Our planet is at a critical inflection point. The standard of living of the world’s seven billion people has significantly improved and is projected to get better. But, as we reach nine billion people and three billion new middle-class consumers in the next twenty-five years, society will experience an unprecedented increase in the demand for food, water, and energy. We will need to produce 50 to 100 percent more of these necessities from environments that are already strained. Our increased demands have the potential to push fragile, natural systems beyond the brink to collapse.¹

Yet there is reason for cautious optimism. Thanks to advances in science, technology, and communications, we know more about the environmental challenges we face than ever before. And for the most part, we know how to address these challenges, barring unforeseen catastrophes.
from the climate system, infectious diseases, or human violence. The state of our environment in 2040 will largely hinge on one critical question: can we create the governmental institutions and processes needed to take full advantage of what we know needs to be done, and get it done before it is too late?

In this chapter, we answer this question with a tentative yes. By combining smart science with smart new systems of governance, we should be able to close the gap between knowing and doing and put ourselves on a path toward a diverse and sustainable planet in 2040, one that integrates conservation values and human development.

Living in the Anthropocene

Traditionally, threats to the environment have been viewed as singular events—isolated by geography, as with Love Canal, or tied to an event, such as the BP Deepwater Horizon oil spill. These types of threats will always remain. However, nature is increasingly at risk from ongoing human activity and the “by-products” of economic development. Agriculture, fishing, forestry, mining, energy production, manufacturing, and urban development are now the dominant forces shaping virtually every natural system across the earth. Population growth, wealth, trade, and technology will continue to accelerate the rate of change in fundamental natural processes affecting our climate, our food, our freshwater, and our oceans.

Human impacts may be magnified by tipping points, time lags, or feedback loops that are often unanticipated. For example, increases in temperature and sea level rise caused by carbon dioxide emitted this year will continue to be experienced for many decades or even centuries into the future. Loss of sea ice in the Arctic amplifies the warming impacts of the greenhouse gases that first caused the ice to melt, as newly open waters absorb rather than reflect the sun’s energy. And if a warming Arctic releases the billions of tons of methane—a potent greenhouse gas—stored under its permafrost, our climate system could rapidly shift to a radically new equilibrium.

Complexities such as these and changes in technology and society make it hard to predict the future of our environment. For example, few people expected the shale gas revolution—and the associated risks
and opportunities of horizontal drilling and hydraulic fracturing (also known as fracking)—even five years ago.

The geographic scope of environmental challenges adds further complexity. The impacts of some of our activities are global in reach and will require global solutions. Warming and ocean acidification caused by carbon dioxide emissions from power production, transportation, and deforestation will not be prevented unless we work together globally in some way.

On the other hand, environmental impacts such as water scarcity, biodiversity loss, and overfishing occur in similar form in many places around the globe but require primarily local actions to fix. Although national and international institutions may provide knowledge and leadership in addressing these threats, it will be the people farming in the watershed, cutting the forest, or fishing the bay who must find the path to sustain the resources upon which their livelihoods depend.

Finally, our capacity for harmful impact on nature is increasing dramatically. The global population has nearly doubled since 1970. At the same time, rising global incomes and increased consumption have combined to further magnify our impact as global economic output has quadrupled over the same period.

But there is good news. Our scientific capacity to anticipate the environmental impacts of our actions has increased even more dramatically. As the following case studies on ozone protection and global fisheries illustrate, developments in science and environmental governance allow for a future where we can better anticipate and avoid the threats to natural services essential for human well-being.

After describing these two cases, we examine three of the greatest threats from human activity: water scarcity, biodiversity loss, and climate change. Surely good science and new technology will play major roles in understanding and addressing each of these threats. But an equally important challenge in each case is governance. Can we apply the lessons learned from addressing the ozone crisis and the collapse of some fisheries to develop and implement new institutions that will guide our behavior so that these threats can be avoided?

In this chapter, the concept of environmental governance reaches well beyond the regulations of governmental agencies and regimes based on international treaties. It includes mechanisms and institutions that
make use of market incentives and consumer information. It includes cooperatives and trade groups where industry participants help design regulations and monitor compliance. And it includes long-standing community institutions, especially in developing countries, that use social norms to cooperatively manage rangelands, irrigation and drainage systems, and small fisheries.

These new forms of governance may take shape as water funds that pay fees collected by cities to farmers to keep drinking water reservoirs clean; forest and bioenergy certification systems that ensure the use of sustainable practices in fiber and feedstock production by providing information to consumers; fisheries cooperatives that manage catch share systems; industrial trade associations that develop best practices and codes of conduct; and networks of nongovernmental organizations that play major roles in shaping national policy and international treaties.

Two hallmarks of success among the new environmental governance institutions are adaptive management—learning by doing—and network maintenance. An adaptive institution may change its form and function over time to reflect the changing nature of environmental threats and the most successful strategies to protect human and natural systems. Success also depends on “bridging” organizations that foster communication across stakeholder communities and across government agencies at various levels.²

We Can Get It Right: Two Case Studies

*Lessons from the Ozone Crisis*

In 1974, Mario Molina and Sherwood Rowland published a paper theorizing that chlorine and bromine in some widely used chemicals could damage the ozone shield—the layer of oxygen molecules in the upper atmosphere that prevents most of the sun’s harmful ultraviolet radiation (UV-B) from reaching the earth’s surface. The main culprit: chlorofluorocarbons (CFCs), nontoxic, highly stable, and relatively inexpensive chemicals used in refrigeration, aerosol sprays, and a number of industrial applications.³

Molina and Rowland’s theory of ozone destruction was controversial.
There were no measurements showing that ozone in the stratosphere was declining. And there was no evidence that UV-B radiation reaching the earth’s surface was increasing. Nevertheless, the nature of the potential risk was extraordinary. The U.S. Environmental Protection Agency (EPA) projected that ozone depletion could lead to 150 million cancer cases with three million deaths and twenty-five million cataract cases over the next century, if Molina and Rowland proved right.

In 1978, the EPA and the U.S. Food and Drug Administration (FDA) banned the use of CFCs as propellants in aerosol sprays. There was broad public support for this step, and many major personal care and household products manufacturers quickly moved to alternative formulations. But only Sweden, Canada, and Norway followed the U.S. lead; some governments, including that of the United Kingdom, expressed doubts about the science.

The EPA continued its study of CFCs and persuaded President Ronald Reagan to press for international action, resulting in the 1985 Vienna Convention for the Protection of the Ozone Layer. The treaty called for monitoring, additional research, and the development of a protocol at some point in the future that might regulate the production and use of CFCs.

That same year, the ozone hole was discovered. The hole—a decrease of 40 to 60 percent in the amount of stratospheric ozone extending over a very large region (10.6 million square miles at its largest in 2006) of the Southern hemisphere—quickly captured public attention. The hole and the subsequent science proving that industrial chemicals were the culprits in its formation quickly built support for the regulation and phaseout of CFCs. The companies that made and used the chemicals promised to develop substitutes on an expedited schedule.

The promised protocol came quickly and was negotiated in Montreal in 1987. It called for a 50 percent reduction in all CFC production by 1998. It has been modified many times since to reflect new science, to accelerate production bans, and to add other chemicals. Today, 197 nations—virtually the entire world—have ratified the protocol. Global production of ozone-depleting substances has been reduced by 98 percent.

Several governance innovations contributed to the protocol’s extraordinary success:
Developing countries with low levels of ozone use were granted a ten-year grace period during which use could actually increase before the phaseout period would begin.

- A multilateral fund was created to assist developing countries in converting their industries to substitutes.
- A trade regime was set up to prevent importation of CFCs from countries that declined to join the protocol.

In 1989, the U.S. Congress enacted an excise tax on ozone-depleting substances. As the tax rate increased over time, it eventually tripled the cost of CFCs and made substitutes economically competitive. Congress put a price on ozone depletion. The European Union also imposed its own excise tax.

The ozone crisis is not only a story of good science but of rapid technological innovation and new mechanisms of environmental governance that made the solution to a potentially catastrophic environmental disaster relatively painless. Though it will take many decades for the ozone shield to heal—CFCs may stay in the atmosphere for up to one hundred years—the risk has been averted. By the mid-twenty-first century, ozone depletion will be a threat of the past.

**Fixing Our Fisheries**

Marine fisheries are an important part of today’s global food system. They provide 20 percent of the animal protein in the diets of more than three billion people. They are also a significant part of the global economy. In 2010, fisheries and aquaculture produced 148 million metric tons of fish and shellfish worth $217 billion. Capture fisheries provided direct fishing jobs for an estimated thirty-eight million people in 2010, with another seventeen million employed in fish farming (aquaculture). The industry also includes processors, distribution systems, gear manufacturers, and vessel construction and maintenance workers. An estimated six hundred million people—10 percent of the world’s population—depend on the industry for some part of their livelihoods.

Overfishing has been a chronic problem. It occurs when the catch of a particular marine species in a specific geographic area is so large that the population cannot recover. The problem can be so severe that the fish stock collapses to near extinction and the ecosystem changes.
in ways that prevent recovery even if the fishing pressure is removed. Overfishing prevents fishers from realizing the full economic reward for their efforts. One estimate puts the global revenue loss at $50 billion per year.\(^8\)

A key factor that has contributed to overfishing since the 1960s is improving technology. The size and power of vessels in the global fishing fleet has increased dramatically. More powerful vessels can pull more gear, and sonar has made finding fish easier. As fish populations decline, fishers have responded by further increasing capacity, often with subsidies from governments that are estimated at nearly $30 billion per year.\(^9\)

Perhaps the most dramatic example of overfishing is the collapse of the cod fishery off the coast of Newfoundland. Overfishing in this three-hundred-year-old fishery began in the 1960s when foreign factory fleets entered the coastal waters of the United States and Canada and the fishery was severely damaged. When the foreign vessels were banned, the Canadian government provided significant subsidies to launch a fleet of Canadian-owned vessels fishing for cod. Scientific projections for the amount of fish that could be caught sustainably were overly optimistic, and the fishery soon began to decline. In 1992, the Newfoundland cod fishery collapsed. The region took a huge economic hit requiring $1 billion in government assistance to those who lost their jobs. Despite removal of the fishing pressure, cod have not recovered.\(^10\)

Today, the Food and Agriculture Organization (FAO) estimates that 57 percent of all assessed fisheries are fully exploited—meaning that no growth in harvesting is possible. Approximately 30 percent of assessed stocks globally are overfished—up from 10 percent in 1974. And the outlook may be worse than the assessments imply. Only 450 stocks are regularly assessed out of an estimated ten thousand fisheries globally. A recent paper suggests that unassessed fisheries (which account for 80 percent of the global catch) are likely to be poorly managed and more likely to be overfished.\(^11\)

Yet there is reason to hope that the trends have begun to reverse. Recent changes in fishing regulations in several countries are showing signs of success. Some of the most promising measures for avoiding economic and environmental disasters like the collapse of New England’s cod fishery include the following:
• *Comanagement* brings fishers into the decision making and implementation of fishery regulations. Not only does this give the fishers a heightened sense of ownership, it also makes good use of their local knowledge.

• *Marine protected areas* take a wide variety of forms. Some areas are closed for a time to some types of fishing to let stocks recover. Marine parks and reserves are permanently set aside to protect important features such as coral reefs or spawning grounds.

• *Ecosystem-based management* sets total allowable catch by considering potential impacts of fishing on the entire marine system. In the past, government regulations have ignored the impacts of fishing on other aspects of the ecosystem such as food web interactions and the destruction of seafloor habitats.

• *Catch shares* give each licensed fisher a specific portion of the total allowable catch for a fishery. The fisher is guaranteed a right to catch that amount and can match the capacity of his or her gear to a sustainable level of fishing. If the right is permanent and transferable, the fisher has an interest in seeing the fishery managed sustainably because success will increase the market value of his or her share.

Just as we solved the global threat of ozone depletion, smart science combined with improved governance offers the prospect of dramatically better management of marine fisheries in the coming decades.

**Global Challenges and Opportunities**

**Water Scarcity**

Before looking to the future, it is important to note that today more than a billion of the world’s poorest people lack access to safe drinking water and perhaps twice that number do not have access to sanitation services (safe toilets and sewage disposal). Illnesses caused by microbes in drinking water kill two million children each year and are the principal cause of infant mortality.12

The water we drink is only a fraction of the water we use. Agriculture accounts for approximately 71 percent of water withdrawals. En-
Energy production and other industries account for another 16 percent, and municipal water supply systems withdraw the remaining 13 percent. While most of the water used by industry and municipalities is returned to surface water courses after use, much of the water used in agriculture evaporates from irrigation systems or transpires to the atmosphere from crops before people can use it again.¹³

The Challenge
Driven by a growing population and the changing diets of billions of people moving from rural poverty to urban prosperity in developing countries, global freshwater withdrawals are expected to increase by 40 percent over the next three decades. Meeting these new demands will be further complicated by changing precipitation patterns caused by climate change. The combined effects of population growth, urbanization, and climate change may soon subject a large portion of the global population to water shortages.¹⁴

Water scarcity takes three forms:

1. Physical scarcity is an imbalance between the size of the human population in a region and its annual freshwater resources. There is simply not enough water to meet human needs.

2. Economic scarcity occurs in regions where investments in water infrastructure such as reservoirs or groundwater pumping could meet human needs but the investments have not been made because they are not affordable. The world’s poor, whatever their rainfall endowment, will be more likely to experience water scarcity than the rest of us.

3. Environmental scarcity can occur even in areas with adequate water flows to meet human needs. However, that supply comes at the expense of nature, including dams that block fish passage, withdrawals that cause rivers to dry up, and groundwater pumping so extensive that streams and wetlands no longer recharge in summer months. Although few regions in developed countries would be categorized as physically or economically water stressed now or even in the next few decades, many of these regions (e.g., the western United States and Mediterranean Europe) are already experiencing environmental scarcity.¹⁵

Today, two billion people live in regions with dry, fragile climates that are threatened by periods of water scarcity. One often cited measure of
water scarcity developed by Falkenmark and others\textsuperscript{16} finds that meeting all human needs including water for agriculture requires seventeen hundred cubic meters of water per person per day. By 2040, two-thirds of the global population will be in areas suffering from water stress (between five hundred and seventeen hundred cubic meters of water flow per person per day) and 1.8 billion people will live in areas of absolute water scarcity (less than five hundred cubic meters of water flow per person per day). Regions most likely to suffer water scarcity in 2040 are northern Africa and the Middle East, South Africa, India, Mexico, northern China, Chile, Australia, and small island nations, especially in the Caribbean.\textsuperscript{17}

Many regions follow a similar pattern to meet the water demands of a growing population. First, either a river or a groundwater aquifer is tapped to meet needs. As demand begins to approach the limit from those supplies, the water agency will create storage reservoirs by damming local rivers and streams. If demand continues to outstrip supply, the supplier may look to transfer water from distant reservoirs to meet local needs.

These infrastructure investments are often subsidized by governments to keep water and food prices low. The subsidies mask the true cost of water, spurring even greater demand. Only when demand finally exceeds the capacity of storage and interbasin transfers will users begin to adopt water conservation practices.

Many of the steps along this pathway have negative consequences for nature. Areas rich in aquatic wildlife habitat such as wetlands and river deltas may shrink in size as water is diverted to human use. Some rivers—even great rivers such as the Colorado—are taxed so completely that water no longer reaches their deltas in most years. As underground aquifers are depleted and water tables drop, the water that would normally discharge to springs and seeps is lost. Dams may alter a river's cyclical rise and fall necessary for the breeding and reproductive behaviors of fish, wildlife, and plants. Dams also block the movement of fish, closing off spawning grounds and segmenting species into small populations that may not survive other threats. As flows in streams and rivers are reduced to build reservoirs, pollution concentrations and water temperatures increase, killing aquatic life adapted to different conditions.\textsuperscript{18}
It’s no wonder that aquatic species face a greater risk of endangerment and extinction than comparable organisms living on the land.

The Opportunity
A majority of the regions that will experience water shortages in the next few decades have one thing in common. If there is more water available to prevent scarcity, it will most likely be found in agriculture. Although the most effective water conservation strategies will vary widely across regions, reducing agricultural water demand will be key to meeting growing water needs. Strategies include more efficient irrigation systems, changes in tilling practices so that less soil moisture is lost through evaporation, shifts to crops requiring less water, and the development of new hybrid plants that can produce good yields in drier conditions.

One of the most promising ways to reduce agricultural water use involves new partnerships that channel payments from city water agencies and other large industrial water users to agricultural producers who put water back into the river. Freshwater is the most valued service that nature provides. Users are willing to pay for it, if institutions can be created that allow agriculture producers to deliver reliable water supply to cities and industries.

Market institutions like this now exist, especially in South America, to prevent pollution of urban water supplies. More than a dozen cities, including New York, Quito, Bogotá, and São Paulo, have created water funds that pay farmers upstream to adopt agricultural and ranching practices that reduce sediment pollution in the river. Cleaner water allows the city to avoid expensive investments in treatment that would otherwise be necessary to remove pollutants.

We should fully expect that similar voluntary and market-based arrangements between farmers and cities will be developed to meet water supply needs as cities struggle with growing scarcity. Properly structured voluntary institutions could avoid a great deal of human conflict as scarcity moves in. Complex questions related to water ownership and assuring that the needs of the poorest are met will require further innovations. New forms of environmental governance—in addition to new science and technology—will be required to enable many cities to meet their water needs.
Biodiversity Loss and Alteration

Biodiversity is the variety of living things on earth. Most people think of biodiversity as the wide range of plant and animal species. But biodiversity also includes genetic variations within a species—think about all the different kinds of dogs—as well as the variety of natural communities that form ecosystems such as tropical rain forests, coral reefs, prairie grasslands, and mountain meadows. Diversity makes these biological communities and their members more resilient, better able to survive disturbances such as changes in climate or the introduction of invasive species and new diseases.

Human well-being is highly dependent on biodiversity, especially in rural areas of the least developed countries. As mentioned earlier, the value of global fisheries exceeds $200 billion per year. The insects and birds that pollinate our crops provide nearly $200 billion per year in value. Forests provide timber for construction and firewood, capture and filter drinking water, and provide food for rural populations. Wetlands and coastal mangrove forests protect human communities from storm surges and river flooding. People living in the poorest nations receive as much as 30 percent of their livelihood from local biodiversity. And everyone benefits from the innate wonder of nature. Imagine what life would be like if there were only a few species that existed everywhere and all places looked the same.19

The Challenge

Human activities are having a profound effect on biodiversity; its loss is one of the major environmental challenges of this century. There are many drivers of this loss, including the conversion of natural areas such as forests and grasslands to urban and agricultural use; the unsustainable use of resources such as fisheries and freshwater as discussed previously; the intentional or accidental transfer of species from one region to another; overuse of nitrogen fertilizers that create imbalance in freshwater ecosystems; and the growing threat of carbon dioxide pollution causing changes in climate, sea level rise, and ocean acidification.

Of the roughly 1.9 million known species, the International Union for the Conservation of Nature has listed sixteen thousand species as declining, threatened, or endangered. Among those, 30 percent of am-
phibians, 23 percent of mammals, and 12 percent of birds are threatened with extinction within the next century. Those depending on freshwater and tropical rain forest habitats generally face the greatest risks.\textsuperscript{20}

Some scientists believe that human activities are causing extinction rates to increase to more than one hundred times the natural background rate. Some predict that over the next few centuries that number may increase to one thousand or even ten thousand times the natural rate. These projections are based on models that relate drivers such as habitat conversion and climate change to estimates of species abundance. If these trends are correct, a huge percentage of species may be lost in a few millennia. Over the past five centuries a few hundred species are known to have been lost. Fortunately, many species on the brink of extinction have actually been recovered through human intervention.\textsuperscript{21}

Extinction is usually a slow event. Large areas of forest cover may be lost to agriculture, but some remnant of the species population that depended on the forest habitat may hang on for many generations in the altered habitat, may evolve and adapt, or may relocate to new areas. We may be setting in motion an extinction crisis that will occur over the next few millennia, but it is not occurring in the next twenty-five years. We still have an opportunity to change the narrative on species extinctions.

Two major trends will affect that narrative. Although habitat conversion—most importantly from forests to croplands—has been the major source of biodiversity loss over the last century, the pattern is likely to change in the coming decades. Conversion of natural systems to crops and pasture will continue to be the most important driver in the least developed African and Asian countries, but it will no longer play the dominant role in Europe and North America nor in emerging economies including China, Brazil, Russia, South Africa, India, and Indonesia. In some of the most developed countries, agricultural land will continue to be abandoned, and ecosystem recovery and regeneration will occur on a significant scale. In addition, recent trends indicate that deforestation rates may be slowing in the Amazon and that some depleted fisheries are recovering.

The other major development will be the increasing role of climate change in biodiversity loss. It may account for 40 percent of the decline in the population of many species by 2040.\textsuperscript{22} The impacts will reach
across both developed and developing countries. Unchecked, climate change will emerge as the major driver of global biodiversity loss in this century.

The Opportunity

Again, one key to protecting biodiversity is in the quality of human governance institutions, whether global (i.e., the Convention on Biodiversity), local (e.g., parks, national forests, wildlife refuges), or in the private sector (individual business commitments to avoid or offset biodiversity losses). Although there are examples of tremendous success at each of these levels, our governance arrangements to protect biodiversity are falling far short of the need, and loss is likely to continue largely unabated over the next quarter century. Unlike water, where optimism for governance solutions is warranted, biodiversity is not currently treated as an urgent human need.

In response to global biodiversity loss, many governments have created protected areas, parks and wildlife refuges set aside and managed for the benefit of biodiversity. The number of protected areas around the globe has exploded over the past forty years, increasing from approximately ten thousand in 1970 to more than one hundred thousand today. Twelve percent of the earth’s land area now has a protected designation, and 188 nations have committed to extend protection to 17 percent of all terrestrial habitats by 2020. Some countries have also created marine protected areas (although they cover only 7.5 percent of global coastal zones). Yet these formal commitments, while impressive, are not a panacea. Many areas are not effectively managed due to a lack of resources. In fact, 14 percent of designated protected areas lack any management measures at all.  

Many nations have also adopted regulatory measures to protect biodiversity and human welfare. One important tool to protect habitat is land-use planning that requires formal environmental assessments before major new projects or policies are implemented. Nevertheless, many of the values associated with biodiversity are not properly accounted for in the market and policy decisions that drive biodiversity losses. For instance, some of the most serious threats to biodiversity are actually driven by governmental subsidies for economic sectors including agriculture, fisheries, and bioenergy development. In this case governance
is the problem, not the solution. Repeal of some particularly harmful subsidies would be an important reform.

Another example is climate change policy. Many observers believe that the most effective policy to reduce greenhouse gas pollution would be to put a price on carbon dioxide emissions from burning fossil fuels. But the policy would be much more effective—both for reducing global warming and for enhancing biodiversity—if it also paid (or provided a tax credit) for the sequestration of carbon in soil, forest, and grassland systems. Although much of the discussion about sequestering carbon in natural systems has been about preventing deforestation and restoring forestlands that have been lost to agriculture and urban development, it is important to understand that much more of the carbon now causing global warming was originally stored in soils rather than vegetation and was lost to the atmosphere by conversion of forests and prairies to croplands. Returning these hundreds of billions of tons of carbon to soils through practices that are also good for agricultural productivity is a high priority.

Consumer information is another recent innovation in governance that is increasing attention to the value of biodiversity in the marketplace. Certification systems for forest products, fisheries, and bioenergy now encourage consumers to insist on sustainable practices including biodiversity protection in crop and harvesting activities. This new tool for governance that operates outside of formal governmental channels may be especially important to protect deep-sea fisheries that are located outside territorial waters and tropical forests in the least developed nations.

Finally, many businesses are beginning to consider the role of nature in their supply chains and the impact of their plant and capital investments on natural systems. Biodiversity offsets for development impacts have been included in the laws of some countries including Brazil, Canada, China, France, Mexico, and South Africa. In addition, many leading global corporations, especially in mining and oil and gas production, are implementing biodiversity offsets to ensure that their activities have no adverse impact on land and water habitats. Public policies and grassroots activism should encourage these new practices to expand rapidly across many industrial sectors and should insist that biodiversity values get increased attention in corporate decision making over the next quarter century.
Climate Change

Human activities—principally the combustion of fossil fuels and the conversion of forests to other land uses—are increasing the concentration of carbon dioxide (CO2) and other greenhouse gases in the atmosphere. CO2 concentrations are now more than 40 percent greater than they were in 1750. This trend has already led to warmer temperatures, more severe storm surges, and changes in rainfall patterns, weakening the natural systems on which we all depend. Yet despite an array of potential strategies, the world has yet to tackle CO2 emissions in a coordinated fashion.

The Challenge

There is some uncertainty about the impact of greenhouse gas concentrations on temperature increases. The best current estimate is that each doubling of CO2 concentrations will increase temperatures by approximately three degrees Celsius (or 5.2 degrees Fahrenheit). CO2 concentrations in the atmosphere at the beginning of the Industrial Revolution were approximately 275 parts per million (ppm). If current emissions trends continue, a doubling to 550 ppm would occur by 2050. Some observers fear that CO2 concentrations may double again by the early 2100s, producing a temperature increase of more than ten degrees Fahrenheit—but not immediately and not everywhere.

Those are average temperature increases, and they will only develop over the long run. There will be great variability in temperature changes around the world; some areas may even get cooler before heating up. Regions in high latitudes such as the Arctic will see much greater temperature increases than tropical regions. Temperatures in winter seasons and at night will increase more than temperatures in the summer and during the day. And temperatures over land surfaces will increase more than temperatures at the surface of the ocean.

Global warming will also alter patterns of precipitation, as a warmer atmosphere can also hold more water vapor. Again, high-latitude areas may see increased rainfall while some areas in the subtropics and temperate zones may experience drier climates.

Although we can already measure some of these changes—global average temperatures have increased by 0.8 degrees Celsius over the
twentieth century\textsuperscript{26} and severe precipitation events are 5 percent more frequent in the United States\textsuperscript{27}—the changes over the next twenty-five years are not likely to be dramatic. So why the urgent need for action?

For a variety of reasons, global warming is a very slow event. First, 90 percent of the sun’s energy captured by the earth is stored in the planet’s massive oceans, which take a long time to heat up.\textsuperscript{28} Once heated, they will release that excess energy back to the atmosphere and land for millennia.

Second, positive feedback loops such as sea ice loss described previously may add to the warming caused directly by CO\textsubscript{2} pollution—even if carbon pollution is greatly reduced.

Third, while a large portion of the CO\textsubscript{2} emitted today will be absorbed by the oceans over the next century, as much as 20 percent of today’s emissions will be in the atmosphere for centuries.\textsuperscript{29} This long atmospheric residence will continue to push temperatures higher and higher each decade for many centuries into the future.

And finally, the investments that we make in power plants and industrial facilities have long lives of their own. Some coal-fired power plants in operation in the United States today are more than sixty years old. Hundreds of additional coal-fired power plants are expected to be constructed in the rapidly developing countries, especially China and India, over the next twenty-five years. They are likely to continue emitting billions of tons of carbon dioxide each year for many decades.

Once the climate change train is fully in motion, it may rumble down the tracks for centuries no matter what we do; thus the urgency to act now. Pundits have often used the “boiling frog” metaphor to shine a light on human behaviors that fail to act on gradually developing catastrophes until it is too late. Presumably, if you put a frog in a pot of cold water, put the pot on a burner, and heat it up gradually, the frog will fail to jump and will eventually be boiled to death. In the case of our impact on the climate system, the pot has long been on the burner. If we do not dramatically change our ways in the next twenty-five years, it will no longer be possible to remove the pot or turn the burner off—even if the water is yet to boil and the frog is still alive. Our planet is the frog.

In another respect, global warming may also be too sudden. If current trends in emissions continue for many more decades, the rate of temperature increase may become so rapid by the end of the twenty-first
century or early in the twenty-second that a large portion of the earth’s biodiversity would not be able to adapt fast enough to survive. The rate of temperature change is already greater than at any time in the last five hundred thousand years; a significant acceleration may leave species with slow reproductive cycles or with small populations trapped in isolated patches with nowhere to go.

Beyond the loss of biodiversity, continued carbon dioxide pollution will have far-reaching effects on human well-being. If current trends continue, by 2040 we can expect to see more frequent severe weather events with loss of life and property, sea level rise, growing water scarcity, lower agricultural productivity, and the spread of diseases into new regions.

The Opportunity
We know what we need to do. Global greenhouse gas emissions need to peak before 2020 and be reduced by at least 50 percent below 1990 levels by 2050.

And we know how to do it. In the developed world more than 60 percent of greenhouse gas emissions come from two sources—power plants and vehicles. As industrial production and household wealth increase in the rapidly developing economies, emissions are likely to assume the same pattern there. We need to reduce CO₂ emissions from coal combustion at power plants and petroleum combustion in cars, trucks, planes, and ships.

Over the next twenty-five years, emissions reductions will be far more likely and more cost-effective in the power sector than in transportation. Although there will be some benefit from greater fuel economy associated with extensive use of hybrid technologies in cars and trucks, this is likely to be overwhelmed by the rapid growth in ownership and use of personal vehicles in developing countries. It is unlikely that zero-carbon-emissions technologies such as fully electric or fuel-celled vehicles will make any substantial penetration in the transportation sector even in highly developed countries by 2040.

But significant changes are possible and would be cost effective in the power sector. Some combination of these four options is most likely: (1) increases in the efficiency of lighting, heating, and insulation of appliances, motors, and compressors in residential and commercial buildings;
(2) substantial power generation from wind and solar energy sources, accompanied by new technologies to store the intermittent power from these sources; (3) the conversion of coal-fired power plants to natural gas, drawing on the new abundance of shale gas resources; and (4) the use of carbon capture and storage systems that reduce emissions by up to 90 percent at fossil-fueled plants.

Some observers assert that it would be possible to generate a significant portion of our electricity from renewable sources such as wind, solar, geothermal, and biomass. But in many countries seeking rapid development, use of their domestic fossil resources will continue to be the preferred source of power. A large portion of the world’s coal reserves are concentrated in a few countries, including Russia, China, India, Australia, the United States, and Kazakhstan. Other countries have other high-carbon fossil resources such as heavy oil and tar sands that they would also like to use or export. It is unlikely that we will persuade these countries to turn away from their dirty fuels. Therefore, research and demonstration on carbon capture and storage systems for the continued use of fossil fuels must be an urgent priority.

The most efficient way to drive changes in the power sector would be to impose a price on carbon. This could be accomplished either through a carbon tax or with cap and trade programs such as those implemented by several states in the U.S. Northeast and in California (that includes credit for sequestering carbon in natural systems). Although partisanship has undermined climate policy at the national level in the United States, more than forty countries and many state and provincial governments have adopted and are successfully implementing carbon pricing policies.

Because the need for coordinated global mitigation policy, at least among the developed and rapidly emerging economies, is so urgent and because carbon pricing policies make so much sense from so many different perspectives, we should be confident that they will be in almost universal use by 2040. But it is harder to envision the diplomatic and governmental mechanisms needed to bring trade harmony and full participation in an international carbon pricing regime. It is unlikely to look like the Kyoto Protocol, with a cap on every nation’s emissions. And unlike the Montreal Protocol, it may come too late to prevent significant damage. As noted earlier, a pricing system that fully incorporates the value of carbon sequestered in natural systems would help compensate
for weaknesses in international policies—and would be of tremendous benefit to biodiversity.

Global warming is the most important challenge of our time. Science has already made a compelling case for the goals we must adopt. New technologies to get us there affordably are emerging every year. What we lack are the leaders, organizations, and governing instruments that will let us act effectively, confidently, and together across the globe. Whether and how we solve this problem in governance will define our environment in 2040 and for many centuries after.

The Reason for Hope

Without much attention, there has been a tremendous change in the structure of global environmental governance over the past forty years. It has moved out of regulatory bureaus and international tribunals into a legion of organizations and informal arrangements that have become the essential glue that holds the agenda for nature protection together and moves it forward across the globe. The new forms of governance involve actors of many types, including landowner associations, resources user groups, indigenous communities, nongovernmental advocacy organizations, academics and scientists, and philanthropists and foundations.

These new institutions are important and effective not so much because of their legal authority or their size but because of their shared knowledge, the trust built from long-standing personal interactions, their reach across scales to achieve local, national, and global coordination, and their commitment to transparency to maintain legitimacy.

This new environmental governance is what we do at The Nature Conservancy. We are a “bridging” organization. Our job is to build and maintain the connections between players—governments, scientists, investors, users, producers, and consumers—who have more traditional roles. We facilitate outcomes across scales, using new tools and adapting to new information to achieve change that would otherwise not be possible.

There are many examples of this work in our portfolio: creating water funds in South America; developing certification schemes for forest products and bioenergy; supporting fisheries co-management; creating markets for investment in forest carbon; designing biodiversity offsets
for energy and mining development; and mapping marine protected areas in coastal zones around the world.

It is necessary to have good science on environmental trends and the technologies offering sustainable alternatives. But that is not enough. What we more often need today is better understanding of the governance and institution-building processes at all scales so that we can turn science and technology into nature protection.

None of us can predict the new environmental challenges we will experience between now and 2040. But we can be sure that we are getting better at building and managing the governance institutions necessary to sustain nature on a planet now defined by our development.

Notes


15. The terms “physical scarcity” and “economic scarcity” were first used in a comprehensive 2007 study: David Molden, ed., Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture (International Water Management Institute, 2007). The concept of “environmental scarcity” is added here.


22. OECD, “Environmental Outlook to 2050.”

23. Ibid.

25. IPCC 2013.
29. IPCC 2013.