US Fossil Fuel Energy Insecurity and Space Solar Power

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Over the last two centuries, human civilization has become almost totally dependent on fossil fuels to enable our current standard of living while supporting billions of humans. For this reason, every hour of every day, the equivalent of nearly 9 million barrels of oil are extracted from the Earth's remaining endowment of these fossil fuels to meet our needs; about 1.6 million in the United States alone. The fact that these fossil fuels are non-sustainable energy sources is well understood. However, the energy security implication of this fact on the United States is widely ignored. This second article in a three-part series focuses on why the rapidly diminishing US endowment of technically recoverable fossil fuels poses an energy security threat for the United States that must be addressed by transitioning to sustainable energy sources this century.

The carbon dioxide environmental security threat

The first article in this series identified how space-based sustainable energy resolves the dilemma presented by the 1992 United Nations Framework Convention on Climate Change (UNFCCC) treaty (see "The Paris climate agreement and space solar power", The Space Review, February 29, 2016). This treaty strives to "prevent dangerous anthropogenic interference with the climate system," meaning our environment. The treaty's focus is on the abnormally high level of atmospheric carbon dioxide, most likely due to humans, and the reasonable concern this creates about causing environmental changes that may bring substantial harm to humanity. This uncertainty, I argue, constitutes an environmental security threat that humanity must ethically address. However, a dilemma exists due to treaty's conflict between limiting fossil fuel carbon dioxide emissions, believed to be a primary cause of the rising carbon dioxide levels, and our civilization' s substantial reliance on fossil fuels to maintain the standard of living in developed nations and improve that in developing nations.

The public, especially in the United States, is not currently concerned about the abnormally high levels of atmospheric carbon dioxide, in part due to many other security-related concerns continually in the news. Unfortunately, it is also due to the poor process undertaken to inform the public about the carbon dioxide issue. As discussed in the previous article, the phrase “global warming” was used inappropriately in a manner causing confusion while substantial importance was also placed on predictive global warming models that have generally failed the test of time. All the while, atmospheric carbon dioxide levels have been steadily climbing—a key point lost in the confusion. I argue that the uncertainty of the serious risk this presents constitutes an environmental security threat the Americans are ethically obliged to address. Space-based sustainable energy, e.g., space solar power, becomes the only ethical path forward to resolve the treaty’s dilemma for powering human civilization with sustainable energy while addressing the high carbon dioxide levels.

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The continued US dependency on fossil fuels constitutes an energy security threat

As noted in the first article, a society’s prosperity, reflected by its standard of living, is closely tied to the affordable energy supply per capita. America has been blessed with immense forests that met the early need for wood fuel, and, then, with substantial fossil fuel resources enabling the Industrial Revolution and the accompanying rapidly increasing American standard of living.

While recognizing that fossil fuels are non-renewable, Americans act as if their substantial supply of fossil fuels is stable into the foreseeable future. While Americans become concerned when fuel costs increase, concern about the reliability of the fossil fuel supply is almost nonexistent. As seen below, for the United States this is a false and very dangerous assumption. America’s continued dependency on fossil fuels, with no well-planned “off ramp” to sustainable energy this century, constitutes an energy security threat that must be addressed.

What constitutes the “foreseeable future”?

A conscientious person is aware of circumstances that may bring harm to themselves or their family in the foreseeable future. What constitutes the foreseeable future varies, depending on the circumstances. For example, running out of food or water would constitute a serious harm, especially for a family with children or the elderly. When impending natural disasters threaten the immediate supply of food and water, many people hurriedly rush to the supermarket to stock up on food and bottled water. Photographs of barren supermarket shelves are common in advance of a hurricane or blizzard. Thus, under normal day-to-day living, the foreseeable future may extend a week for two into the future.

The framers of the UNFCCC treaty consider the rest of this century to be within the foreseeable future. In the 2015 Paris Agreement, developing nations are encouraged to complete their actions to cap and, then, significantly reduce carbon dioxide emissions by the end of the century. Hence, to address the environmental security threat of the potential harm caused by abnormally high carbon dioxide levels, looking forward three to four generations is not unreasonable to the treaty's parties.

One way to approach establishing what the foreseeable future should be for energy security planning is to estimate how long it would take to replace fossil fuels with something else like conventional nuclear energy. Nuclear power plants can provide electricity and hydrogen fuel using electrolysis. Thus, fossil fuels could be replaced by nuclear power. In rough numbers, the typical one-gigawatt nuclear power plant could supply the electricity and hydrogen fuel needs for about 100,000 Americans, or 10 plants per million people. In 2015, the United States' population was about 320 million people. Roughly 80 percent of the US energy supply now comes from fossil fuels. Thus, the energy needs of the 256 million people dependent on fossil fuels could be met by about 2,560 one-gigawatt nuclear plants.

I estimate that it would cost about $6.5 billion to build a modern nuclear power plant providing electricity and hydrogen fuel.[1,2] In this simple example, the cost of the needed 2,560 plants would be $16.6 trillion. In 2014, the US federal government expended $3.5 trillion, of which only about $583 billion was for non-defense discretionary spending. Everything else was for interest on the debt, Social Security, health care, defense, and other mandatory expenses.

Let's assume that all $583 billion would now to be spent building nuclear power plants to replace fossil fuels, that a plant would take five years to build, and that the US population does not grow. About 34 years—to 2050—would be needed to build the 2,560 plants needed to complete the transition. Of course, allocating all non-defense discretionary funding to this effort would be politically impossible. If only half were allocated, the task would not be done until around 2078. If only a quarter were allocated, it would end about 2135—yes, well into the twenty-first century. And, this assumes no US population growth, a very important point discussed below.

A reasonable person would conclude that the foreseeable future for US energy security planning should be linked to how fast replacements for fossil fuels can be built and how long the fossil fuel supplies will last.

From this simple example, a reasonable person would conclude that the foreseeable future for US energy security planning should be linked to how fast replacements for fossil fuels can be built and how long the fossil fuel supplies will last. Obviously, the replacements need to be completed before the fossil fuel supplies run out, as they are, after all, non-sustainable.

How long will US fossil fuel supplies last?

The United States Geological Survey (USGS) was founded in 1879. Congress charged it with the "classification of the public lands, and examination of the geological structure, mineral resources, and products of the national domain." The USGS provides estimates to Congress of the amount of oil, coal, and natural gas technically recoverable in the United States.

That the Earth holds large stores of carbon in geological storage is well understood. But, how large is large? Let's look at coal. In 1972, the USGS estimated that the United States had 3,200 billion tons of coal—the total coal resource base. For perspective, the United States now mines about 1 billion tons a year, primarily for electricity generation. Hence, this "total coal resource base" value implies immense quantities of coal are available. But in 2011, the USGS reported that the recoverable coal reserve base—that portion of the total coal resource base that can be profitably brought to market—is only 261 billion tons. Thus, only 8 percent of the coal under the United States is available for extraction and use. Why the difference? Coal deposits may be too deep to mine, too thin to mine, too dispersed to be cost-effective to mine, under protected lands, and so on. The 8 percent represents that portion of the total resources base considered “technically recoverable” and likely to eventually be profitable to be used.

In 2011, the Congressional Research Service published the USGS 2010 estimate of United States fossil fuel reserves plus yet-to-be-discovered technically recoverable resources—what the USGS calls the “endowment”.[3] These include oil and gas resources recovered using fracking. The unit of measure is the barrel of oil equivalent (BOE), the amount of thermal energy contained in 42 US gallons of oil. The thermal energy content of coal and natural gas can be easily expressed in terms of BOE. These are the USGS values shown in Table 4 below:

- Technically recoverable oil: 161.9 billion BOE (12%)
- Technically recoverable natural gas: 304.4 billion BOE (22%)
- Recoverable reserve base of coal: 900.5 billion BOE (66%)[4]
- Total endowment with coal: 1,366.8 billion BOE (100%)
- Total endowment without coal: 466.3 billion BOE (34%)

Table 4. U.S. Fossil Fuel Reserves Plus Undiscovered Technically Recoverable Resources Expressed as BOE

(BOE = Barrels of oil equivalent)

Fossil Fuel	Native units	BOE
Technically recoverable oil[a]	161.9 billion barrels	161.9 billion BOE
Technically recoverable natural gas	1717.8 trillion cubic feet	304.4 billion BOE
Recoverable reserve base of coal	261 billion short tons	900.5 billion BOE
TOTAL U.S. technically recoverable fossil fuel endowment		1366.8 billion BOE

Source: USGS, http://certmapper.cr.usgs.gov/data/noga00/natl/graphic/2010/summary_10_final.pdf; BOEMRE, http://www.boemre.gov/revaldiv/ResourceAssessment.htm; and EIA, http://www.eia.doe.gov/cneaf/coal/reserves/reserves.html.

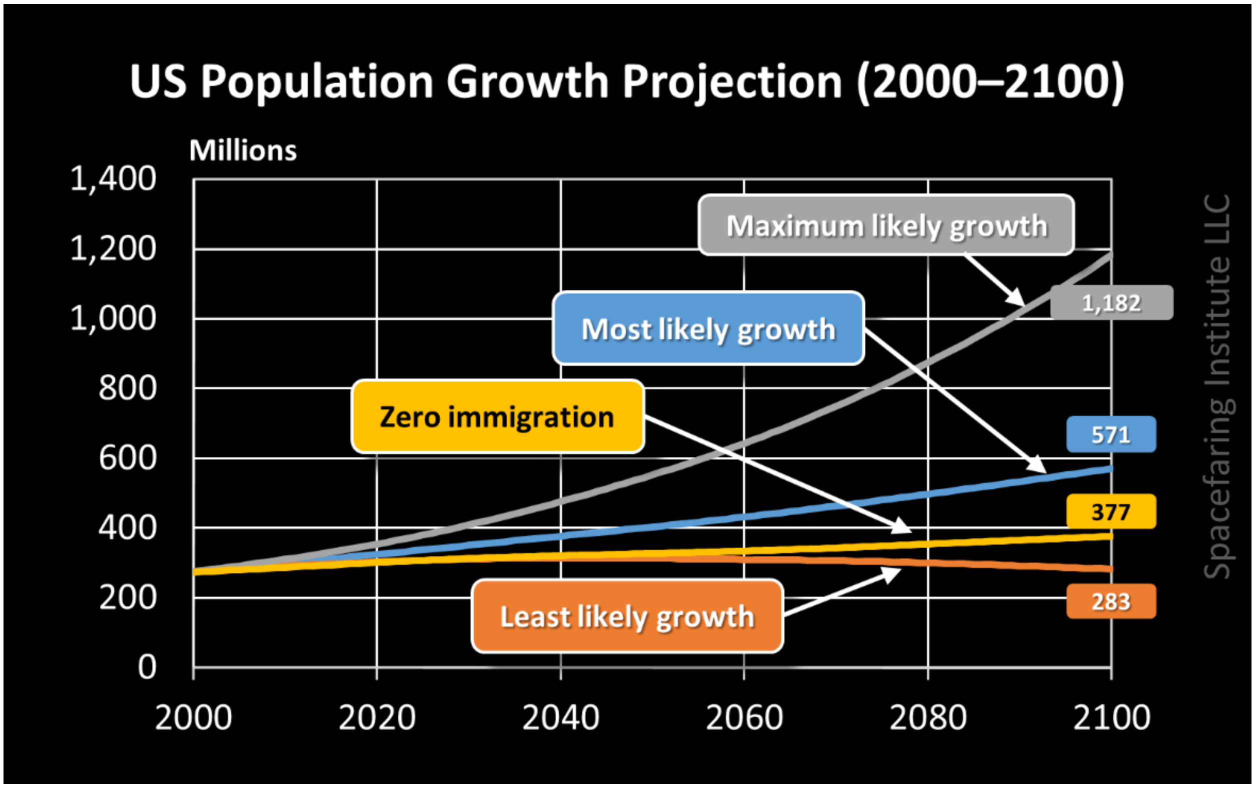
a. Technically recoverable resources of oil and natural gas include proved reserves plus undiscovered technically recoverable resources. Includes conventional and unconventional (continuous), offshore and onshore.

With a population of 309 million in 2010, the United States consumed 13.95 billion BOE of fossil fuels, or 1.6 million BOE each and every hour. The per capita fossil fuel use was 45.14 BOE, consumed directly as well as indirectly through goods and services. Currently, to maintain the US standard of living for the current population of about 320 million, the United States now consumes about 14.4 billion BOE of fossil fuels. With no change and no further population growth, the entire USGS endowment of 1,366.8 billion

BOE would be exhausted in about 95 years from 2010. This, however, is optimistic. Why? Because two-thirds of this endowment is from coal and the US government is undertaking a “war on coal”.

From 2010 to 2100, with no further population growth, the United States would need about 1,300 billion BOE of fossil fuels. The United States has been producing about 1 billion tons, or about 3.45 billion BOE, of coal each year. The current administration is implementing regulations to reduce or eliminate the use of coal. Hence, we’ll optimistically assume that no increase in coal production is permitted, perhaps to conform to the Paris Agreement to curtail carbon dioxide emissions. From 2010 to 2100, about 311 billion BOE of coal would be produced. Through 2100, the United States would then need the balance of about 989 billion BOE from oil and natural gas. As shown above, the US endowment of known and yet-to-be-discovered technically recoverable oil and natural gas is only 466 billion BOE. The United States would need about 11 billion BOE of oil and natural gas each year. In this scenario, the United States would exhaust the 466 billion BOE of oil and natural gas in as few as 42 years from 2010 or around 2052. Again, this assumes no population increase. Is the United States’ supply of fossil fuels secure for the foreseeable future? No.

What is the impact of immigration-driven US population growth?



The United States is experiencing continuous population growth primarily due to immigration. In 1999, [the US Census Bureau made four projections of the growth of the US population through 2100] based on various levels of net immigration. These are shown above. Two cases are relevant:

1. With the most likely fertility and mortality rates, but with zero immigration, starting at 274 million in 2000, the US population would likely climb to 377 million by 2100.
2. With the most likely fertility and mortality rates combined with the most likely net immigration, using then current immigration policies, the US population would likely climb to 571 million by 2100, more than doubling the 2000 population.

From 2008 to 2012, the Census Bureau updated its forecast, but only for 50 years. A private demographic analysis company, Decision Demographics, Inc., used this data to create a model matching the Census Bureau projections and [then used this model to extend the projections to 2100]. The starting point was the US population of 309 million established in the 2010 census. Of the several sets of assumptions modeled, two are very informative:

1. With zero net immigration, the US population peaks around 2050 at 358 million and declines to 343 million in 2100.
2. With the Census Bureau's most likely level of immigration of just under 2 million per year, the US population in 2100 increases by about 275 million to 618 million—double the 2010 population—and continues to increase thereafter.

Using the updated census information, with zero net immigration, the likely 2100 US population falls from the 377 million, projected in 1999, to 343 million. However, this is still greater than the 309 million used to estimate the life of the US fossil fuel endowment. Hence, we can expect the life of the oil and natural gas endowment to be less than 2052 even with no immigration-driven population growth.

Of far greater concern is the reality of the impact of likely net immigration-driven population growth on US energy security. It is likely that the US population in 2100 will include an additional 275 million due to new immigration. Obviously, this immigration-driven growth will substantially increase the rate at which the US oil and natural gas endowment is depleted, even with fracking, thereby worsening US energy security.

From the perspective of national energy security, the US fossil fuel industry's purpose this century is to undergird this critical transition with a reliable supply of affordable energy—in effect, to wind down the fossil fuel age smoothly.

When the fossil fuel endowment is exhausted, this 275 million will need to be provided with non-fossil fuel energy sources. Again, using a hypothetical switch to nuclear power, the energy needs of this additional 275 million would require an additional 2,750 one-gigawatt nuclear power plants be built by 2100. The additional cost of this would be in the ballpark of $18 trillion. Through 2100, the United States would need to spend an additional $223 billion each year on average from 2020 to 2100 to meet the sustainable energy needs of new immigrant-driven population growth.

We may conclude that continued immigration to the United States:

- Increases the United States' use of fossil fuels at the time it is trying to reduce its carbon dioxide emissions to implement the UNFCCC treaty;
- Increases the rate of exhaustion of the remaining US oil and natural gas endowment;
- Substantially increases the US cost of transition from fossil fuels to sustainable energy sources;
- Increases the energy insecurity of the current US population by causing the remaining oil and natural gas endowment to be exhausted sooner; and,

- Negatively impacts global environmental security by increasing US carbon dioxide emissions.

The remaining US fossil fuel endowment will provide the energy bridge to sustainability

With no change in US immigration policy, the United States will likely grow from a population of 309 million in 2010 to a 618 million in 2100. In 2010, 80 percent of the total energy was provided by fossil fuels. Assume that by 2100, within the foreseeable future of US energy security planning, all energy supplies should become sustainable to comply with the UNFCCC treaty. In this simple scenario, how much more fossil fuels will be needed this century?

Consistent with this simple analysis, it will be assumed that the United States immediately embarks on building the necessary new sustainable energy sources to go from about 20 percent in 2010 to 100 percent by 2100 while also meeting the increased demand for energy from a growing population. Thus, the demand for fossil fuels will fall steadily from 14.4 billion BOE in 2010 to zero in 2100.

Across this 90-year period, an average of 7.2 billion BOE per year of fossil fuels would be needed, totaling 648 billion BOE from 2010 to 2100. Of this, 466 billion BOE would be from oil and natural gas with the balance of 182 billion BOE from coal. Thus, to transition to sustainable energy completely by 2100, all of the remaining technically recoverable US oil and natural gas will be used and about 20 percent of the "dirtier" coal.

Many see this transition from fossil fuels to sustainable energy as a battle for market share between these two energy providers. This simple analysis shows that to smoothly transition to sustainable energy by 2100, the United States will need to produce all of its oil and natural gas and a substantial percentage of its remaining coal. There is no practical way for the United States to undertake the now inevitable transition to sustainable energy in a manner that does not cause economic upheaval without making full use of most of its remaining fossil fuel endowment. Thus, from the perspective of national energy security, the US fossil fuel industry's purpose this century is to undergird this critical transition with a reliable supply of affordable energy—in effect, to wind down the fossil fuel age smoothly.

To conclude this simple analysis, let's look at the flip side – what will it take to compete the transition to sustainable energy? For the likely population of 618 million, the energy equivalent of that produced by about 6,000 one-gigawatt nuclear power plants will be needed at a rate, starting in 2025, of 80 new gigawatts of capacity brought online each year. For a zero net immigration population in 2100 of 343 million, this reduces to 3,400 gigawatts at a rate of 45 gigawatts per year. The difference of 35 gigawatts per year is the impact of likely net immigration.

If new sustainable energy systems are not built at this rate, then the consumption of fossil fuels will grow, oil and natural gas will be exhausted quicker, and coal will be substituted as oil is exhausted. Coal can be converted into a synthetic oil at a rate of 2 BOE of coal to yield 1 BOE of oil. Thus, as synthetic oil is substituted, the rate of coal use, and its increased carbon dioxide emissions, climbs dramatically. Hopefully, this makes clear the nature of the fossil fuel energy security threat to the United States and its relationship to the environmental security threat posed by increasing atmospheric carbon dioxide levels. In neither case is delay in aggressively transitioning to sustainable energy beneficial to addressing either the environmental or energy security threats.

> **As each terrestrial alternative energy source is scratched from the list, what remains is space-based sustainable energy, including space solar power.**

Space-based sustainable energy is the needed path forward

As noted in my first article, Americans have an ethical obligation to meet the twin objectives of the UBFCCC treaty: to "prevent dangerous anthropogenic interference with the climate system" and "to enable economic development to proceed in a sustainable manner." Accomplishing this requires substantial new sustainable energy sources to replace fossil fuels and, in time, to remove excess carbon dioxide from the atmosphere and return the carbon, as synthetic oil and methane, to geological storage in depleted oil and gas reservoirs.

The expectation of many is that the United States will readily and quickly turn to terrestrial renewable and nuclear energy to undertake this transition to sustainable energy. As discussed above, the scope of this transition is staggering. As will be discussed in the final article in this series, for the United States, the practical scale of terrestrial nuclear and renewable energy production capacity is woefully short of what will be needed, especially for a population doubling in size due to immigration. As each terrestrial alternative energy source is scratched from the list, what remains is space-based sustainable energy, including space solar power. Thus, to address the twin environmental and energy security threats to the United States, driven by our use of fossil fuels, America has no choice but to become a true commercial human spacefaring nation focused on building the immense new space-based sustainable energy industry.

Conclusion

The United States has environmental and energy security threats that must be addressed to protect our children and grandchildren from potential harm. The US environmental security threat arises from the ethical obligation to "prevent dangerous anthropogenic interference with the climate system" that may occur as a result of the abnormally high and growing atmospheric carbon dioxide levels. The US energy security threat arises from the insufficiency of the remaining US endowment in fossil fuels, particularly oil and national gas, to meet the growing US need for energy. This energy security threat is significantly aggravated by the likely 275 million increase in the size of the US population in 2100 due to continued immigration.

These two threats combine to make clear that the era of fossil fuel use in the United States is ending this century. For the United States, space-based sustainable energy, including space solar power, is the only practical solution to smoothly transitioning from fossil fuels to new sustainable energy sources and sustain the US standard of living. That the United States will need to become a true commercial human spacefaring nation in order to lead the world in addressing these two threats is crystal clear.

Endnotes

1. This is what is referred to as the overnight capital cost. Financing costs and similar costs will increase this amount.
2. For quantitative values used in this article, see this analysis.
3. Carl R. Behrens et al., "U.S. Fossil Fuel Resources: Terminology, Reporting, and Summary," Congressional Research Service, R40872, December 28, 2011.
4. The 261 billion short tons (2000 lbs.) of coal included in this endowment reflects only that portion of 486 billion short tons of available resources—called "demonstrated reserve base" in coal industry terminology—thought by the Government eventually to be profitable to produce.

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