different forms of this relationship is the first step toward the effective governance of expertise.

Perhaps not surprisingly, the policy response to climate change has neglected the complexity of the relationship of experts and decision makers. That relationship is dominated by issue advocacy—and far too often, stealth issue advocacy, where political battles are hidden behind science. Notable for their absence are institutions that serve as honest brokers of policy alternatives. Improving science advice to decision makers on climate change depends in no small part on bringing political disputes out into the open and creating a safe place for discussions of uncertainties and a wide range of policy options. This will require a new sort of leadership among climate scientists and, in particular, a willingness for some to step back from the overt and stealth advocacy that has come to consume the climate science community, and for leading scientific organizations to take on a role as an honest broker of policy alternatives. Climate policy is notable for its lack of such honest brokers.

We have choices in how experts relate to decision makers. These choices shape the ability to use expert advice well in particular situations, but also shape the legitimacy, authority, and sustainability of expertise itself. Whether we are taking our children to the doctor, seeking to use military intelligence in a decision to go to war, or using interdisciplinary climate research to inform decarbonization and adaptation policies, better decisions will be more likely if we pay attention to the role of expertise in decision making and the different forms that it can take.

CHAPTER 9

Obliquity, Innovation, and a Pragmatic Future for Climate Policy

IMAGINE THAT NATIONS around the world were to decide that they want to increase human life spans. They might start their work by deciding on a goal. Today, the global average life span is about sixty-nine years. One nation might suggest a target of a seventy-five-year average life span by 2050. Others might criticize the lack of ambition in this target, and press for eighty-five years by 2050. A great amount of time could be spent arguing about what the right target should be, and the negotiations might founder there, without even an agreement on the goal, let alone implementing it.

But let's say that a target is agreed upon. One way to reach it would be to put an economic price on death: countries would be responsible for paying some amount when someone dies. There could be a death tax or, even more creatively, a cap on the number of allowable deaths in each country, with a decreasing number of permits issued each year. If a country experiences more deaths than they have permits for, then they will have to buy permits from other countries that are experiencing a lower death rate, and thus have surplus permits. Advocates for this approach would claim that the cap would stimulate innovation in medical research and prompt behavioral changes that lead to longer life expectancies. The permit market would mean that the market would decide efficiently how resources are best allocated, so that the "lowest hanging fruit"—the simplest or lowest-cost actions to increase life expectancy—would get funded. The legal cap would provide certainty in achieving the targeted extension of life expectancies.

Such a scheme would not be without its challenges. For instance, some countries, such as Japan, already have long average life spans, and thus have less ability to make progress. They might argue for some sort of excess permits to reflect their historical achievements on health. Similarly, many countries in sub-Saharan Africa have shorter average life spans, reflecting historical realities and long-standing inequities. These countries might argue for some time period to develop before being included under any sort of binding agreement, in recognition of history and their present circumstances.

Perhaps, a very creative policy entrepreneur might argue, a system of "death offsets" might be created, under which rich countries could get additional "death permits" by paying poor countries to improve their health outcomes, where there is much greater progress to be made. With a declining cap on deaths and a market-based instrument to efficiently allocate death permits, the world would inevitably move toward increasing the average human life span. Who could be against such an elegant approach to improving health outcomes? No one, obviously, except perhaps the nefarious industry-funded "health deniers"!

I have used this parable in many talks over the past few years, and inevitably the audience laughs at the notion of a cap-and-trade regime for extending life expectancies. The laughter is appropriate, as the example is a joke. But it is no more of a joke than efforts to reduce emissions of carbon dioxide employing the same type of policy. In much the same way that the amount of carbon dioxide in the atmosphere is a consequence of our actions, average human life spans are a consequence of actions, and consequences are extremely difficult to modulate directly via policy.

Policies are more effective when they focus on causes, not consequences. Despite the lack of internationally negotiated goals, the world has in fact seen a steady increase in average human life spans. This increase has been achieved with a focus on causes of poor health. We advanced average human life spans not by targeting it directly, but by

focusing on a large set of individual diseases and public health challenges that lead to mortality. When we make progress on these health challenges, the fruits of our efforts show up in statistics of advancing average human life spans. The best route to advancing human life spans is indirect, focused not on seeking to change it directly, but on the phenomena that influence it. This logic is so compelling that any policy maker suggesting a global cap-and-trade regime on death would not be taken seriously, and for good reason.

Global emissions of carbon dioxide are the result of economic activity and the technologies of energy production and consumption. People in countries around the world expect to see continued economic growth, which means that, all else being equal, emissions will increase. In Chapter 2 I call this contemporary reality (which is grounded in a deeply held global and ideological commitment to economic growth) the iron law of climate policy. The iron law holds that for the foreseeable future, efforts to reduce emissions through a willful contraction of economic activity are simply not in the cards. Countries around the world—rich and poor, North and South—have expressed a commitment to sustaining economic growth, and these commitments are not going to change anytime soon, no matter how much activists, idealists, or dreamers complain to the contrary. People will pay some amount for environmental goals, but only so much before drawing the line. That is just the way it is, regardless of whether economic growth measures what matters most to a country's well-being or if there are other metrics that might better capture quality of life.

Given the iron law, then, there are only two ways that decarbonization of economic activity will occur. One is through improving the energy efficiency of the economy—which includes changes both in the efficiency of specific activities, such as steelmaking and automobile gas mileage, as well as in the nature of the economy, such as the increasing role played by less energy-intensive services sectors—and the other is through decarbonization of the energy supply.

In recent decades improvements in energy efficiency have been the primary driver behind decarbonization of the global economy, with decarbonization of energy supply a distant second. This must change, if decarbonization is to accelerate to rates consistent with low targets for atmospheric carbon dioxide, such as 350, 450, or even 500 ppm. The need to focus on decarbonizing the energy supply results from the simple fact that under all scenarios of future energy demand, even those based on relatively modest economic growth, the world will need a vastly larger energy supply. Whether that need is 30 percent, 50 percent, or 100 percent more than today's supply does not alter the basic calculus that to reach low stabilization targets implies a massive transition to a nearly carbon-free global energy supply. Advances in efficiency can alter the pace at which that transition takes place, but they will not change the end point. There is good news in that advances in efficiency often make sense for reasons other than decarbonization, most important being economic reasons, and thus have an independent justification. The bad news, of course, is that to the extent that efficiency gains do result in economic benefits they can stimulate the economy, leading to greater energy demand and thus greater emissions, unless the energy supply itself is decarbonized. Scholars and practitioners have debated the degree to which energy-efficiency improvements lead to greater energy demand. Even if there is no positive feedback effect on energy demand from energy-efficiency improvements, decarbonization of the energy supply still must happen.

But how do we accelerate decarbonization of the global economy through increasing the deployment of a low- or zero-carbon energy supply? Here again, we can look to efforts to improve health outcomes. Human life span is addressed disease by disease, public health issue by public health issue, and it will be through a similarly focused approach that decarbonization is accelerated. Of course, innovation in medicine and public health does not guarantee better health outcomes, just as innovation in military technology does not guarantee victory in battle. Both health care systems and military conflicts reflect deep complexities in society and its institutions that are independent of technological innovation. Similarly, success in energy innovation is necessary but not sufficient to decarbonize the global economy.

To make progress accelerating the decarbonization of the global economy we are going to have to overcome two further aspects of con-

ventional wisdom that underlie the debate over climate change, and ultimately take a new approach. The first bit of conventional wisdom that we must overturn is the idea that we use too much energy. As described in Chapters 3 and 4, the world will need much more energy in the future, and this is reflected in all scenarios of leading national and international energy agencies. There are presently 1.5 billion people around the world who lack access to a basic energy supply. This is almost five times the population of the United States and three times the population of the EU. If all of these people were instantaneously granted energy access and produced the global average per capita emissions of 4.4 metric tons of carbon dioxide, they would add more than 20 percent to global carbon dioxide emissions from the consumption of fossil fuels, and the emissions from the bottom 193 countries would instantaneously double.[1] The uncomfortable reality of large increases in emissions that accompany greatly expanded access to energy may help to explain why some scenarios for stabilizing concentrations of carbon dioxide leave the vast majority of those lacking access in the dark. But as we'll soon see, providing energy to those without access may be a key element of an "oblique" strategy to accelerate decarbonization.

The second aspect of conventional wisdom that we must overturn is the idea that fossil fuels are too cheap. A fixture of the climate debate has been the notion that the best way to make alternative energy sources more cost competitive with fossil fuels, and thus preferable in markets of energy supply, is to increase the costs of fossil fuels. However, this line of thinking, whatever its merits to be found in economic theory, runs smack into the unyielding iron law of climate policy. Evidence from around the world clearly shows that while people are willing to accept some increases in their energy costs, this willingness has its limits. And those limits are nowhere near those needed to motivate the complete decarbonization of the world's energy supply. It is on these shoals that climate policy has repeatedly foundered.

If substantially raising the price of fossil fuels is not a viable option, then we must think differently about the challenge. British economist John Kay provides some insight as to how differently our thinking must be for complex challenges: "If you want to go in one direction, the best route may involve going in the other. Paradoxical as it sounds, goals are more likely to be achieved when pursued indirectly. . . . Oblique approaches are most effective in difficult terrain, or where outcomes depend on interactions with other people. . . . Obliquity is characteristic of systems that are complex, imperfectly understood, and change their nature as we engage with them."[2] An oblique approach to climate policy is necessitated by the complexity and inherent "wickedness" of the issue, one that, as Mike Hulme has argued, is not a problem to be solved but a condition that can be managed for better or worse.

An oblique approach to decarbonization begins with the realization that whatever the future holds for energy demand, we can stabilize concentrations of carbon dioxide at a low level only via a massive expansion of the availability of the carbon-free energy supply. This means that any policies based on the idea that we, as a world, use too much energy are on the wrong track from the start. The world needs more energy. Much more. Over the long term increasing demand for energy and limits on the easily accessible supply of fossil fuels will together lead to some degree of decarbonization of economic activity, though how much and how fast are uncertain. But as we've seen, the historical rate of so-called spontaneous decarbonization—and even a rate twice as fast—is inadequate to stabilize carbon dioxide concentrations at a low level, such as 450 ppm.

Justifying dramatically accelerating decarbonization of the global economy requires an oblique approach involving the application of policy jujitsu. Consider the 1.5 billion people who presently lack access to energy. It seems obvious that basic access to energy is, if not a human right, a matter of human dignity. A main obstacle to securing access to energy for all is that present supply options, which include both fossil fuels and their alternatives, cost too much. Cheaper sources of energy would advance human dignity by making it easier to secure energy access for all; the cheaper that energy is, the broader the benefits and the greater the demand for energy. Meeting this massive demand requires technological innovation in support of diversification of the energy supply. Greater diversification implies decarbonization of the energy supply and economic activity. The greater the rate of innovation, the greater the potential pace of decarbonization.

Expanding access to cheap and secure sources of energy appeals to overlapping interests. The advantages for countries with large numbers of people without access to a basic energy supply are clear. Others around the world would benefit from the opening of new markets, both through building the infrastructure of the energy supply and through the explosion of economic activity in these newly powered communities, creating new opportunities for trade and growth. A focus on expanding the energy supply thus unites two virtues—addressing fundamental human needs while providing inescapable motivation for accelerating decarbonization of the global economy—and eliminates the pathological trade-off between development and emissions reductions implicit (and at times explicit) in conventional climate policies. An oblique focus on expanding the energy supply may offer the best prospect of accelerating decarbonization. Heading in what might seem to be the wrong direction—dramatically expanding the energy supply, access, and consumption—may offer the best prospect for getting us to where we should be headed.

Of course, if, through some discovery or technological advancement, the costs of fossil fuels fall dramatically in coming years, then a policy goal of dramatically expanding access to energy could be achieved without accelerating decarbonization of the energy supply. The recent progress in freeing up natural gas from shale deposits suggests that there are still surprises in the technologies of fossil fuels. Nevertheless, even with such discoveries it seems unlikely that the costs of fossil fuels will decline significantly; enormous effort and subsidies have been devoted to providing fossil fuel energy at the lowest costs possible (so low, in fact, that some governments tax them due to people's willingness to accept paying a bit more). It is unlikely that the costs of fossil fuels can be further reduced, meaning that they will still cost too much for many people to use, and diversification will remain a compelling strategy for securing a reliable energy supply.

In fact, the costs of fossil fuels should increase in coming decades for simple reasons of supply and demand, providing a separate, compelling basis for innovation-focused energy policies. All of this implies a policy challenge to develop alternative sources of energy supply that are cheaper than fossil fuels. Google.org has expressed this policy challenge elegantly in terms of a simple equation: RE < C, which stands for *R*enewable *E*nergy that *costs less* than *C*oal.[3] Google.org explains that "today renewable electricity costs too much to compete with coal."[4] Developing cheaper electricity will aid in expanding energy access around the world and would also contribute to energy security and economic development. A significant side benefit to such a strategy is that, if successful, it will also contribute to the dramatic acceleration of the decarbonization of the global economy. Google.org's innovative approach reflects the notion that rather than being too cheap, fossil fuels cost too much.

Economics alone probably won't be enough to motivate a dramatic reduction in consumption of fossil fuels, even if alternatives to fossil fuels are developed at lower costs. The reason for this lies in the fact that the process of securing lower-cost alternatives to fossil fuels may have the perverse effect of motivating an accelerated extraction of fossil fuels as owners of those resources see no better time than the present to capitalize on their value, as the resources will only be worth less in the future. German economist Hans Werner-Sinn calls this the "green paradox."[5] What this means is that some form of political commitment to leaving fossil fuels in the ground will likely have to accompany innovation of alternative sources of energy. Such a commitment will be made far more likely with alternatives cheaper than fossil fuels available, and will be impossible without those alternatives. Innovation thus has to be front and center.

Critical to driving this innovation will be government. Government-sponsored work has been integral to other efforts, such as the fight against disease, where investments have focused on a disease-by-disease approach. Likewise, progress on energy innovation will occur technology by technology, via investments in innovation. Fortunately, as progress in medicine as well as other fields such as agriculture and defense attests, innovation is something that governments at national and international levels have often managed well over periods of decades.

In 2009 Arizona State University and the Clean Air Task Force, a nonprofit organization based in Boston, organized a series of workshops examining the role of the public sector in fostering technological innovation in climate policy.[6] Their resulting analysis focused on efforts in the United States, but their conclusions have implications for accelerating energy innovation worldwide:

To improve government performance, and expand innovation options and pathways, Congress and the administration must foster competition within the government. Competition means allocating resources based on performance. The United States, they argue, relies too much on a single agency for energy innovation. Agencies or programs that show results should be rewarded with additional resources; those that do not should be downsized or terminated. The implication is that energy innovation needs to be conducted in a diverse set of institutions, with performance continuously being evaluated.

To advance greenhouse gas–reducing technologies that lack a market rationale, the government should selectively pursue energy-climate innovation using a public-works model. If it is in the public interest to expand the secure, low-cost energy supply and in the process to slow or reduce the emission of greenhouse gases, then there is a public-sector role for investing in energy technologies that complement a more globally focused effort to secure energy access for all. The workshop participants offer vaccines for pandemic flu, flood-control dams, and aircraft carriers as analogous technologies supported by the public.

To stimulate commercialization, policy makers must recognize the crucial role of demonstration projects in energy-climate innovation, especially for technologies with potential applications in the electric-utility industry. Demonstration projects can help to overcome concerns about technical and cost uncertainties that often limit the adoption of new technologies. They point to carbon capture and storage as an example of such a technology that would benefit from full-scale demonstration in order to prove (or disprove) its viability.

To catalyze and accelerate innovation, the government should become a major consumer of innovative energy-technology products and systems. Governments spend a large amount of money on energy and as such can stimulate market demand, driving down prices and building confidence in products that are close to being market ready.

There is ample experience worldwide with public and private efforts to stimulate innovation to serve as the basis for designing new approaches to energy innovation, building on existing institutions. Such experience includes that of the Consultative Group on International Agricultural Research,[7] the Global Alliance for Vaccines and Immunization,[8] and the accumulated experience of the world's military establishments which have overseen innovation in many areas of technology.

We seem to know how to do innovation well enough to get started on the challenge. That leaves two questions: How will we carry it out, and how we will pay for it?

It is important to understand that the technologies of the future are almost certainly going to be technologies of the present, only better. Breakthroughs that lead to fundamentally new sources of energy—such as nuclear fusion—while possible, are unlikely. The alternatives to fossil fuels are well known and include various technologies of wind, solar, biomass, nuclear, hydropower, carbon neutral fossil fuels, and a few others. The technologies of consumption involve issues of storage of energy, such as in batteries that might be used to displace liquid fuels for transport, and the management of energy such as in advanced electrical grids capable of handling intermittent sources. All of these technologies are with us in one form or another, but not many are developed to the point where the technology or economics is suggestive of readiness for large-scale deployment.

Consequently, any successful innovation-based approach to decarbonization will benefit from a policy stance that might be called technological agnosticism, since we do not presently know where advances might lie. A broad portfolio of technologies and practices should be supported in a global energy-innovation policy, despite the fact that no one energy technology will be universally popular. Every energy technology has its supporters and opponents, but to give in to every naysayer risks turning NIMBY (not in my backyard) into BANANA (build absolutely nothing, anywhere, near anyone). Under democratic systems of governance, tough choices will inevitably be made involving deployment of energy technologies. That should not preclude innovation, lest we limit our options before those options are even available. The uncomfortable reality is that the more technologies deemed politically unacceptable, the greater the challenge of accelerating decarbonization, the longer we'll depend upon fossil fuels, and the longer more than a billion people will lack basic access to energy.

It is often said that public investments in energy technologies should not "pick winners." This stance is only partially correct. One important reason for public investment is in fact to pick winners—those technologies that are cheaper than fossil fuels and can reliably supply copious amounts of new energy in the decades to come. The important thing is not to pick specific winners in advance, which includes taking options off the table before they have been explored.

Paying for this research is the other major challenge facing policy makers and the public. After all, experience in medicine and the military suggests that innovation does not come cheap. Consider, for instance, that the United States government alone invests about $30 billion annually in medical research and development and about $80 billion in military research and development. Such investments have been made for a period of many decades, complemented (and sometimes exceeded) by private-sector investment. Successful innovation in the energy sector that contributes to the sustained acceleration of decarbonization of the world's economy will require similar levels of investment for similarly long time periods.

Where will that money come from? Isabel Galiana and Chris Green of McGill University have argued for an innovation-led approach to climate policy, and they estimate that a $5 per metric ton tax on carbon

TABLE 9.1 Implications of a $5 per metric ton carbon tax for the prices of coal, oil, gasoline, and natural gas

	Carbon-tax equivalents		
	CO_2 (tonnes)	at $5/t CO_2 ($)	2009 price ($) per unit
Metric ton of coal	2.86	14.30	16–110
Barrel of oil	0.37	1.85	45–70
Gallon of gasoline	0.0088	0.044	2.00–2.50
1,000 cubic feet of natural gas	0.055	0.22	10–11
1,000 cubic meters of natural gas	2.025	8.10	~400

Source: I. Galiana and C. Green, "An Analysis of a Technology-Led Climate Policy as a Response to Climate Change," Copenhagen Consensus on Climate, 2009. http://fixtheclimate.com/fileadmin/templates/page/scripts/downloadpdf.php?file=/uploads/tx_templavoila/AP_Technology_Galiana_Green_v.6.0.pdf.

dioxide would have a relatively small effect on fossil fuel prices, with the exception of the cheapest forms of coal, and would raise as much as $150 billion per year—about $30 billion in the United States and China, a bit less in Europe, and substantial amounts elsewhere.[9] Table 9.1 shows their estimates for the effects of such a tax on the price of fossil fuels. A tax of $5 per metric ton is also attractive because a tax at this level has been proposed by the CEO of ExxonMobil, the energy company most often identified as the chief villain opposed to action on climate change.[10] If ExxonMobil can support such a tax, then it would suggest a lot of possible room for a broader political consensus. Galiana and Green compare a low carbon tax to the fuel tax placed on gasoline by the Eisenhower administration in support of building the U.S. interstate highway system. That tax had public support because it was linked to investments that paid off in tangible near-term benefits.

It is important to emphasize that the point of a carbon tax at this level is not to change people's behavior, to restrict economic activity, or to price fossil fuels at a level higher than alternatives. The purpose of a low carbon tax is to raise revenues for investments in innovation. Galiana and Green suggest that a key part of an innovation-focused approach to accelerating decarbonization would be a commitment to a forward-looking increase in the carbon tax, perhaps a doubling over ten years. Such a commitment would signal a manageable increase in the price of fossil energy and raise additional revenues along the way.

Of course, if innovation actually begins to result in an accelerated decarbonization of the economy, then it will prove politically easier to raise the tax, as its effects on consumers would be increasingly less profound as the economy slowly decouples economic growth from emissions. Over time, as the tax increases, there would be a convergence in outcomes between those who have argued for starting with a high price on carbon and the view expressed here of starting with a low tax. To some degree, a rising tax would help to address the so-called green paradox.

Such a tax would most efficiently be set "upstream," on the act of extracting fossil fuels itself. The precise amount of the tax itself—whether $5 per metric ton, or $10, or only $3—is less important than that the tax be implemented at the highest price politically possible. Using politics as the metric for pricing the tax would be far superior to trying to meet some theoretical ideal, such as through estimates of the "social cost of carbon" developed through complex economic models that require discerning trends and preferences decades and longer into the future. Starting with a low tax seems like an obvious strategy in any case for the simple reason that a high price on carbon—whether via a tax or through trading regimes—is just not going to be implemented in the near term. The only way to a high carbon tax is to start low.

The Indian government seems to have already recognized the importance of an innovation-led approach based on funding raised from low prices on fossil fuels. In February 2010 Pranab Mukherjee, India's minister of finance, proposed a 50 rupee (about $1) tax on every metric ton of coal mined in or imported by India to support a "National Clean Energy Fund." The tax would raise about $600 million per year to be invested in alternative energy with a focus on reducing pollution from coal energy and also expanding energy access.[11] The Indian government's plan provides an example of the approach recommended here, including a focus on expanding energy access as a basis for gaining short-term political buy-in to the tax.

At the international level, there would be many details to work out, of course, but there is no doubt that this type of scheme would be far less complicated than that of the present climate regime. Imagine what a difference it would be for nations to gather at an international climate convention with a single point to negotiate: at what level do we wish to collectively tax carbon dioxide emissions from fossil fuels? With a decision reached on that question—which still would not be easy to achieve—nations could then turn to the question of how to invest the proceeds in a manner that addresses political demands, but also does not compromise on the need to focus the revenues on energy innovation in an efficient and effective manner.[12] One of the greatest challenges facing this approach would be the ability of nations, individually and collectively, to direct funds raised by a carbon tax to energy innovation. Given the debt situation facing many nations around the world, not least the United States, it would be exceedingly tempting to agree to a carbon tax and then funnel the proceeds into general government revenue, giving innovation short shrift.

Once one takes a look at the simple mathematics of emissions reduction described in Chapters 3 and 4, it is inescapable that the world does not in any practical sense have "all the technology that it needs" to achieve low levels of stabilization of carbon dioxide. This point is further reinforced when a commitment is made to providing access to energy presently lacked by 1.5 billion people around the world. Energy innovation must be at the core of any policy focused on stabilizing carbon dioxide levels in the atmosphere.

We have seen the simple mathematics that show convincingly that progress on accelerating decarbonization of the global economy will be a consequence of technological innovation. Thus, whatever policies are ultimately adopted, the real measure of progress will begin with the effects of those policies on the rate of innovation. With little attention to innovation, progress will be correspondingly small. If there is a single variable that will serve as a measure of progress toward emissions reduction or carbon-intensity goals, it will be the proportion of global energy consumption that comes from carbon-neutral (or even-negative) sources. In recent years that value has been well under 10 percent of total global consumption.[13] To achieve stabilization at low levels, that proportion will eventually have to exceed 90 percent. The mathematics of decarbonization are as simple as the practical challenge is difficult.

For decarbonization, the most effective path is to focus on innovation funded by a low carbon price that rises over time. An innovation-focused approach retains some of the elements of a pricing scheme in that it prices carbon, albeit at a level far lower than followers of conventional wisdom demand. But the iron law of climate policy limits what can be done in the near term. By explicitly connecting carbon pricing with energy innovation, a virtuous circle is enabled that allows those asked to pay the tax to see its benefits and thus builds the support necessary to sustain investments over decades and longer. Ironically, a more direct focus on decarbonization of the global economy means a less direct focus on climate change, as there are other reasons to accelerate decarbonization focused on expanding energy access, increasing security, and reducing costs. As we've seen with the oil catastrophe in the Gulf of Mexico in 2010, less reliance on fossil fuels might lead to environmental benefits that go well beyond climate.

An important and perhaps uncomfortable aspect of the approach recommended here is that it leaves much uncertain: we do not know, exactly, how we are going to achieve the long-term goals of providing energy access, security, and low cost that, if achieved, will also drive accelerated decarbonization of the global economy. This uncertainty is inescapable, but not crippling. Rather, this sort of uncertainty exists in other challenges that we collectively face. How will we improve human life spans over coming decades? How will we secure economic stability? How will we maintain peace? No one pretends that there is a comprehensive solution, much less a definitive road map to success, for any of those questions. Rather, we proceed incrementally on many parallel paths while learning from, and adjusting to, experience. Acceptance of policy uncertainty can be liberating as well: no one depends on a cost-benefit analysis integrated over the better part of a century to assess individual policies focuses on health, security, or the economy.

To summarize, the approach to accelerating decarbonization recommended here has four related elements. First, it begins by setting goals. Policy making is more likely to succeed with a clear sense of direction. The world should aim to provide secure access to inexpensive energy to everyone on the planet by some date in the not too distant future, perhaps 2030 or 2040. Achieving that goal will require unprecedented innovation in energy technologies such that alternatives to fossil fuels are cheaper than fossil fuels. Climate thus becomes relegated to a secondary consideration. John Kerry, Democratic senator from Massachusetts, explained a very similar logic when discussing reworked climate legislation in early 2010 after cap and trade was determined not to be the way forward, "It's primarily a jobs bill, and an energy independence bill and a pollution reduction–health–clean air bill. Climate sort of follows. It's on for the ride."[14]

Second, achieving that goal will necessitate rapid innovation in energy technologies. Innovation will be necessary in both efficiency of energy use and technologies of energy production. Efficiency gains can lead to reduced costs of energy for particular users, but may also have the consequence of increasing overall demand for energy. Thus, progress will also have to be made in developing sources of energy that are cheaper than fossil fuels. Innovation policies should be implemented based on the lessons of experience from areas such as health, agriculture, and the military. Progress in innovation policies will be enhanced by adopting an attitude of technological agnosticism from the outset, where the broader goals are set and the details are not prejudged.

Third, raise funds to invest in innovation via a low carbon tax, priced as high as politically possible, perhaps $5 per metric ton and applied "upstream" where fossil fuels are removed from the earth. The point of the tax would not be to change behavior, as any price on energy high enough to be felt will indeed change behavior—most likely the voting behavior of citizens protesting against costly energy. A commitment to a long-term increase in the tax, rising at a level that keeps pace with energy-technology innovation but does not violate the iron law of climate policy, will provide the market a forward-looking price signal. If the approach recommended here were to succeed, then decades hence the world will have a high carbon tax, widespread deployment of low-carbon technologies, and a decarbonized global economy.

Fourth, progress should be continuously monitored, and policies should be adjusted based on performance. Key variables will include the number of people remaining without access to electricity and the cost of

energy. If the world makes progress in providing vast amounts of energy at costs less than fossil fuels, one inevitable consequence will be an accelerated decarbonization of the global economy and lower emissions.

The practical need for such an approach can be seen in a decision by the World Bank in April 2010 to underwrite the building of a massive new coal plant in South Africa. The decision was opposed by environmentalists who called on the United States and European nations to block the loan, in order to halt construction. Pravin Gordhan, South Africa's finance minister, explained why the project was so important: "Today, the South African economy is two-thirds larger than it was in 1994, when Nelson Mandela took office as the country's first democratically elected president. With this growth has come strong new demand for electricity. Millions of previously marginalized South Africans are now on the grid. Unfortunately, as in other major emerging economies, supply has not kept pace." He also explained that the need for energy trumped concerns about carbon dioxide emissions: "We are using every tool at our disposal—legislative, regulatory and fiscal—to promote clean and renewable energy and manage demand. If there were any other way to meet our power needs as quickly or as affordably as our present circumstances demand, or on the required scale, we would obviously prefer technologies—wind, solar, hydropower, nuclear—that leave little or no carbon footprint. But we do not have that luxury if we are to meet our obligations both to our own people and to our broader region whose economic prospects are closely tied to our own."[15]

Gordhan's dilemma is a real-world reflection of the analysis presented in this book: "A question that has to be faced is whether stunting growth prospects in our region will in any way serve the goal we all share of eliminating greenhouse gas emissions over the long term. Whatever paths we take toward that goal, whether shifting to renewables and nuclear, or finding ways to keep harmful gases out of the atmosphere once created, the journey will inevitably be costly, requiring massive investments in technology, research and re-engineering the ways in which we live and do business. It will also require a true spirit of consensus and collaboration." When the time came to approve the World Bank loan to South Africa, the US, UK, and the Netherlands all chose to abstain, such that they were able to save face with domestic political constituencies but also not stand in the way of South Africa's development prospects. A political dilemma was thus resolved, but the decarbonization challenge persists.

The approach laid out above to focus decarbonization policy on expanding energy access via innovation in energy technology funded by a low carbon tax is but a rough outline, leaving many specifics to be worked out. The plan it offers, though, provides a much greater likelihood for success than the current policies, focused on targets and timetables for reducing emissions, which has been at the center of international negotiations for the past several decades. Still, this recommended approach could fail, too. Such an outcome is a risk of any climate policy.

The prospect of policy failure has led many observers of climate policy to suggest a need for a "Plan B" focused on geoengineering the earth's climate system. Chapter 5 argues that the idea of a simple technological fix is appealing, but illusory. To qualify as a technological fix a technology must meet three criteria, according to Sarewitz and Nelson: (1) the technology must largely embody the cause-effect relationship connecting problem to solution, (2) the effects of the technological fix must be assessable using relatively unambiguous or uncontroversial criteria, and (3) research and development is most likely to contribute decisively to solving a social problem when it focuses on improving a standardized technical core that already exists.

Technologies of geoengineering fail comprehensively with respect to the three criteria of a technological fix. Efforts to modulate the global earth system in an effort to counteract the consequences of increasing carbon dioxide in the atmosphere are certain to fail in the same manner that efforts to introduce cane toads into Australia as a tool of ecological management also failed. The global climate system is enormously complex and remains poorly understood in many respects. Efforts to intervene are just as likely to lead to undesirable outcomes as to beneficial ones. In any case, intervention in the climate system brings forth a whole host of legal and social challenges that have no simple answers. For instance, under a regime of engineering, who bears responsibility for climate extremes that take place, with uncertainties about the causal role of the geoengineering intervention? It seems clear that those who would seek to assert control of the climate then own the resulting weather outcomes, regardless of what the science may say about attribution.

Geoengineering is best left in the realm of the speculative. Even so, we should expect research related to geoengineering to continue to be conducted, for the simple fact that it is closely related to aspects of basic research on the climate system (such as what happens when a volcano erupts, sending large amounts of aerosols into the upper atmosphere?). In important respects, research on geoengineering shares characteristics with research on nuclear weapons. Some would argue that such research should be restricted, simply to take the possibility of deployment off the table. Others will argue for research to keep options open, or to understand technologies that others may deploy. Whatever course is taken, and it seems likely that some forms of geoengineering research will take place, such research should always be conducted in parallel with discussions of the social and policy implications of the technology, just as has been the case with respect to research on other contested technologies, such as on nuclear weapons.

The capture and storage of carbon—which is sometimes lumped in with geoengineering, although it is more accurately a technology of remediation—ought to be pursued. The air capture of carbon dioxide refers to chemical, biological, and geologic technologies that might contribute to drawing down and stabilizing atmospheric concentrations of carbon dioxide. While such technologies do not offer anything like a silver bullet, they do at least meet the three criteria for a successful technological fix. However climate policy evolves, several decades hence policy makers may wish to adopt a "brute-force approach" to stabilization if drawing down carbon dioxide becomes a much higher priority or to "mop up" the remaining carbon dioxide that was left unaddressed by more conventional mitigation policies. As a result, any portfolio focused on energy policy innovation with a pragmatic philosophy of "technological agnosticism" should include some research focused on developing technologies of air capture. One outcome is certain: if air capture is ignored, then little innovation should be expected with respect to these technologies.

As discussed in Chapter 1, carbon dioxide is far from being the only human influence on the climate system. Other greenhouse gases, such as nitrous oxide and methane, play important roles, as do more obscure trace gases such as sulfur hexafluoride and various chlorofluorocarbons. Soot, known as "black carbon," and other aerosols also influence the climate system by affecting cloud formation, precipitation, and the reflectivity of snow and ice. Patterns of land use, irrigation, fertilization, urbanization, and other human activities also have discernible influences on the climate. So, while many policy makers and advocates have emphasized carbon dioxide as the dominant or most important human influence on climate, it should be clear that carbon policy is not climate policy. The diversity of human influences on the climate system means that even if the world successfully decarbonizes the global economy to levels consistent with stabilization of carbon dioxide concentrations at low levels (such as 450 ppm), the world will still face a human-caused climate change problem.

To better align scientific understandings of the complexities of human influences on climate with policy, it is important to thus distinguish between carbon policy and climate policy. One important way to reflect this alignment would be to refocus the UN Framework Convention on Climate Change as a Framework Convention on Carbon Dioxide (and Other Long-Lived Greenhouse Gases). Such a focus would recognize that carbon is not all that matters with respect to the human influence on climate and emphasize the futility of trying to manage the enormously complex global climate system under a single policy instrument.

The degree to which the focus on carbon has become conflated with issues that best stand on their own merits was reflected in a research paper on whales published in early 2010. The author of that paper argued, "If you think about whales and fish in terms of their carbon, there is a potential for using carbon offset credits as an additional incentive for rebuilding this population."[16] According to the study, a single blue whale contains about 9.4 metric tons of carbon, equivalent to the per capita emissions of about eighteen months by a single American. The blue whale's "carbon value" would be only about $500 based on recent prices for carbon on market exchanges. To think that saving the whales might be tied to their role as a means of carbon storage is to take carbon policy to an utterly absurd end point. Saving whale populations makes good sense independent of their value as a carbon storage device. In similar fashion, placing other aspects of climate policy on the shoulders of carbon policy has led to a policy framework that has collapsed under its own weight.

The consequence of a narrowly focused carbon policy is a need for a more broadly conceived climate policy. As scholars have begun to point out, there are other policy instruments that might be used to address other human influences on climate, beyond carbon dioxide. The Montreal Protocol, which deals with the harmful effects of chlorofluorocarbons on the upper atmosphere, might be extended to address other influences of these chemicals on the climate system. Black carbon is not presently addressed under the climate convention but might be addressed under a separate policy instrument. In similar fashion policies focused on other aspects of the human influence on climate could be considered under existing and newly developed policy instruments. A diversified approach will require letting go of the fantasy that it is possible to deal with climate change comprehensively under a single, global policy instrument, and to resist the urge to allow narrow policies to become incrementally more complex. It also means that solutions to policy problems associated with forests, agriculture, biodiversity, global inequities, and other issues—even saving the whales—that have piggybacked onto the climate issue will once again have to stand on their own merits.

A reworked Climate Convention focused narrowly on carbon dioxide would need to reconsider its ultimate objective, which presently is focused on avoiding "dangerous interference" in the climate system. A more appropriate focus would be achieving decarbonization of the global economy to a level consistent with meeting long-term targets for stabilization of concentrations. A focus on decarbonization—perhaps obliquely as a consequence of the innovation necessary for expanding secure and low-cost energy access for those without—rather than danger would elevate the importance of technological innovation in carbon policy and de-emphasize the role of science, particularly long-term climate predictions. This would help to depoliticize climate science, as it would no longer serve as the fulcrum on which action is to be judged, and enable a healthier relationship of science and policy across the spectrum of issues related to a human influence on climate.

A focus on decarbonization rather than danger would have the beneficial effect of untethering adaptation from mitigation. The Climate Convention could do away with its narrow and scientifically untenable definition of "climate change" as referring only to those changes that result from accumulating greenhouse gases. Adaptation could then be freed from carbon policy and reunited with broader agendas focused on the development of sustainable, resilient communities able to weather extremes, disease, and other shocks irrespective of the precise human role in influencing the climate system. As we've seen, adaptation agendas can well stand on their own, with consideration of but independence from concerns about human influences on the climate system.

Focusing carbon policy on decarbonization and adaptation on development would place achieving goals of human dignity at the center of climate policies, which raises the odds of sustaining political support over the many decades necessary to make progress on these difficult challenges. By disaggregating climate policy into its component parts we can better align short-term costs with short-term benefits, which is critical to putting the policy jujitsu of oblique approaches to work. Besides that, placing human dignity and democratic ideals at the center of climate policies is also the right thing to do.

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