Much Faster Sea Level Rising Ahead! [Opinion Paper]

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Low-lying, coastal cities such as Miami Beach, New York City, New Orleans LA, and Norfolk VA are currently threatened by even modest sea level rise. On average, world sea level has risen by about nine inches since 1880, at a rate of 0.7 inch per decade, although recently this rate has nearly doubled to 1.3 inches per decade. The rise is even faster along the USA's east coast.

The vast majority of leading climate scientists agree that this observed rise is caused by excessive greenhouse gas-induced global warming of the atmosphere. The main culprits are fossil fuel burning, deforestation and methane releases,

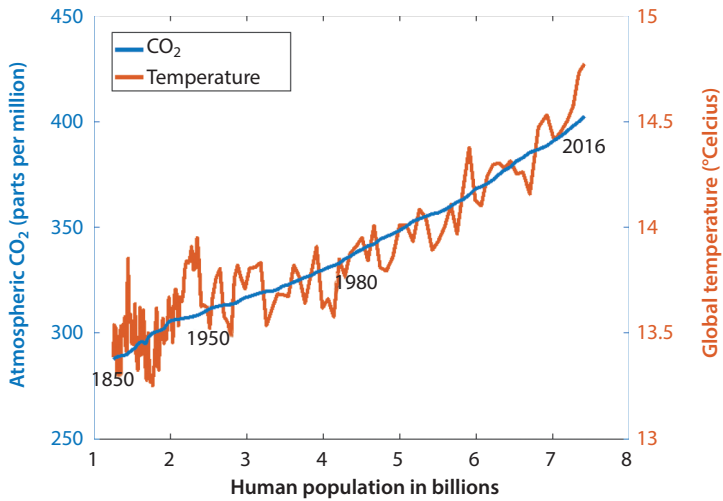

Figure 1. Increasing Human Population, Atmospheric CO_2, and Global Temperature from 1850 to 2016.
(*Source*: Brian G. Sanderson)

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driven by ever-increasing growth rates of human and domestic animal populations and the associated demands for energy and food.

Global warming expands the upper layers of the ocean, raising sea level. More coastal flooding results at high tides and makes even modest storm-induced surges more dangerous. Global warming accelerates thinning and loss of Arctic Ocean sea ice cover, as well as Greenland and Antarctic glaciers breaking off and melting into the ocean.

So far, vulnerable coastal cities around the world have been largely spared from the accelerating melting and fracturing of Greenland and Antarctic glaciers, but that is changing. As Florida Senator Bill Nelson notes, Florida is "ground zero for sea level rise". The mayors of Miami, Tomas Pedro Regalado, and New York City, Bill de Blasio, are also concerned. Even a few feet of sea level rise would be disastrous to much of southern Florida, New York City, the Louisiana coast and Virginia's Tidewater region.

A foreboding observation is the 75% decrease of the summer Arctic Ocean sea ice volume since 1979 , from 4,048 cubic miles to 1,056 cubic miles. Ice breakers can now easily break through the thinned ice all the way to the North Pole. Ice acts as an insulating "blanket" between the severe cold of the Arctic atmosphere and the Arctic Ocean water. This protective blanket is expected to disappear entirely by the summers of the 2040s. Last December, sea ice had difficulty forming near the North Pole itself, where winter temperatures were up to 50 deg. F. warmer than normal.

Arctic Ocean sea ice reflects much of the incoming solar radiation back to space. But darker open sea water has low albedo (reflectivity) and absorbs more incoming sunlight. Thus there is a positive feedback effect leading to an ever increasing heating of the ocean-atmosphere system.

Accelerated climate warming and sea level rise from Greenland ice melt during the next few decades appear all but unavoidable. Worse, the ice cover mass loss is apparently triggering many Greenland earthquakes (up to magnitude five on the Richter scale). Earthquake-accelerated ice loss also has a positive feedback that may lead to even more violent earthquakes. Meltwater flows more quickly toward the ocean.

It is difficult to estimate precisely how quickly Greenland ice will be lost. Total loss would eventually raise sea level by about 20 feet. Forebodingly, over 600 icebergs were seen floating in the Labrador Current during April 2017; the normal number is about 80 icebergs. Thus iceberg formation appears to be accelerating at an alarming rate. This is bad news for low-lying coastal communities, which may have to relocate to higher ground earlier and faster than anticipated.

At the opposite end of the planet, the huge Larsen "C" ice shelf has just broken away from the adjacent glacier mass south of it. That removes its buoyant support

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of that glacier mass, destabilizing the Arctic land ice cover and allowing more to fracture and slide into the Southern Ocean – an inherently stochastic process that is difficult to predict. This may raise sea level a few inches during the next few decades. But since there is much more ice cover in the Antarctic than over Greenland, the long-term sea level rise may be much greater than the 20-foot rise attributed to Greenland melting alone.

The consequences of increased Arctic climate warming include more severe and devastating lower-latitude storms and hurricanes, e.g., the "Arctic and Siberian Expresses" in early December 2016; major west and east coast storms in February 2017; and frequent tornado outbreaks. In short, weather is becoming more volatile, extreme, and costly.

A little-known process may be contributing to the rapid loss of Arctic Ocean ice cover, fueled by the biogeochemical combustion of dissociated methane hydrates buried in deep ocean sediments. There is more known methane chemical energy in these sediments than in all known coal and oil deposits. The resulting heat release may melt Arctic Ocean ice near its bottom, where the temperature remains near freezing as the ice melts.

In the coming decades, humanity must greatly reduce reliance on fossil fuels to mitigate catastrophic climate change threatening to destabilize Earth's livability, especially along populated coastlines. In the United States, we must quickly migrate to solar, wind, and although very unpopular, probably more nuclear power generation.

Innovative, site-specific energy approaches abound. Excess solar energy generation during sunlight hours can be used to pump water to higher levels (pumped storage), especially where natural reservoirs exist near oceans or large inland lakes, and drained during dark hours (hydroelectric power generation), as planned for a 600-megawatt power plant in Chile.

The world's largest solar power plant was recently built in India in only eight months, generating 648 MW, enough to power 150,000 homes. And more are under construction, with more jobs already generated in solar and wind power industries than exist in the fossil fuel industry.

Renewable energy in the United States set a record earlier this year when wind and solar combined generated 10 percent of electricity (8% wind; 2% solar) in March. The intermittency of renewables, of course, is a major limitation of just how much of the constantly fluctuating electric load they can supply, and the U.S. Department of Energy and many other institutions are researching batteries and energy storage more broadly not just for electric vehicles but for electrical grid applications.

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Innovative Americans should be leading the transition to green energy, but we aren't. Clean, solar-panel-generated electricity costs about 1/3 of what utilities currently charge in the USA. Warren Buffett, Bill Gates and Elon Musk's Tesla and Solar City have bet on this being a major future industry. Tesla's electric car battery material is a closed-cycle process with all materials recycled, with a battery's planned end-of-life (EOL) probably being 30 years or so. Nothing is discarded. The recycling of solar panel structural material such as aluminum is also expected, after an anticipated panel lifetime of about 30 years.

Nuclear fission in the form of light-water reactors currently generates about 20 percent of electricity in the U.S. Some prominent climatologists such as James Hansen and even some environmentalists such as the U.K.'s George Monbiot, a columnist for *The Guardian*, argue that nuclear, rejected in many developed countries in recent years because of cost, safety, waste disposal, proliferation, and terrorism concerns, needs to be given a second look and another chance.

Well-publicized, costly accidents at Three Mile Island (1979), Chernobyl (1986), and Fukushima Daiichi (2011) have given existing nuclear technology a black eye. However, nuclear power advocates contend that newer generation fast breeder reactors, small modular nuclear reactors and other developing technologies can address the problems inherent in current systems. A prototype 500 MW fast breeder reactor being built in Kalpakkum, India is undergoing testing this year.

Some energy analysts doubt that renewable energy alone can do all the heavy lifting (such as providing baseload power for the electrical grid) needed to run advanced, industrialized economies. Furthermore, geochemists Harald Sverdrup and Kristín Ragnarsdóttir refer to photovoltaic solar only as "semi renewable" because "the energy collected is renewable, but the materials in the technology are not."

In view of ongoing debates and uncertainties concerning the long-term ecological and economic viability and sustainability of diverse candidate energy sources, it behooves us to not exclude any promising energy options prematurely. In this regard, while nuclear fusion has long been studied as an alternative, the technology to control it while obtaining useful net energy output is still not available after a half-century of research by nuclear physicists; yet research toward that so-far elusive goal should continue.

Humankind is running out of time to offset and mitigate global warming by decreasing reliance on fossil fuels, finding alternate sources of energy and by reforesting the planet. Unfortunately, "fake news" denying global warming and the greenhouse effect has misled the American public in recent years. President Trump and his cabinet are working to cripple the EPA, have withdrawn from the 2015 Paris Climate Accord, and advocate unlimited fossil fuel extraction and

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combustion as the road to permanent prosperity. Meanwhile, other developed and developing nations are working to increase their reliance on renewable energy.

We have just a few more years to change our ways; otherwise the future we leave to our children and grandchildren looks very bleak.

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