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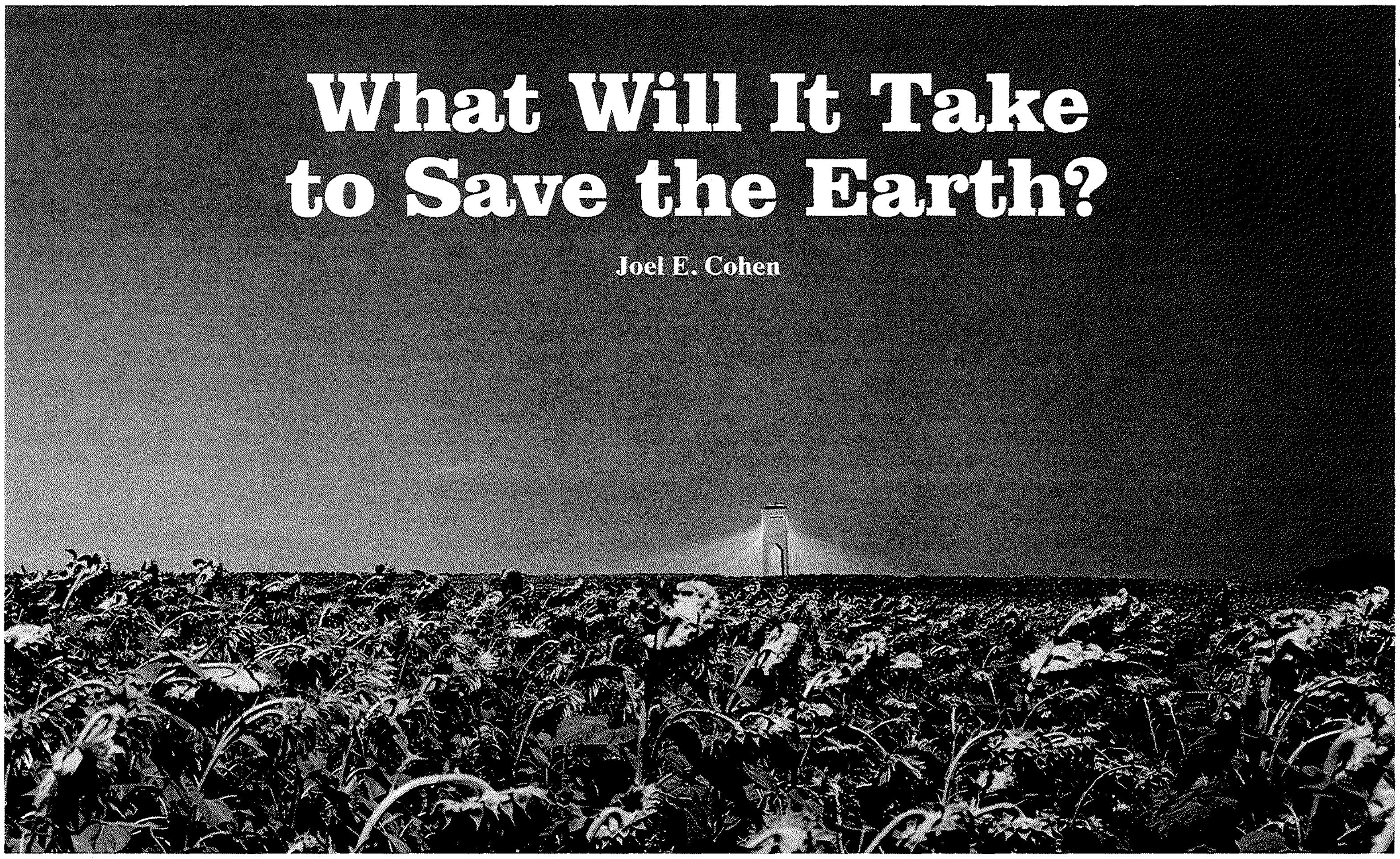
What Will It Take to Save the Earth?

Joel E. Cohen



Henrik Saxgren

A solar power plant with sunflowers in the foreground, Seville, Spain, 2007; detail of a photograph by Henrik Saxgren from his 2009 book Unintended Sculptures, *which collects his images of man-made objects—paved roads, power lines, and wind turbines among them—that appear to have been abandoned to nature. It is published by Hatje Cantz.*

The Quest:
Energy, Security, and the Remaking of the Modern World
by Daniel Yergin.
Penguin, 804 pp., $37.95

Sustainable Energy—
Without the Hot Air
by David J. C. MacKay.
Cambridge, England:
UIT Cambridge Ltd., 372 pp.,
$49.95 (paper); free PDF available at www.withouthotair.com

The lights must never go out,
The music must always play.

—W. H. Auden,
"September 1, 1939"

Daniel Yergin's 804-page *The Quest: Energy, Security, and the Remaking of the Modern World* raises large questions:

> Can today's $65 trillion world economy be sure it will have the energy it needs to be a $130 trillion economy in two decades? And to what degree can such an economy, which depends on carbon fuels for 80 percent of its energy, move to other diverse energy sources?

Will energy sources that rely less on carbon become available fast enough, at costs low enough, to avoid the disastrous consequences of climate change, to lift billions of people from poverty, and to enhance the prosperity of rich countries? Yergin provides a highly readable history that explains well how these questions arose and why they are so important and difficult. But it does little to answer them. Indeed, for Yergin, "the answers are far from obvious."

The Quest combines four books. The first, more than half the total, provides a global history of oil, natural gas, and nuclear power from 1991 to 2011. Yergin argues that commercial competition for oil sources and markets is not now, and need not become, a contest of nations (e.g., between the United States and China); rather it is a competition between powerful multinational corporations that often try to bend nations to serve their interests. *The Quest* picks up at the collapse of the former Soviet Union in 1991, where Yergin's Pulitzer Prize–winning eight-hundred-page history of global oil, *The Prize*, left off. His new book is more ambitious. Whereas *The Prize* focused on the oil industry, the first half of *The Quest* ends with the broader question of what fuels to choose.

Global electricity consumption has doubled since 1980. If it doubles again between now and 2030, as anticipated, and if it will cost $14 trillion to build the additional generating capacity to make the next doubling possible, what kinds of power plants should be built? How will they get built? What will be the consequences? These questions, too, Yergin leaves unanswered, providing instead entertaining anecdotes and quotations from historical sources and his many interviews.

The second part of *The Quest* traces a path from the discovery of climate change as an esoteric interest of a few scientists in the nineteenth century to the introduction of

> new climate change policies... intended to make a profound transformation of the energy foundations that support the world economy—a transformation as far-reaching as that when civilization moved from wood to coal and then on to oil and natural gas.

The Irish scientist John Tyndall in the mid-nineteenth century was so fascinated by glaciers and by evidence that ice ages preceded the present era that he set out to discover why Earth is warm. His invention, the spectrophotometer, showed that water vapor and certain carbon-containing gases trap the energy of the sun's heat, causing temperatures to rise. Yergin moves from the measurement of rising carbon dioxide concentrations in the atmosphere by Charles David Keeling, starting in the late 1950s, to the invention of carbon markets, the not very effective intervention by President Obama in the 2009 Copenhagen climate negotiations (which had no legally binding outcome), and the deadlock over climate politics in Washington.

Now overwhelming scientific evidence has persuaded many governments that continuing to burn carbon-based fuels contributes to climate change and increases the risk of adverse human consequences, including deaths from flooding and disruption in food supplies. With this in mind, *The Quest*'s third part looks at nuclear and renewable alternatives to fossil fuels. Yergin recounts the history of nuclear energy neutrally, noting its bright sides (no carbon dioxide, steady power production regardless of wind or sunlight) and its dark (expense, accidents at Three Mile Island, Chernobyl, and Fukushima, long-term waste storage, nuclear proliferation).

Renewable energy sources include wind, sunlight (captured by photovoltaic cells, rooftop heat collectors, or concentrators of sunlight that drive electric generators), biofuels (from corn, algae, and other plants), biomass (wood, dung, and bagasse, the residue from sugar cane and other processed plants), geothermal power, and hydropower (from waves and falling water). Renewables have suffered greatly from policies Yergin aptly characterizes as "pendulumatic." For example, Jimmy Carter installed solar panels on the roof of the White House in 1979, then Ronald Reagan removed them in 1986. The Obama administration announced on October 5, 2010, that solar panels and a solar hot water heater would be in place on the White House roof by the following spring. By late October 2011, neither had appeared.

When Yergin looks to the future in his fourth book, he asks how the economic benefits from an average megawatt of power can be increased while at the same time reducing its negative effects on the environment and health. (Per dollar of GDP, the United States today uses only half the power it used in the 1970s, but a significant fraction of that gain results from transferring abroad production that makes intensive use of power.) How can energy conservation become a politically appealing strategy? How can we create and protect a more flexible, reliable, and efficient electrical grid? How can the revolution in life sciences provide new technologies to the energy business? Will electric cars be the main form of personal transportation in the future? If so, what kinds of electric cars? Will electricity for future cars come from oil- or coal-driven turbines, natural gas, or fuel cells that burn hydrogen or hydrocarbons? "Over the next couple of decades," Yergin writes,

> two billion people—about a quarter of the world's population—will... likely move from a per capita income of under $10,000 a year to an income of between $10,000 and $30,000 a year. Even with much improved efficiency in energy use, their rising incomes will be reflected in much greater need for energy. How will that need be met? What kind of energy mix would make this possible without crisis and confrontation?

Yergin, a prominent consultant to energy industries, gives little hint of answers to these questions other than projecting that "75 to 80 percent of world energy is expected to be carbon based two decades from now." He writes that, with the use of electricity, natural gas, and other fuels, oil will lose its "almost total domination over transportation," but he does not give clear projections of by how much that domination will be reduced. He is confident that cars will get smaller. Yet a recent report from the Organization for Economic Cooperation and Development (OECD) warns that fossil fuels are likely to continue to dominate the global energy mix. The OECD projected that, by 2050, without more effective energy policies fossil fuels would supply 85 percent of energy demand, thus implying a 50 percent increase in greenhouse gas emissions and worsening urban air pollution.

Yergin does illustrate how science both creates possibilities for capturing energy and constrains its use. Sadi Carnot, a French railroad engineer, published in 1824 a short book that led to the second law of thermodynamics, which set limits on what could be achieved in converting energy from one form to another. Albert Einstein in a

1905 paper explained the photoelectric effect in terms of quanta of light. This paper laid the theoretical foundations for photovoltaic devices that convert sunlight into direct-current electricity.

The twenty-first century's major discovery of new oil resources was the result, according to José Sergio Gabrielli, the president of Petroleo Brasileiro, of "pure mathematics." From 2007 on, new algorithms for processing signals made it possible for seismic soundings to locate oil reservoirs through a mile-thick layer of salt beneath the seabed in the Santos Basin off the southern coast of Brazil. One was "a supergiant field—at least 5 billion to 8 billion barrels of recoverable reserves—the biggest discovery since...2000." Brazil's president described the discoveries in the Santos Basin as "a second independence for Brazil." Yet the upper estimate of eight billion barrels represented less than one hundred days of the world's daily oil consumption in 2006.

But, for Yergin, science is a spectator sport, not an instrument to answer his large questions, which are left hanging. The only equation in *The Quest* is $e=mc^2$ and it is wrong. (The equation should be $E=mc^2$, even in the middle of a sentence, because E stands for energy while lower case e is, in physics, the elementary positive charge, the charge carried by a single proton, or, in mathematics, the base of natural logarithms.) Yergin's text abounds in numbers but they are largely ornaments, not used to clarify the future of energy and climate change.

Garth Lenz

A plant owned by the Syncrude company, which processes oil from the tar sands of northern Alberta, the world's greatest oil reserves outside Saudi Arabia, Canada's biggest source of carbon emissions, and America's largest source of oil; photograph by Garth Lenz from his traveling exhibition 'The True Cost of Oil,' documenting the enormous impact of tar sands mining. It will be on view at the Telluride Mountainfilm Festival in late May.

David MacKay's *Sustainable Energy—Without the Hot Air*, less than half the length of Yergin's volume, starts with three concerns Yergin also raises: "fossil fuels are a finite resource" and cheap oil may run out in this century; relying on other countries' fossil fuels endangers any country's energy security; and "it's very probable that using fossil fuels changes the climate.... The climate problem is mostly an energy problem."

Like Yergin, MacKay asks large questions: "Can we *conceivably* live sustainably?" (his italics) "Will a switch to 'advanced technologies' allow us to eliminate carbon dioxide pollution without changing our lifestyle?" What are "practical options for large-scale sustainable power production for Europe and North Africa [and the rest of the world] by 2050"? Unlike Yergin, MacKay, a professor of physics at Cambridge, answers these questions. The main text of his book is readable (and witty), and its technical appendices bristle with equations and numerical data sufficient to validate MacKay's credentials as chief scientific adviser to the UK's Department of Energy and Climate Change (since 2009).

To make the necessary comparisons among alternatives, MacKay asserts, "we need numbers, not adjectives"—numbers in consistent, interpretable units, systematically organized so they can be compared. MacKay draws up a balance sheet of power consumption and sustainable power sources. He estimates the daily energy consumption of a "typical moderately-affluent person" in the UK for transport (cars, planes, and freight), heating, cooling, lighting, information systems, other gadgets, food, and manufacturing. To see if the United Kingdom can conceivably live on its own renewable power sources, he estimates the potential UK production of power from wind, solar energy (photovoltaics, thermal, and biomass), hydroelectric, tide, geothermal, and nuclear sources. Initially MacKay says "it's not clear whether nuclear power counts as 'sustainable,'" but he goes on to define and answer the question.

The UK's annual GDP per person and power consumption per person, as calculated by MacKay, are typical of high-GDP countries like Germany, France, Japan, Austria, Ireland, Switzerland, and Denmark. This analysis could become increasingly relevant to the billions of people who now live on low incomes and little power, as they escape from poverty.

After 102 pages of detailed but intentionally approximate arithmetic, MacKay estimates power consumption for a moderately affluent Briton at 8.1 kilowatts, the equivalent of eighty-one hundred-watt light bulbs always on.* If we assume complete social and political acquiescence to the cost and ubiquity of power-producing infrastructure, the UK's future potentially physically available renewable power amounts to 7.5 kilowatts per person. This seems pretty close, but MacKay cautions that his assumption that solar photovoltaic farms would use 5 percent of the country's land might not be compatible with his assumption that 75 percent of the country could be planted with energy-producing crops. "If we were to lose just one of our bigger green contributors—for example, if we decided that deep offshore wind is not an option, or that panelling 5% of the country with photovoltaics at a cost of £200,000 per person is not on—then the production...would no longer match the consumption."

The gist of MacKay's summary is: "I don't think Britain can live on its own renewables—at least not the way we currently live.... People love renewable energy, *unless it is bigger than a figleaf*" (his italics). Because renewable power sources are so diffuse, they can contribute significantly to national energy budgets only if installed on a national scale, for example, "wind farms with the area of Wales." Public objections, MacKay estimates, would limit the renewable power Britain could capture from its own resources to less than a tenth of consumption.

Britons will have to make big changes in power consumption and power supply, MacKay argues. His options for reducing power demand include reducing population size ("a difficult policy to sell," he concedes), changing the way we live to involve less power consumption per person (also difficult to sell), and reducing the intensity of power usage required by present lifestyles through greater efficiency and new technology.

MacKay proposes that the UK electrify transport to make it more energy-efficient and to eliminate its dependence on fossil fuels, and that it supplement solar-thermal heating with electrically powered heat pumps to warm water and air in buildings. Heat pumps work like refrigerators in reverse, pumping heat from outside air or the ground into the air or water inside a building. The electrical energy that heat pumps require is about a quarter of the heat energy they deliver, making them four times more efficient than conventional electrical heaters. Both electrifying transport and using heat pumps in buildings would increase demand for electricity. To increase the electrical power supply, MacKay proposes that the UK get electricity "from our own renewables; perhaps [also] from 'clean coal;' perhaps [also] from nuclear; and finally, and with great politeness, from other countries' renewables."

The "clean coal" option—based on coal whose carbon is captured and sequestered—is qualified by "perhaps" because, with the added costs in energy of capturing and storing emissions from burning coal, and a finite amount of coal in the ground, "clean coal" is at best a stopgap. "If the growth rate of coal consumption were to continue at 2% per year (which gives a reasonable fit to the data from 1930 to 2000), then all the coal would be gone in 2096," MacKay writes. At the growth rate in coal consumption of the last decade, 3.4 percent per year, the coal would be gone before 2072.

The nuclear power option is also qualified by "perhaps," and even a defense: "Please don't get me wrong: I'm not trying to be pro-nuclear. I'm just pro-arithmetic." MacKay defines an exhaustible power source that would last at least a thousand years as "sustainable." One such power source would be uranium extracted from ocean water to fuel fast breeder reactors, "two technologies that are respectively scarcely-developed and unfashionable." And costly: five to fifteen times the cost per kilogram of uranium from ore, and demanding much space for the extraction, with the present technologies still in the experimental stage. Still, MacKay estimates that ocean uranium in fast breeders could supply 17.5 kilowatts per person, more than current consumption, over 1,600 years, using 10 percent of the uranium in ocean waters. But "nuclear has its problems too," as the catastrophe in Fukushima in 2011 showed once again. Decisions announced in Germany and Switzerland in May 2011 to phase out nuclear power suggest how difficult it will be to depend on it.

For MacKay, "a technology that adds up" would be to buy electricity from countries with low population density, large land area, and high renewable power production per square meter of land. His prime example is electricity generated by concentrating solar power in countries like Libya, Kazakhstan, Saudi Arabia, Algeria, and Sudan. (He does not discuss the evident political problems of installing solar power generators in some of these countries.) He also recommends managing demand on a large scale by coordinated increases in the number of both electric vehicles and wind farms. Spare vehicle batteries could be charged whenever wind power was available in excess of current demand for it, and these charged batteries could be exchanged for vehicles' depleted batteries. The vehicle batteries collectively would provide a

*8.1 kilowatts means 8,100 joules per second, the joule being the international measure of a unit of energy.

reservoir of transport power generated by variable wind, creating "a beautiful match between wind power and electric vehicles."

MacKay sketches six energy plans for Britain. His economic analysis of the sixth plan, a blend of the preceding five, suggests a starting point for political discussions of a new balance of energy sources. He estimates that "a major switching from fossil fuel to renewables and/or nuclear" would cost roughly "£870bn, with the solar power facilities dominating the total.... Costs might well come down dramatically as we learn by doing." Such investment would require decades.

To stop burning fossil fuels and therefore slow the rate and risks of climate change, Europe and North America, like Britain, will, in MacKay's view, need some combination of nuclear power with large amounts of solar power from deserts (for Europe, deserts abroad; for the US, deserts at home), even if North America's demand is reduced by half from the present 10.4 kilowatts of power per person to the average European and Japanese levels of 5.2 kilowatts per person. How can "post-European consumption" of 3.3 kilowatts per person (the power consumption of Hong Kong) be reached for the entire world (whose population MacKay mistakenly estimates as six billion—it is about seven billion now)? All nonsolar renewables could not meet even half of demand: "a plan that adds up... must rely on one or more forms of solar power" or nuclear power or both.

If the planet and its people are the patient, Yergin's book is a doctor's clinical case history without the test results or prognoses, and MacKay's book is the lab results, temperature chart, and electrocardiogram without the clinical case history. Neither alone suffices for diagnosis and prescription. The only assertion of MacKay's I'd differ from is his exclusive claim that "we need numbers, not adjectives." Translating science for human use requires both numbers and adjectives.

Each book needs the other, and each leans toward the other. Yergin's recognizes the importance of science and technology for energy futures but lacks scientific analysis of potential solutions. MacKay's acknowledges that public acceptance, economics, and politics are decisive in selecting among the technical possibilities but protests that "politics and economics are not part of this book's brief," though in fact they are to some extent. Both books recognize the strong impacts of demographic factors like population size and density on energy demand and production. For example, at any level of average power consumption per person, more people demand more power—but also more space. The more densely and evenly settled a country, the more difficult it will be to cover large parts of it with devices to capture renewable energy.

Both books lack—and neither attempts—a diagnosis of the underlying disease afflicting current uses of energy. MacKay comes close:

> The principal problem is that carbon pollution is not priced correctly. And there is no confidence that it's going to be priced correctly in the future.... The price of emitting carbon dioxide should be big enough such that every running coal power station has carbon capture technology fitted to it.

But he does not ask: Why is carbon pollution not priced correctly? Yergin recounts the troubled history of carbon taxes and cap-and-trade, but does not explore why neither has been successfully applied.

Here is a tentative diagnosis. The disease afflicting Earth derives from incompatibility among four central facets of its life: (1) the local interests of different governments, including national democracies and autocracies; (2) economic globalization, particularly through international corporations; (3) the threat to environmental sustainability (a different concept from MacKay's sustainability of energy sources); and (4) the growing human population.

The core incentives of voters and politicians in a national democracy are primarily local (within the country's boundaries, or even more local than that) and primarily short-term (until the next election, for most elected officials; for many voters, until the next paycheck or tank of gasoline—which, as of March 2012, had reached a US national average of $3.92 per gallon. Gasoline is further projected to rise to around $4 nationally by Memorial Day). The economic, social, and political consequences are unpredictable. In the US, for example, the effects of raising average corporate fuel efficiency standards on campaign contributors, jobs, and voters matter more than the effect on atmospheric greenhouse gases. The atmosphere has no vote in the next US election. Neither do citizens of small island nations—such as Tuvalu in Polynesia—that are surrounded by rising levels of a warming ocean. Nor do the future generations living in US seacoast cities that may be threatened by rising waters.

In multinational corporations, the core incentives of management and stockholders are global. They hire wherever labor is cheap, find land, timber, or fish wherever they are easily harvested, pollute wherever environmental standards are low, sell products wherever demand is high. In most (not all) cases, the incentives are short-term: the next quarterly report, the next meeting with stock analysts, the next meeting of the board of directors' compensation committee. If a forest increases its stock of timber at 2 percent per year and its market value could be invested elsewhere to bring a return of 3 percent a year, the economically rational choice for a company is to clear-cut the forest, sell the timber and land, and invest the proceeds where they bring a higher return.

Environmental sustainability (not MacKay's thousand-year standard for consuming finite fuel sources) entails preserving Earth's physical and biological stocks, flows, and services. Stocks include, for example, the atmosphere, oceans, lands, and biological species. Flows are precipitation and human extractions of fish, timber, and fresh water. Services include the ways by which the atmosphere exerts control of temperature, water purification by wetlands, and flood control by hillside vegetation. The core concerns of people involved with environmental sustainability are long-term, on the scale of thousands to millions of years, locally and globally.

MacKay explains why "we have enough fossil fuels"—including oil, natural gas, and coal—"to seriously influence the climate over the next 1000 years," long after this generation's children's children's children are dust. But today's national governments, corporations, and consumers decide whether to protect the atmosphere and the climate under which our children's children's children will have to live.

The root problem of decarbonizing energy supplies, climate change, and many other aspects of environmental sustainability is the lack of institutions to reconcile the conflicting incentives of people involved in national democracies and other governments, globalization, and environmental sustainability. Small steps have been taken. The US Climate Action Partnership (USCAP), launched in 2007, brings together leading businesses (like Alcoa, Chrysler, and Dow) and leading environmental organizations (like Environmental Defense Fund, Natural Resources Defense Council, and the Nature Conservancy) "to call on the federal government to quickly enact strong national legislation to require significant reductions of greenhouse gas emissions." But USCAP's progress has been slow. Powerful American politicians still deny climate change, though its reality and causes are clear from many reliable sources, including both these books.

Meanwhile the human population is rising by 75–80 million people a year, adding the equivalent of another Bangladesh or Nigeria or Central America including Mexico every two years. In 1600, MacKay writes,

> Europe lived almost entirely on sustainable sources: mainly wood and crops, augmented by a little wind power, tidal power, and water power.... Today...even if we reverted to the lifestyle of the Middle Ages and completely forested the [UK], we could no longer live sustainably here. Our population density is far too high.

Since 1700, human numbers have grown elevenfold, soon to be twelvefold, while economic activity per person has grown twelvefold. The result is a collision of these major factors: national democracies and other forms of government, with their own parochial perspectives in space and time; the global reach and short-term incentives of economic globalization; and the long-term integrity of Earth's biological and physical systems that support all humans.

The difficult challenges of our energy future include, first, designing and creating institutions that adjust the incentives of globalization and national governments so that the self-interested choices of consumption, production, and distribution of all goods and services, not only the use of power, will reflect the full costs of how those choices affect climate change and all other elements of environmental sustainability. Second, we should promote slower or no population growth through universal education, voluntary family planning, improved nutrition, job opportunities, the elimination of poverty, and a host of other strategies that are good in themselves.

We have made some progress in meeting many of these challenges but we still have a long way to go. □