Nuclear Salvation

Kerry Emanuel (NAS) is the Cecil and Ida Green Professor of Atmospheric Science at the Massachusetts Institute of Technology.

Kerry A. Emanuel

I am a climate scientist highly motivated to find the best and fastest route to decarbonizing energy. As with many of my colleagues, I have felt an obligation to engage directly with the public on the issue of anthropogenic climate change. Collectively, we have become adept at presenting the compelling scientific evidence that human civilization is being put at considerable risk by dramatically increasing the content of long-lived greenhouse gases, especially carbon dioxide.

Audiences are understandably put off by this negative message, however, thus we are inclined to step outside our professional comfort zone and talk about how civilization might solve the problem. To do this effectively and honestly, we have to understand the technology and economics of power generation and carbon extraction. I have no special expertise in energy technology or economics and no professional allegiance to any particular method of solving the problem, but I am fortunate to have access to energy experts at my home institution.

Two things are crystal clear: To avoid the worst risks of climate change the global economy must be thoroughly decarbonized over the next few decades, and progress is nowhere near fast enough.

Projected Electricity Growth

Demand for electricity is likely to nearly triple over the next 40 years. Globally, about 940 million people—almost three times the population of the United States—are without access to electricity; providing them with electric power is an essential step in lifting them out of poverty. Decarbonization of vehicles, today responsible for about a quarter of global greenhouse gas emissions, will also drive up demand for electricity.

The task is thus not only to decarbonize existing power grids but to extend them and to build new carbon-free grids in the developing world. In addition, major hard-to-electrify markets such as industrial processes, residential heating, and maritime transport rely overwhelmingly on combustion of fossil fuels, and in doing so account for about 35 percent of total carbon emissions: those sectors also urgently have to be decarbonized.

A few nations with small populations and plentiful non–fossil energy have decarbonized electricity; Norway with abundant hydro power and Iceland sitting atop an enormous geothermal source come to mind. Otherwise, nations that have successfully decarbonized electricity, such as Sweden, Switzerland, and France, did so largely with hydro and/or nuclear power, and they did so very quickly—within a dozen years or so. These are reality-based examples of how to decarbonize fast.

By contrast, most nations that have pushed hard to ramp up solar and wind power alone have seen relatively slow growth in carbon-free energy and have not reduced their emissions appreciably. Germany, for example, managed to ramp up solar and wind power to almost 40 percent of net production, but because it is shutting down its nuclear power plants, it has reduced greenhouse gas emissions by only a small fraction. It also has one of the highest electricity costs in western Europe, has increased volatility in the European power market, and is compromising the stability of the European power grid.

Advocates of solar and wind rightly point to steep declines in costs of solar photovoltaics and wind turbines in painting a bright future for those sources. At low market penetration, the intermittency of these power sources is balanced by dispatchable sources such as natural gas. Once their market penetration becomes substantial, it becomes necessary to store energy during periods of low sunlight and/or wind, and the considerable costs of storing energy must be added to the production and operating costs of solar and wind arrays.

Solar, wind, and hydro also have environmental costs (as do all energy sources), and most hydro sources are already being exploited, so there is not much further capacity for growth.

Challenges to Nuclear Adoption

Nuclear power has its own liabilities, real and imagined. In the West, inefficient manufacturing practices, together with the low cost of fracked natural gas and high subsidies of fossil fuels and renewables, have created major economic obstacles for building new nuclear plants. Long delays and cost overruns of reactors currently under construction in the United States and Europe have led to capital costs three times higher than those of equivalent plants in South Korea. The steep decline of new nuclear construction in the West has also caused trouble for manufacturing supply chains and nuclear engineering talent, both of which are vital to the industry.

Industrial processes, residential heating, and maritime transport rely overwhelmingly on combustion of fossil fuels and account for about 35 percent of total carbon emissions.

On top of this, the nuclear industry has arguably been terrible at marketing itself. The word “nuclear” is often associated with inconceivably destructive weapons, terrorism, and lethal radiation, so much so that nuclear magnetic resonance imaging (which has none of these problems) was unpopular until someone had the bright idea to simply drop the word “nuclear,” resulting in MRI scanners that are now commonplace.

Although nuclear energy is considered dangerous by many, there has been only a single fatal accident involving radiation (Chernobyl) and a handful of nonlethal accidents. But these, like aircraft accidents, weigh heavily in the popular imagination, aided by popular disaster films.

Advantages of Nuclear Energy

Modern nuclear reactors are very reliable and robust machines. Per kilowatt-hour generated, nuclear is among the very safest sources of energy, comparable to solar and wind and much safer than hydro and all fossil fuel sources. Transport and storage of spent fuel are technically manageable and in fact routinely practiced (Finland and Sweden are close to opening permanent repositories), but face substantial popular resistance.

Environmentalists and others who argue that new nuclear energy is too costly may be right so far as their analysis pertains to the West. But in several eastern nations, nuclear energy is alive and expanding. South Korea has been building new 1 GW reactors for $2–3 billion both at home and in the Middle East. There is vigorous competition between China and Russia for the nuclear power export market, and, owing in part to the income generated from exports, these nations are also developing and building advanced reactors that are much more efficient and even safer than existing light water reactors.

Using the current South Korean capital costs, all of the projected global electrical power need of 5 terawatts in 2040 (IEA 2018) could be generated by building about 125 2 GW plants per year at a cost of $500 billion per year, about 0.6 percent of current gross world product (GWP) (CIA 2019). This does not include likely cost reductions from innovation and mass production. Moreover, shuttering fossil fuel plants results in large reductions in respiratory disease and deaths, at the economic equivalent of about $400 billion a year by 2040,[1] so the $100 billion net annual cost of decarbonizing is roughly 0.1 percent of GWP.

Capital costs of building solar energy overnight storage with current technology would run in the hundreds of billions of dollars per year, but judicious combinations of nuclear and renewable energy would greatly reduce the need for storage, while nuclear heat could help decarbonize the large and growing industrial demand for high-temperature heat sources. Even conservative estimates of the costs of unmitigated climate change are far higher than the costs quoted here; for example, the Intelligence Unit of *The Economist* magazine estimates that the annual cost of climate change by 2050 will be 3 percent of the world's GDP (EIU 2019), or about $3 trillion.

Concluding Thoughts

The elimination of fossil fuels from the global economy is both technically and economically feasible if nuclear energy is brought to bear on the problem alongside renewables. But history may well record that the decline of nuclear energy in the West merely shifted nuclear innovation and production to the Far East. Fortunately, bills and programs with bipartisan support are now being implemented by the US government to regain nuclear technology leadership, offering some hope of progress.

As a climate scientist, I do not care where carbon-free energy comes from, but as a citizen I am disappointed that my country is not yet a serious player in the green transformation of the roughly $7 trillion global energy market.

References

CIA [Central Intelligence Agency]. 2019. World Factbook. Jul 24. Langley VA.

EIU [Economist Intelligence Unit]. 2019. Global economy will be 3 percent smaller by 2050 due to lack of climate resilience, Nov 20.

IEA [International Energy Agency]. 2018. World Energy Outlook 2018. Paris.

[1] Assuming 7 million premature deaths per year (from the World Health Organization, https://www.who.int/airpollution/infographics/en/) and the value of a statistical life in 2040 of $2.3 million and a working life of 40 years.