commercial human spacefaring nation.**

Today, the American average industrial price of electricity is about $0.07 per kilowatt-hour; $70 per megawatt-hour; or, $70,000 per GW-hour. The 4,000 gigawatts of space power will deliver 35 million GW-hours of energy. The potential revenue totals $2.45 trillion per year. For the possible 70,000 gigawatts needed by the world, this increases to $43 trillion per year. Assume just 10 percent of this global revenue is spent on the spacefaring logistics needed to build and operate the space power industry. This would have a global spacefaring logistics market potential of roughly $4 trillion in annual revenue.

## Sustainable energy gateways

As illustrated above, space-based power will likely be transmitted to ground receiving stations. Due to several design considerations, a five-gigawatt receiving station is expected to be the typical size. For America, this means that 800 five-gigawatt ground receiving stations will be built in the United States to provide continuous sustainable electrical power and fuels. Each ground station, including a safety perimeter, will occupy about 205 square kilometers for a total of 164,000 square kilometers—much better than the 700,000 square kilometers needed for ground solar energy.

The Hoover Dam produces two gigawatts of electrical power. Think of each of these ground receiving stations as being 2.5 Hoover Dams. In transitioning from fossil fuels to space-based sustainable energy, 800 locations in the United States will have 2.5 Hoover Dams built serving as energy gateways to the local economy. New, modern, spacious 21st century cities will be built adjacent to these gateways to take advantage of the sustainable power being supplied without the need for long-distance transmission lines. The design of the receiving antenna will be such that farming operations can continue under the elevated antenna because the antenna passes about 85 percent of the sunlight, rather than being opaque like solar arrays. Place the antenna on the roof of greenhouses and industrialized greenhouse food production can be undertaken to supply the adjacent city with locally-grown fresh food year-round regardless of the climate. Build industrial plants under the antenna or on the station grounds and these industries will have direct access to gigawatt-levels of electrical power. Repeat this 800 times across the nation and America's energy production, food production, and industry becomes highly decentralized, creating significant new business and job growth opportunities almost everywhere. This is a clear economic advantage of space-based energy that cannot be matched by terrestrial renewable energy solutions. America will be substantially rebuilt and modernized during the 21st century as it transitions from fossil fuels to space-based energy.

Now, extend this model to the world. The world will need 10,000 of these sustainable energy gateways to meet the growing world energy needs. The equivalent of another 4,000 will be built to capture excess carbon dioxide from the atmosphere. Across the globe, independent of traditional sources of energy, the world's population will have access to space-based sustainable energy. This is what the UNFCCC treaty wants to have happen and what a renegotiated Paris Climate Agreement can make happen by turning to space-based sustainable energy as the primary technological replacement for fossil fuels.

With each of these energy gateways, the government's revenue from excise, income, and property taxes will increase. The United States has an immense debt of $20 trillion. States and local governments have substantial additional debt and future expenditure obligations. The commercial space energy, space mining, and space manufacturing industries, and the new cities, industries, businesses, and jobs created by the energy gateways will add significant new national wealth and income generation: just what America needs to rebalance government income and expenditures and reduce public debt. The same will happen worldwide as impoverished nations gain energy gateways to enable them to transform the economic potential of their citizens and country into new national wealth while establishing a modern standard of living and economy. Terrestrial sustainable energy sources will not be able to accomplish this.

**NASA's pathfinder mission**

During the 1850s, when the idea of a transcontinental railroad spanning the United States began to take hold, the federal government sent exploration teams into the West to locate needed natural resources and survey potential routes. This followed similar efforts undertaken to chart coastal and interior river and lake navigation routes. These were early examples of the important federal role to assist private enterprise in opening new physical and technological frontiers.

Undertaking space-based sustainable energy will require the establishment of new American space energy, space mining, and space manufacturing industries. To reduce private investment risk and increase public confidence, NASA should initiate a pathfinding mission to identify lunar and asteroid resources that will benefit these efforts and develop and mature the key enabling technologies. NASA is already considering human missions back to the Moon and to near Earth asteroids. Combined with ongoing NASA science and technology development efforts, NASA is well-positioned to undertake an aggressive human space program to lead American private enterprise into routine commercial human space operations.

## National Space Council

Getting this ball rolling will require robust, effective leadership within the Trump Administration. A reinvigorated White House National Space Council, under the vice president, may be ideal for the broad, interdepartmental planning that will be needed to put America on the path to become a true commercial human spacefaring nation. While the focus of this discussion has been on space solar power, areas like space mining, space manufacturing, and spacefaring logistics will be equally important and require new and updated national policies, legislation, interdepartmental coordination, budget planning, and more. Throughout the Trump Administration, the National Space Council would be critical to successfully beginning America's transition into a true human spacefaring nation with a new NASA pathfinding mission leading the way.

## Conclusion

Americans want to be a human spacefaring nation, not just a space exploring nation. To achieve this goal, sound economic reasons are needed. America's clear need to transition from fossil fuels to space-based sustainable energy provides the justification for the incoming Trump Administration to embrace this change. As outlined in this article, the benefits to realized, not just for the United States but also for the entire world, will be immense. America will be strengthened economically and technologically while, for much of the world, the scourge of energy impoverishment will be banished. Human civilization will emerge from this century as a true spacefaring civilization.

Imagine you have traveled back in time a century to 1917. Then, aeronautics was just in its technological infancy with aircraft being built of wood and cloth. Meeting with America's leading aeronautical engineers, you explain how by the end of the century, America will be building thousands of airliners a year, each capable of carrying hundreds of passengers while flying five miles in altitude at near sonic velocity for thousands of miles without refueling. You will explain how thousands of these airliners fly every morning, afternoon, and evening, routinely, for years without crashing; how long-distance airliners can fly halfway around the world while passengers watch movies or sleep to pass the time. While they would find this future astonishing, this is exactly what happened.

A comparable spacefaring revolution is now beginning. I want America to lead this revolution. This is the opportunity that the incoming Trump Administration can make happen. Urge them to make it so!

## Notes

1. For the quantitative energy information discussed, see Analysis of US 2100 Energy Needs and Sustainable Energy Sources, Mike Snead, August 31, 2016. For short videos on the topics of carbon dioxide, U.S. energy security, nuclear power, and wind and ground solar energy, see the Spacefaring Institute's YouTube channel.
2. For information on the Paris Climate Agreement, see Climate Change: Frequently Asked Questions about the 2015 Paris Agreement, Congressional Research Service, September 1, 2016, R44609.

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