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Scott L. Montgomery , Thomas Graham, Jr
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Introduction

On December 7, 2015, seventy-one Nobel Laureate scientists presented a document that spoke in one voice to the United Nations climate summit in Paris. The document they had signed, known as the Mainau Declaration, was a forceful call to action for all the world's nations. The threat faced by humanity from a warming climate, it stated, was greater than any that had ever existed, with only one possible exception.

Indeed, human civilization on planet Earth clearly faces a growing existential crisis. This risk is beyond denial, confirmed many times by scientific work, and is now fully evident in the climatic changes that people are witnessing and, increasingly suffering from in their own experience, from the poles to the equator. Science is conservative in embracing new truths. The requirements for evidence are prodigious and the place of doubt and debate central. Climate change, however, has not only moved well past these stages of validation. It has repeatedly exceeded every forecast for its effects.

So strong is the scientific consensus today, in fact, that fossil fuel industries, not least major oil and coal companies, have accepted it and have pressed the US government under President Donald Trump to retain American membership in the Paris Climate Agreement. Though some prominent officials and commentators do continue to discount the role of human activity in warming of the globe, it is abundantly clear that they do so for ideological reasons, above all the fear of government gaining the power to irrevocably take command over the economy by means of energy choices and control of the environment, writ large. An overwhelming majority of the world, however, including the global scientific community, understands that this is not the real matter at stake. Changes to modern energy, partly or largely through government policies and decisions, will not bring hopeless tyranny. They are far more likely, if intelligently planned, to bring hope that the worst, most oppressive impacts of global warming will

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not happen. One thing, after all, is certain: carbon emissions must be brought under control and reduced, not a little but a minimum of 40 percent below 2010 levels. It is a colossal undertaking, and it will not be completed soon, in a few short decades. This is because of the immense scale of what needs to occur – the unmaking of 200 years of modern energy.

To achieve what is needed will require every means that nations can employ to produce energy from low- and, especially, noncarbon sources. Fortunately enough, modern society has created sources of this kind, those that can now be expanded and advanced to address the challenge. Simply choosing a few options, because they seem the "greenest" and are backed by wishful computer models, will never be enough. The task is too real, grave, vast, and demanding for diversions that treat it as an opportunity for ideological preferences on the other side of the political spectrum.

Yet climate change, for all its risks, is only part of the existential crisis today. There is another type of threat, once thought to be quelled but that has returned with a vengeance and which looms over large parts of humanity with impacts now known to be spectacularly lethal. Nearly 18,000 people lose their lives every day due to toxic material in the air they breathe. This amounts to 6.5 million deaths annually, which the World Health Organization (WHO) emphasizes is significantly greater than combined fatalities from HIV/AIDS, tuberculosis, and traffic accidents [1]. Energy production defines the main contributor to this global threat to health, above all the burning of fossil fuels, particularly coal. Hundreds of millions of people live in cities today whose air cannot be called fit to breathe. Worst of all are those urban areas blanketed with smog containing very small particulate matter that enters and damages the lungs and circulatory system. In China's eastern cities, up to a million people are now thought to die prematurely every year due to air pollution dense with such matter, whose sources are coal-burning power plants, factories, local businesses, and residences. China is only one example, however. Coal use has grown in many countries around the world, even as it has fallen in most of Europe and North America. That global use may have reached a plateau in recent years and even dropped slightly provides no comfort, as it mainly reflects the change in high-use nations and disguises the continued rise in many smaller nations whose air quality is now worse than at any time in the past. Coal is not the only source of particulate matter (burning of agricultural fields is another potent source in some areas), but it is the most widespread and the most damaging to human health.

It turns out, then, that two of the greatest threats facing humanity largely have the same cause. They therefore can be dealt with, at least in part, using the same means.

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A Brief Long Story

The long story of energy has brought us to this point. For many thousands of years human civilization relied on the muscles of large animals, including themselves, for work. They supplemented this with wind and sails, the power of water, the heat of the sun, the burning of wood and, eventually, charcoal. This long era was overturned in a small handful of places between the sixteenth and the nineteenth centuries. The era of coal began most clearly in England as the result of a wood famine, caused by a combination of population growth, growth in local industries (brewing, blacksmithing, glass and brick making, smelting of ores), and a great buildup of merchant and naval shipping. By 1800, the Industrial Revolution had moved from water power to steam, and thus from rivers to coal and the true beginnings of the machine and factory age, which soon spread to other parts of Europe and North America. A point in coal's favor was its widespread occurrence: England, France, Germany, Italy, the Netherlands, Poland, Russia, the US all had significant reserves. Supply was reliable, abundant, cheap, and, for a time, secure. Despite certain drawbacks, especially fouling of the air, exploding boilers, and danger in the mines, coal's risks were deemed acceptable by the ruling powers and were somewhat reduced over time, temporarily.

The coal era lasted a full 150 years, to be replaced by the age of oil. This took time, as enormous amounts of infrastructure had to be disassembled and built. Begun in the 1860s, the oil industry grew rapidly, first as a source of illuminant for lamps and then, in the early 1900s, for land, marine, and air transport, all before 1920. Even so, coal maintained its dominion in core sectors (industry, heating) up until the 1950s and 60s, by which time oil and, to a smaller degree, gas had taken over. The reign of oil was very short, however. From a near-universal source, fueling industry, commerce, power generation, homes, and transportation, it had largely retreated to the last of these sectors by 1980 in the advanced nations. The reason was the oil crises of 1973 and 1978–79. By the 1980s, a greater diversity of sources had been put in place, with coal regaining a good part of the market share it had lost to oil. This was especially true for power generation, which shifted away from oil in these nations toward a combination of coal, natural gas, hydropower, and the first truly noncarbon form of energy generation, nuclear power.

Electricity, in fact, was first generated on a commercial basis in the 1880s. Hydropower developed by conversion of mills into power stations to serve the industrial towns and cities that had grown up in such areas. Very soon, coal-powered generators were added and became preferred, as they were not limited to sites with flowing water and steam power proved able to generate increasing amounts of electricity. With the expansion of the railroads, shipping, large-scale

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industry, and now power generation, coal use rose to become 80 percent or more of US and European energy consumption by 1900. US consumption alone went from about 35 million tons in 1850 to over 285 million tons at the turn of the century, and by the 1920s, more than 575 million tons [2]. The twentieth century turned out to have an ever-more insatiable use for electricity, spread over nearly every sector of the economy. Coal rode this enormous flood in demand, which only ended for the industrialized, wealthy nations in the next century. By that time, however, a new phase of surging demand was underway in the rest of the world, bringing coal use to unforeseen, even unimagined, heights.

There had been warnings, to be sure. By the 1940s, so-called "killer smogs" were occurring in Western cities with growing frequency. In the US, these happened in Los Angeles, Chicago, New York, and were due to vehicle exhaust mixed with coal emissions. But in Europe, particularly London, it was coal smog that dominated. Seeming without warning, it reached a dramatic peak in the Great Killer Smog of 1952, which took the lives of 4,000 people in two short weeks and nearly 8,000 more in the following few months. Far from the first "pea soup fog" for London, it did translate into the first traumatic demonstration of how lethal air pollution from the burning of coal could be. Still, coal use continued to climb in the advanced nations for another half century. Though power plants built since the 1970s mostly have pollution controls, including those for particulate matter, those that are older do not and were never forced to adopt such controls.

This did not have to be the case. A closer look shows that wealthy nations[1] use of coal for electricity actually declined in the 1960s and 70s, as other sources came to be used, but then returned to a pattern of overall growth that lasted into the 2010s. There are variations within this group of countries, of course: where coal use in the US never decreased until after 2000, and both Japan and Korea's consumption had not declined as of 2017, Europe's consumption did fall significantly, reaching a plateau in the 1990s and then declining again starting in the 2010s.

While there were several reasons for the growth in coal consumption, one deserves mention in particular. The halt to construction of new nuclear power plants in the 1980s, particularly after the Three Mile Island and Chernobyl accidents, decidedly aided coal's return to dominance in electricity generation. If such a halt had not happened, nuclear would have combined with the gradual growth in natural gas consumption to reduce America's level of pollution and carbon emissions substantially. It is likely that many older coal plants without pollution controls would have been retired, reducing emissions and pollution still further.

[1] Included here are nations in the Organization for Economic Cooperation and Development (OECD).

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So despite its deep disadvantages, coal remained a favored fuel into the twenty-first century, even as the era of oil expanded and a new period of growing source diversity got underway. Yet, there is another way to view the past 200 years of modern energy. It is this: from the 1870s, when coal reached 50 percent or more of energy production, down to the present day, we have never stopped inhabiting the era of fossil fuels. Indeed, if not for hydropower in nations where it can exist and nuclear in most of the wealthy nations and a few others, carbon-based fuels would have fulfilled 100 percent of modern energy needs since the start of the last century. As the world approaches the year 2020, and new sources of renewable power generation along with new nuclear plants come on line, fossil fuels still command more than 80 percent of global energy use. A rough estimate is that systems of carbon energy around the world equal somewhere near $30 trillion in natural resource value, infrastructure, refining, trade, and labor. To imagine what is needed to reduce all this, to dismantle and replace it or adapt large parts of it, can only be called essential.

A new civilization – modern civilization – unlike anything that had gone before, was created and built on fossil fuels: coal, oil, and natural gas, extremely rich sources of energy. And in the twentieth century these three sources spread throughout the world. Human life has been revolutionized because of this, and will continue to be altered by it, becoming both more prosperous and at the same time more threatened.

It wasn't until the 1970s that some scientists came to understand the Faustian bargain. Means were available to hugely improve the quality of life but if overused could eventually make large parts of the planet much less livable for human beings. This was because the burning of these fuels releases over time vast amounts of carbon, largely in the form of CO_2 gas, into the atmosphere, absorbing and reradiating the Sun's heat, raising the temperature of the lower atmosphere and the oceans. Beginning with the rise of coal use during the Industrial Revolution, the growth of carbon in the atmosphere has raised the world's average, near-surface temperature by 1.3°C (2.3°F) over the past two centuries. This means that the entire atmosphere surrounding the planet has absorbed enough heat so that essentially every cubic meter of it has grown warmer. Because of this, the atmosphere has more energy overall. More extreme weather events, with greater force, causing greater damage and more deaths, now occur. Yet this represents only a small fraction of the total thermal energy that has been added to the Earth's surface and near-surface. Another part has gone to melt sea ice, ice caps, and glaciers around the world, in dramatic fashion. And the largest portion of thermal energy has been absorbed into the upper 700 m (2,310 ft) of the oceans, whose chemistry is being altered and whose volume is actually expanding due to the added heat. Together, these phenomena are

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causing sea level to rise. It has risen nearly ten inches in the last 135 years, and half of this has happened since the 1970s: the rate of rising is accelerating. As a result, low-lying islands are beginning to disappear, deltas are becoming salinized by encroaching salt water, and coastal areas in many parts of the world are now being flooded far more often by major rainstorms and hurricanes or cyclones. These effects are really only beginning; sea level in many areas will possibly be 3 ft (0.9 m) higher or more by 2100.

Climate change is many threats to many nations – political, social, cultural, economic, and even military. It is a direct challenge to the world's stability, not only because of its impacts but because of the changes that it requires to be made by societies. The core of these changes lies in the realm of energy, which must be moved toward a more noncarbon basis. This means nuclear power and renewables, the only real options that exist today. Neither one of these can achieve what is necessary by itself; to choose one and abandon the other is to amputate an arm from the effort that is needed.

The Paris Climate Agreement of December 2015 brought 190 nations to a consensus that they would work to reduce carbon emissions such that the world's average temperature would not reach 2°C above preindustrial norms, the point interpreted by the scientific community as defining when the most severe impacts will begin in force. These would not just be droughts, storms and higher seas, but effects in the oceans less often described, like more acidic waters reducing the abundance of phytoplankton, a form of life at the base of the marine food chain but that also produces half of the world's oxygen. No small amount of talk at the Paris meetings was devoted to 2015 being the warmest year on record. A year later, 2016 has taken its place. In the decades ahead, it is safe to say that planet Earth will be fine. It is the life that lives upon it that will suffer, indeed that is already enduring.

This book essentially begins with these realities and seeks to inform its readers about the necessity of nuclear power in the new century, the time of climate change and growing air pollution. It takes as a given that readers want and need to know about many aspects regarding nuclear energy – its history, its strengths and flaws, its accidents, the key scientific concepts behind it (in ordinary terms), as well as the potent issues that surround it, like those related to radiation, nonproliferation, cost, waste disposal, safety, and the history and status of public fear.

Nuclear power became available in the immediate wake of the largest, most destructive war ever fought by humanity. For a large number of people, it has been associated with this conflict, with the two monstrous bombs that ended it, ever since. If understandable in some measure, this has ended up as a great misfortune, since nuclear plants could now be everywhere and the climate

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crisis almost non-existent. Despite having injured or killed the smallest number of people of any major energy source in the past sixty to seventy years, nuclear is thought by more than a few to be the riskiest of all. On the basis of the most extensive, long-term study, between forty-eight and fifty-six deaths (records are less than perfect) and some 4,000 thyroid cancers are associated with Chernobyl after three decades, numbers that are dwarfed by the 12,000 who died in London's killer smog of 1952. This is not to mention the yearly toll of thousands whose lives are lost to extreme weather events today, nor the hundreds of thousands who die from toxic air in Asian cities – deaths that do not require an accident or other extraordinary event. Today, around the world, air pollution from coal and oil kills ever year several times the number of people that died at Hiroshima and Nagasaki. This truth does not in the least alter the horror of the atom bombings and the suffering they caused. It does, however, suggest the dimension of suffering that must be addressed now. It also makes plain that it is time to put away the fear that associates nuclear power with nuclear weapons and face the real threats to society that now exist.

The Mainau Declaration makes this point in terms as clear as we might wish. They are terms with a particular resonance, given the history behind them:

> Nearly 60 years ago, here on Mainau, a similar gathering of Nobel Laureates in science issued a declaration of the dangers inherent in the newly found technology of nuclear weapons . . . So far we have avoided nuclear war though the threat remains. We believe that our world today faces another threat of comparable magnitude . . . [T]he world must make rapid progress toward lowering current and future greenhouse gas emissions to minimize the substantial risks of climate . . . Failure to act will subject future generations of humanity to unconscionable and unacceptable risk.[3]

With these words in mind, it can only be a major step forward that a new age of nuclear power has actually begun. It is to help support and advance this new era, to quicken an understanding of it and why it is much needed, that this book has been written.

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