UNDERSTANDING CLIMATE CHANGE

Science, Policy, and Practice

SARAH L. BURCH AND SARA E. HARRIS

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Preface

After decades of negotiation, education, and contentious debate, climate change has pervaded the public consciousness. It has become a political weapon, a topic of dinner conversation, and a crucial entry point for discussing the multitude of ways in which many industrialized societies have become fundamentally unsustainable. As climate change gains popular visibility, however, it is clear that the most basic causes and consequences of the problem are frequently misunderstood, leaving crucial gaps in the search for solutions. Furthermore, because of the complex and constantly evolving nature of climate change, efforts to analyze it commonly shave off a thin slice and avoid interconnections: economic dimensions without consideration of the political implications, introductions to the scientific underpinnings without insight into the social dynamics that characterize responses. The result is that those interested in engaging in the discussion might lack the tools they need to characterize the problem adequately. Furthermore, critical opportunities to deliver on multiple priorities simultaneously may be missed if the true complexity of social and biophysical systems remains unexplored.

The goals of this book are threefold. First, we offer the fundamentals of climate change – both the biophysical and human dimensions – to equip both the novice and the experienced practitioner or scholar with a clear and concise depiction of this pressing challenge. Second, we interweave human responses

and solutions with the scientific facets of climate change, to position mitigation and adaptation strategies within the context of planetary energy flows. Finally, we use the lens of transformative change, through which the abundance of climate change action plans, proposals, and campaigns can be examined, to reveal the potential of these actions to dramatically alter emissions pathways and vulnerability. The lens of transformative change also suggests that the challenge of climate change, in fact, presents a powerful opportunity for *improving* the social, economic, and environmental sustainability of our communities – a much more inspiring task than simply striving to avoid disastrous impacts.

This book can be used as an introduction for interested individuals, a tool for undergraduate and graduate students seeking background in either the science or socio-political dimensions of climate change, and a reference for experienced scholars and practitioners who want to be clear on the basics. We have designed the sections geared towards policy and social issues to withstand the rapid pace of change in this arena, while the chapters that explore the science of climate change provide timeless fundamentals.

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CHAPTER ONE

Climate Change in the Public Sphere

MAIN POINTS:

- All around us we see evidence of the human impact on climate, with serious implications for environmental, economic, and social sustainability.
- Communicating the need to address climate change requires an understanding of the key stakeholder groups at play: the public, government, industry, scientists, and civil society.
- Tackling the climate change challenge requires the creation of a compelling vision of a desirable future, not just recapturing a mythical past or "tinkering around the edges" of our current development path.
- International climate change policy has been dominated by the United Nations Framework Convention on Climate Change and the work of the Intergovernmental Panel on Climate Change.
- Humans can respond to climate change either through mitigation (dealing with the causes) or adaptation (dealing with the effects).
- More data or science alone will not change individual behavior, but they are crucial for evidence-based decision-making.

From around the globe come the reports: rising sea levels and eroding coral islands in the Maldives, increasing hurricane activity affecting the US eastern seaboard and Gulf coast, drought in central Africa, declining amphibian populations in the Amazon. Accompanying these alarming reports, however, are stories of innovation, including promising developments in the creation of jet fuel from algae, zero-waste and carbon-neutral experimental communities in the United Arab Emirates, and grassroots community initiatives such as the Transition Town movement. The common link that connects these phenomena is the growing evidence that humans are having a dramatic impact on Earth's climate. Making sense of it all is a challenging task. How serious are the near-term effects of climate change? What will the world look like in 2100? Who should pay to solve the problem? Why do interminable international negotiations rarely seem to pay off with results?

The dominant rhetoric of the climate change conversation has emerged out of the modern environmental movement, which has been growing and reinventing itself since the early 1960s.[1] As evidence has mounted of accelerating deforestation, the widespread effects of toxic pesticides and industrial emissions on human health and ecosystems, a growing list of endangered species, and exploding human populations, the conversation at the core of the environmental movement largely (and understandably) has become focused on the damaging effect of human activity.[2]

The theme of limits – of modern development as a scourge or virus that has run rampant over the planet – has pervaded global consciousness and is fundamentally shaping our response to environmental challenges.[3] Furthermore, we have become fixated on defining, calculating, and predicting the exact extent to which humans have exceeded these limits. There is no denying, as we shall see in this book, that the challenges are indeed monumental, but these inherently negative messages are having two major consequences.[4] First, a common response to a message of unavoidable and impending apocalypse is often one of apathy, disempowerment, and shame. How did we let ourselves get to this point? Is human civilization simply an experiment

in mass greed, recklessness, and violence? If so, and if our ultimate demise is virtually inevitable, what good is merely "tinkering around the edges" to try to fix it?

The second consequence, intimately related to the first, is that this apocalyptic framing suggests that human behavior needs to be constrained and managed so as to do slightly less harm. But what if we want more than just to recapture the "healthier" planet of two hundred years ago, but instead to *improve* well-being, health, equity, community, and a host of other factors? The framing that currently dominates the climate change discourse, however, reduces the likelihood of a focus on a creative, positive, nuanced vision of the future – one that is rooted in a deep scientific understanding of Earth systems but that also captures (or at least begins a conversation about) core human values such as equity, compassion, innovation, and connection.[5]

In this book, we offer a deeper understanding of the state of climate change science, and develop a profoundly human picture of the opportunity that now exists to create a healthier, more equitable, more resilient future. This is an entirely different task than recapturing some mythical past when humans lived in harmony with the Earth (and each other), or simply minimizing our destructive impact on the planet. In this first chapter, we introduce a few of the core concepts needed to delve into the science and policy of climate change. We explore the scientific community's broad findings of humanity's influence on the climate system, the policy tools available to respond to this challenge, and the core of the climate change debate in the scientific, political, and public communities.

1.1. Communicating about climate change

Since the late twentieth century, the issue of climate change has been taken up and debated by scientists, politicians, pundits, activists, and concerned citizens. The search for solid ground amid uncertainty and efforts to design effective and equitable policy responses to climate change have come to dominate the

environmental agenda, pushing issues of water scarcity, deforestation, pollution, and species preservation deeper into the background of public consciousness.

All around us is evidence of climate change. It emerged first as a scientific issue, and scientists remain its most vocal messengers. Indeed, the debate is permeated with scientific terminology, which, some argue, has caused a disconnect between our understanding of the problem and the reality of the challenge we face: the causes and effects of, and solutions to, climate change are as much about values as about science. Scientists, furthermore, often lack the communication skills to engage meaningfully with public and policy-maker audiences, which inhibits the effectiveness of evidence-based decision-making. Casting climate change as a values-based issue, however, brings its own challenges. A moral framing of climate change brings to the fore cultural differences (such as varying perceptions of human rights), deeply entrenched political pathways, and religious beliefs. At the heart of the climate change debate are fundamental questions:

- Is the current mode of development in the West (and elsewhere) sustainable?
- What right does any one group have to affect the well-being of current and future generations?
- Who should pay to solve a problem – those who created it in the first place or those who are most likely to contribute to it in the future?
- How certain must we be about the science before we take precautionary action?

Note that only the last (and elements of the first) of these questions is scientific; the others are ethical, political, economic, and even spiritual. It is for this reason that the climate change debate is so fierce. The debate, indeed, defies simplification. One cannot assume that those who argue for action on climate change understand the science and are demanding the implementation of policy on a purely rational or altruistic basis. Similarly,

one cannot assume that those who question taking action are unfamiliar with the science, influenced by vested interests, or lack concern for current and future generations. There are legitimate questions about the ability of models to predict future climatic shifts, and the most effective suite of policy responses has certainly yet to be found. Nevertheless, it is important to recognize that very high levels of certainty exist among scientists in the field about the fundamental conclusion that humans are affecting the climate.[6]

The challenge of climate change draws together stakeholders with both consistent and inconsistent values, goals, and priorities. None of these stakeholder groups is homogeneous, and thus they are difficult to characterize. For instance, while "the public" is often considered a major stakeholder, this group encompasses not only those who might have suffered from the dramatic effects of climate change (such as sea level rise or extreme weather events) but also those whose lifestyles have benefited enormously from the consumption of fossil fuels, as well as those who are informed and active in the climate change debate, those with little access to accurate scientific information, and those with no inclination to participate in decision-making processes, including elections.

Similarly, industry stakeholders include those with vested interests in perpetuating an economy rooted in fossil-fuel-based energy and those who stand to benefit from a transition to renewable technologies. Although some companies feel it is critical to show leadership on climate change as part of socially responsible business practice, others disagree with proposals to reduce greenhouse gas emissions or feel it is not their responsibility to act.

Governments, too, are playing a key role in the climate change debate, especially because most recent climate change policy has developed at the international level. This, however, generally excludes individuals and even non-state actors (such as civil society organizations and the private sector), leaving climate change decisions to be made by political elites. Governments also clearly have an important role to play in

implementing legislated greenhouse-gas-reduction policies and sustainable land use plans and in supporting research into renewable energy. Even so, governments are subject to constantly changing political pressures, broader geopolitical conflicts, and term limits that influence the extent to which they are willing or able to plan for the long term.

The scientific community obviously plays an important role in our perception of, and response to, climate change, but that role is shifting. Scientists traditionally have been viewed as "objective" or value-neutral parties who simply communicate discoveries to policy-makers and the public, but it has now become clear that science itself is a value-laden practice. Decisions about which scientific research projects deserve funding are often shaped, in part, by the political context. Some governments funnel spectacular quantities of cash into the development of clean energy technologies or infrastructure design projects, while perceiving little use for studies of behavioral change, politics, and policy design. In addition, scientists often forge professional collaborations on the basis of personal relationships and perceived demand for particular work. This is not to claim that value-based aspects of science necessarily create bias in outputs or conclusions; rather, it highlights that the objective and subjective worlds are deeply intertwined and serve to produce knowledge that must be placed in the human context from which it emerges. Navigating these waters carefully is a crucial task, and it is certainly not an attractive option to leave the scientific community on the sidelines of decision-making. If we are to face the challenge at hand, leading-edge science on the causes and consequences of climate change must be fed into the decision-making process.

Another key stakeholder or actor that has emerged in the climate change debate is the media. If climate change was once the sole domain of scientists and science journalists, it is now explored by political, economic, security, and even fashion writers, with dramatic implications for the framing of the issue. Most obviously, the sensational elements and emotional stories associated with climate change are the first to be picked up and publicized by the media: polar bears and their sensitivity to

diminishing sea ice have become the media's symbol of climate change, as have shocking storms or raging wildfires. Social scientists Max and Jules Boykoff have explored the ways in which the media influence the framing of the climate change debate and the messages the public consumes.[7] A core tenet of responsible reporting is balance; typically, this means giving equal "air time" to both sides of an issue. In the case of global warming, however, this has created an unintentional form of bias in which the opinions of a small group of skeptics are given weight equal to those of the vast majority of scientists, who have found climate change to be a real and valid concern. This bias dramatically misrepresents the state of scientific consensus on climate change.

Acknowledging that climate change is not simply a scientific issue but one that passes through the filter of human psychology raises the issue of risk perception, the study of which has burgeoned with escalating public concern about issues such as nuclear power, pollution, and natural disasters. What do we think are the risks from climate change? How important is it to respond to them? Should we respond to them before they occur or after? These questions reveal the multitude of ways in which such risks are perceived, and help to explain varying levels of action.

Humans' perception of the magnitude and likelihood that a risk will affect their lives is the product of a constellation of factors, many of which are relatively unrelated to the actual objective nature of the risk itself. Many hazards exist: air pollution, noise, and radiation, for instance, and the effects of climate change, such as extreme weather events, drought, and rising sea levels, are hazards as well. In their day-to-day activities, individuals might not come in contact with these hazards – they might live in a wealthy city, for example, away from a coastline or floodplain – but others might make a living from farming, or live in vulnerable low-lying areas prone to floods, or far from the disaster-management or public health resources that some cities have at their disposal. Many demographic characteristics also feed into this matrix, helping to determine both the activities that

put us in the path of the hazard and the perception we have of it. Studies show that socially marginalized populations often perceive risks to be greater than do those who are relatively empowered.[8] Furthermore, perception of risk is directly influenced by individuals' worldviews and values, and the level of knowledge they possess. Research shows that the more scientifically literate people are, the more *polarized* they are in their opinions about climate change.[9] In other words, individuals' beliefs about risks are formed by what is appropriate in their community – their family, friends, the political groups they associate with – rather than strictly based on facts, figures, and scientific information.

The complications do not end there, of course. Even when individuals perceive a risk to be severe, they might not act to protect themselves or prevent the risk from occurring. Climate change is a testament to this paradox. Human behavior is a complicated phenomenon, one that we desperately need to understand better. Although the focus traditionally has been on educational campaigns to improve people's understanding of climate science or the need to respond to climate change, the scholarly community generally believes that this approach is dramatically insufficient to yield sustained shifts in behavior. Underlying values play a critical role in determining the effectiveness of information campaigns, as do beliefs about whether or not humans are at risk.[10] In the end, human beings are rarely simply rational creatures. Our emotions play a central role in determining which behaviors we choose,[11] and the most effective campaigns to persuade people to change their behavior recognize this. Furthermore, the context in which individuals go about their daily lives might present significant external barriers to behavioral change. For instance, they might value environmental sustainability and perceive significant risks associated with climate change, but be unable to make the shift from driving cars to using public transit if it is unavailable or inconvenient.

It is important to keep these complex drivers of human behavior in mind as we learn more about the fundamentals of climate science. In the interest of injecting a little sanity into the

climate change debate, this book highlights what scientists are certain about, as well as areas where the science is still rapidly evolving. These distinctions are crucial to making informed decisions about response options, and form the context within which we can start to have an informed conversation about what sort of future we desire.

1.2. The state of the science

Earth is getting warmer, the past century of heating (about 0.8°C) is mostly due to increases in atmospheric greenhouse gases, and these increases are due to human activity. These statements have high scientific certainty, and are the core of the conclusion that human activities influence Earth's climate. The evidence for rising global average temperature comes from many thousands of measurements, analyzed in different ways by different groups of scientists, all of whom have found very similar temperature patterns over time. There are no credible challenges to this evidence.

How do we know that greenhouse gases are the primary culprits? Climate has three basic controls: the Sun's incoming energy, reflection of the Sun's energy back into outer space, and the atmospheric greenhouse effect. Neither a change in incoming solar radiation nor a change in reflection can explain the recent warming, as we discuss in Chapters 3 and 4. An increase in the greenhouse effect is the only major control going in the same direction as the temperature observations. In addition, the lower atmosphere has warmed, while the upper atmosphere – the stratosphere – has cooled a little, which is consistent with more greenhouse gases keeping more energy in the lower atmosphere for longer. If the Sun were responsible, we would expect warming throughout the atmosphere, which is not what we observe.

How do we know humans are responsible? From historical records of fossil fuel extraction, we know how much fossil carbon we have burned and how much of that carbon has

accumulated in the atmosphere. We have measured the chemistry of atmospheric carbon dioxide and found that the changes in chemistry match what would be expected from releasing carbon from fossil fuels and in the amounts that have been released. No known natural releases of carbon to the atmosphere could have done it. Climate models that include only natural variability – for example, changes in solar radiation and the discharges from volcanoes – cannot produce the observed temperature increase of the past century. Only by including human influences can the models simulate what has actually happened. Humanity's fingerprints on Earth's climate are clear.

What pieces do we know well? We have excellent information about the physical properties of greenhouse gases, how they absorb and re-emit energy, and how long they persist in the atmosphere. We have a good grasp of some of the climate responses that occur in a warming world, such as the behavior of water vapor (which enhances the heating) and how, as Earth warms, it emits more energy into outer space (which helps counteract the heating).

We know less about some other responses and drivers. How do clouds respond to warming? How much cooling do reflective droplets and particles in the atmosphere provide, offsetting some of the greenhouse heating? We also need better information about what to expect in specific places, such as coastlines and agricultural areas. Which crops will be well suited to the regional climates of the future? How often will flooding events occur and how severe will they be? Scientists are working to get a handle on these aspects of regional climate change.

Even with some imperfect pieces, however, the scientific questions around present-day climate change, on a human time scale, are not about whether climate is changing or even whether human actions influence climate, but about how fast and how much climate will change. Scientists will continue to test current thinking and fill in the gaps in the climate picture. Resolving the remaining questions will clarify the details, but it is unlikely to overthrow our current understanding of how Earth's climate works.

1.3. Responding to climate change: Mitigation and adaptation

Human systems and Earth systems are inextricably linked. The ways we choose to develop our cities, grow our food, and live our lives significantly influence both the quantity of emissions we put into the atmosphere and the degree of climate change we cause. Similarly, the places we choose to settle, and the way we build those settlements, directly influence our degree of vulnerability to the impacts of climate change. These connections suggest that there are two broad, and deeply interwoven, categories of responses to climate change: we can change the impact we have on climate, and/or we can minimize the impact that climate has on us.

Mitigation means getting at the "roots" of climate change. The goal is to prevent climate change before it starts or, at least, to reduce its effects once it has started. Mitigation has been the most common policy response to climate change since evidence of human interference with the planet's delicate climatic balance began to emerge. So, the most commonly held definition of mitigation refers to efforts to reduce greenhouse gas emissions or enhance the storage of carbon (the main culprit) in "carbon sinks" such as forests, oceans, and soil.

Adaptation involves strategies such as building higher dikes to keep out rising seas, growing crop varieties that thrive under warmer, or wetter, or drier conditions, and protecting vulnerable populations during extreme weather. Adaptation thus means tackling the consequences, rather than the causes, of climate change. As we shall see, adaptation is a challenging proposition when, as is common, those who will suffer the most severe impacts of climate change are likely not those who are responsible for causing it.

1.4. A brief history of climate change policy

Climate change is a complicated phenomenon to attempt to manage. It pervades and affects the very foundations of our way of

life, requiring navigation through a maze of economic, scientific, societal, and governance concerns. Widely diverging interests collide in the international arena, and the risks associated with climate change are weighed against security threats, economic fluctuations, human rights debates, and geopolitical posturing. As such, the path towards legally binding global climate change legislation has been a bumpy one plagued initially by complex science and policy design, and later by significant controversy.

Over the past twenty years, the international community has toyed with mandatory greenhouse gas emissions levels for developed countries, voluntary limits for developing countries, mechanisms by which funds can be transferred from rich to poor to stimulate the growth of green technology, and funds to sponsor the protection of communities against climate change impacts. These efforts have met with mixed success, as we shall see throughout this book.

The core justification for responding to climate change at the global level is simple. Greenhouse gases released anywhere on the planet act essentially the same way in the climate system: they distribute evenly and affect the global climate, not just the region in which they were emitted. This means that a metric tonne of greenhouse gas emitted in Canada has the same impact as a tonne emitted in China or Cameroon. Furthermore, the global economy is now so tightly interwoven that the repercussions of exchanging cheap, dirty technologies for more expensive but clean ones can reverberate in ways that are difficult to predict. Fossil fuels are currently cheap for two reasons. First, billions of dollars are poured into subsidies around the world to ensure an inexpensive supply of fuel[12] and to support local industries, and, second, our current transportation, heating, and electricity infrastructure has been created with fossil fuels in mind. We are now faced with inertia: it is currently less costly (in financial terms) to stick with what we have than to overhaul our systems in favor of renewable energy. We deal with this in greater detail in Chapter 6.

A related implication of the global nature of climate change is that the world's distribution of wealth is such that a small fraction of the population is responsible for producing most of

the emissions that are driving global climate change. In other words, the actions of a wealthy and consumptive few are creating a potentially unstoppable chain of events that could transform the livelihoods of billions of people the world over.

Finally, international climate change policy might lead to more efficient and coordinated outcomes than efforts that take place in isolation from one another at the local level. For instance, it might be cheaper to replace extremely dirty or inefficient coal-fired power plants in developing countries, rather than to pay much greater sums to yield small efficiency improvements in already relatively clean technologies.

From the negotiation of the Kyoto Protocol – the first major international agreement aimed at managing greenhouse gas emissions and responding to climate change – to protests associated with recent climate change negotiations, it is clear that creating effective international climate change policy is a far from simple task. The complexity of the global geopolitical landscape translates into varying goals and pressures at the negotiating table, while the cost of emissions reductions runs counter to political priorities at home. A lack of understanding of what a low-emissions world might look like exacerbates these issues.

Added to these challenges are barriers to the implementation of policy once it has been agreed upon. Without a ruling international government, only political pressure and economic measures can be brought to bear on those who fail to meet their promised emissions-reduction targets. This creates a strong incentive for "free riding" – that is, reaping the reward of actions taken by others. For example, if you sneak into a music concert and enjoy the show without paying, you are free riding; if the other people at the concert also had not paid, the musicians would not have performed, but since the musicians' costs were covered by tickets fairly paid for by others, you are receiving a benefit for which you did not pay. Other examples of free riding are enjoying smooth roads and clean water without paying taxes or, more to the present point, receiving the "benefit" of a stable climate without reducing one's greenhouse gas emissions while others have taken steps to reduce their own emissions.

In the sections that follow, we introduce the central elements of international climate change policy: the Intergovernmental Panel on Climate Change, and the United Nations Framework Convention on Climate Change. We address these, along with subnational and local efforts to respond to climate change, in greater detail in Chapters 6, 9, 10, and 11.

1.4.1. The United Nations Framework Convention on Climate Change and the Kyoto Protocol

In 1992, at the Conference on Environment and Development in Rio de Janeiro, Brazil, UN members produced the United Nations Framework Convention on Climate Change (UNFCCC), which forms the backbone of global climate change policy. The Convention was created to manage emissions of greenhouse gases and the resulting climate change, and although the UNFCCC did not contain binding emissions-reduction targets, these were adopted in a subsequent and related treaty, the Kyoto Protocol. The UNFCCC currently has 195 parties, not all of which have both signed and ratified the Kyoto Protocol.[13] One of the most important functions of the UNFCCC is to hold periodic meetings of parties to the Convention. These meetings, called Conferences of the Parties (COPs), occur approximately every twelve months – it was during COP3, for instance, in 1997, that the Kyoto Protocol, the most significant piece of international climate change policy to grow out of the UNFCCC, was created.

The issue on the table at COP3 in Kyoto, Japan, was the creation of emissions-reduction targets for all developed countries that would ratify the Protocol and to establish mechanisms through which reductions could be stimulated in developing countries. The ultimate goal was to stabilize greenhouse gas emissions at a level that would prevent dangerous levels of climate change. The targets were to be met between 2008 and 2012, with a successor to the Kyoto Protocol to be negotiated during that period. This has been a contentious issue, however, as many scientists argue that the agreed reductions were too modest to mitigate human influence on the global climate

effectively. Furthermore, debate has been sparked by the role of developing countries, most notably India and China, in future emissions reductions. Of the list of countries that have not ratified the Protocol, the most notable, even though it is a signatory of the UNFCCC, is the United States. Moreover, in 1990 – the base year upon which reduction targets in the Kyoto Protocol were set – the United States was responsible for approximately 30 percent of global greenhouse gas emissions. Canada ratified the Protocol, but it appears to be one of the least successful in meeting its Kyoto obligations, its emissions having increased by more than 26 percent since 1990, rather than diminishing by the 6 percent to which it agreed. Indeed, in December 2011, Canada's lack of progress was made manifest when the federal environment minister publicly announced that Canada would formally withdraw from the Kyoto Protocol.

More recent COPs have been held in Copenhagen, Denmark; Cancun, Mexico; Durban, South Africa; and Doha, Qatar. The key issue at stake in the Copenhagen COP, held in December 2009, was the negotiation of the agreement that was to take effect following the end of the Kyoto Protocol commitment in 2012. After two weeks of intense negotiations, however, the parties failed to deliver a successor to the Kyoto Protocol, producing instead a brief, non-binding political declaration, although the richer nations did agree to make the first formal financial commitment to help poorer nations adapt to climate change.[14]

Following the perceived failure at Copenhagen, optimism surrounding international climate change negotiations experienced a modest recovery, mainly due to success in reducing emissions from deforestation and forest degradation (REDD) and the development of an adaptation framework. Even so, the emissions-reduction commitments agreed to would have gone just *60 percent of the way to a 50-50 chance* of reaching the goal of limiting warming to 2°C, and by 2013 the future of the Kyoto Protocol was left undecided.[15]

The points of contention at Copenhagen, and the very modest successes at the COPs that followed, reflect the broader debate swirling around global climate change policy. In particular, many

developed countries are concerned that greenhouse gas emissions cannot be managed effectively without the binding participation of key developing countries whose emissions threaten to dwarf those of the West in the not-so-distant future. Other issues include funds to support climate change adaptation in developing countries, whether emissions from shipping by sea and international air travel should be included, and how to encourage the parties to agree to deep and binding reduction targets in a future protocol. Indeed, the mixed success of international negotiations has led to the growing popularity of bilateral (two-party) or "club" (a handful of parties) negotiations. For examples, it appears that the United States may pursue climate policy through the Major Economies Forum, a club of seventeen members that together emit more than 85 percent of global greenhouse gas emissions.

1.4.2. The Intergovernmental Panel on Climate Change

A core element of international climate change policy-making is the advice provided by the hundreds of scientists who constitute the Intergovernmental Panel on Climate Change (IPCC). Created in 1989 by the United Nations Environment Programme and the World Meteorological Organization, the IPCC gathers together the world's leading climate scientists to produce reports based on the latest scientific research. In periodic assessment reports, the IPCC reviews progress on climate change science – including work on both adaptation and mitigation – and synthesizes the material for use during policy negotiations. The importance of the IPCC's work was acknowledged in 2007 when, in tandem with US politician and climate activist Al Gore, it was awarded the Nobel Peace Prize. The award brought unprecedented attention to the work of the IPCC and pushed the climate change issue to new heights of public awareness.

To produce its reports, the IPCC divides its efforts into three working groups, each of which addresses one major component of climate change. Working Group I explores the science of climate change, and assesses our understanding of the drivers of

climate change, projected changes in the climate, and observed changes around the world. Working Group II assesses studies on adaptation and impacts, including those on human health, settlements, and ecosystems, among many other areas. Working Group III explores the critical question of mitigation – strategies to prevent climate change from occurring or becoming more severe. Each working group draws upon the expertise of a wide range of scientists from many disciplines who act as authors and/or reviewers of the assessment reports. Together, the working groups make up a plenary panel, which feeds findings to the UNFCCC.

The IPCC is the largest scientific collaboration of its kind in human history. Experts in the three working groups meet frequently to collect, assess, and synthesize the scientific findings produced in thousands of publications around the world – a uniquely rigorous scientific process. This work is voluntary, and the individuals who participate are selected through a nomination and review process. Care is taken to ensure that author teams are comprised of individuals from a variety of views, nationalities, and scientific backgrounds, although criticism nonetheless has emerged about gender imbalance and the relative lack of inclusion of scholars from developing countries. As the assessment reports come together, they are subjected to an intensive review and critique virtually unparalleled in the scientific community. Experts who are not IPCC authors play an integral role in evaluating the assessment reports, including supplying new studies to evaluate and critiquing conclusions, to which IPCC authors must respond.

Despite its extensive review and revision processes, the IPCC is not without its critics. Valid concerns have been raised, for example, about the future value of the IPCC. As well, because the IPCC seeks consensus, its findings are often portrayed as scientifically conservative, a characterization that has been reinforced by the emergence of new findings, such as the increasing rate of ice melt in the Arctic, shortly after the completion and publication of a major IPCC assessment. Critics also charge that the IPCC neglects outlying views. Although these views are not

necessarily incorrect, the IPCC seeks to gather science that has been validated and replicated by multiple experts, and cannot reasonably include the views of all scientists in the field. Furthermore, the IPCC must be policy relevant, but not policy prescriptive: it can document the ways in which human activities are affecting the climate, and propose response options, but it cannot argue for a particular policy solution. This is becoming an increasingly challenging line to walk, however, as pressure builds to demonstrate which response strategies are working, to grapple with the scale of the challenge, and to accelerate the transition towards sustainability. Indeed, since the IPCC grew out of the United Nations, it cannot directly criticize the climate change policies (or lack thereof) of the sovereign nation-states that are members of the United Nations. But this has led to criticism that the IPCC is abdicating its essential role as a scientific body that ought to be driving action on climate change. These and other criticisms have stimulated healthy debate, and could shift the role that the IPCC plays in the future.

1.5. The scale of the challenge: Accelerating action on climate change

The question of an effective response to the very real problem of human-induced climate change is a complicated one, touching on our scientific understanding of the problem, inertia built into technologies, and deeply rooted values. Closely interwoven human and natural systems make it challenging to determine how best to respond. Can we design cities that are low carbon, resilient in the face of climate change, and foster healthy, vibrant communities? Can we devise strategies that unleash the potential of innovative social enterprises, channel the ingenuity of the private sector, and bring policies at all levels of government in line with one another? Can we resist the urge to hive off one particular part of the problem and consider it in isolation? In attempting to create a desirable future, can we have a conversation that is simultaneously about social justice, ecological integrity, and well-being?

As daunting as this task may seem, we already possess many of the tools we need. Throughout this book, we will learn about real strategies that have been put into practice around the world that can help to shift communities onto more sustainable development paths. With core climate science concepts in hand, we will see how these response strategies relate directly to the causes and consequences of climate change, and evaluate both their feasibility *and* desirability. Climate change presents an opportunity to transform the way society functions. This book attempts to pull together the pieces of the puzzle and to equip you with the tools you will need to engage meaningfully in this debate and, ultimately, to accelerate our progress towards sustainability.

1.6. Roadmap of the book

In this book, we provide the scientific basics of climate change and possible response options – with respect to both mitigation and adaptation. We avoid an exclusive focus on the science of climate change, since this approach does not allow for a nuanced understanding of the social implications. Similarly, exclusively political or economic analyses of climate change frequently neglect the underlying science in terms of thresholds, feedbacks, and the potential for abrupt change. Our approach, rather, is to see the problem through the unique lens of "transformative change": are current climate change response strategies putting us on the path towards a fundamental transformation of emissions trajectories and vulnerability? We aim to explore visions of the future that are positive and ambitious, and that respond to what we know about the way humans are influencing the climate.

We begin by exploring the key scientific concepts that are crucial to understanding climate change. In Chapter 2, we look at systems, including stocks, flows, and feedbacks. In Chapters 3, 4, and 5, we explore the influence of energy from the Sun, reflectivity, and the greenhouse effect on the planet's weather

and climate, looking not just at the causes of climate change, but also potential mitigation solutions.

In Chapter 6, we focus on a core driver of climate change: the global energy system. We also explore some of the most powerful currently available mitigation strategies, innovative actions that are being taken around the world, and leading-edge ideas on tackling the roots of climate change. In Chapters 7 and 8, using climate models and scenarios, we examine the challenges inherent in trying to predict the future, and offer a glimpse at what climate change might look like in the decades ahead.

In the last third of the book, we explore the human and natural consequences of climate change. In Chapter 9, we examine the impacts of climate change on natural systems, and potential strategies (or those that natural systems might follow spontaneously) to respond to these impacts. We also consider ways in which adaptation might imply synergies or trade-offs with mitigation strategies discussed in earlier chapters. In Chapter 10, we focus on the implications of climate change for human systems and settlements, with a particular focus on development, social justice, and equity. We explore specific adaptation strategies, the heated debate surrounding the costs of adaptation, and the linkages between adaptation and mitigation.

Given what we now know about the science behind climate change and the strategies at our disposal for responding to it, in the final chapter we look forward to the frontier of innovative action on climate change. We finish with a glimpse into the future of climate change policy and a look at the most promising opportunities for both managing the effects of climate change and ensuring a rapid transition to a fundamentally low-carbon development path.

Notes

1. Climate Change in the Public Sphere

1 Many people mark the publication of Rachel Carson's landmark book *Silent Spring* (New York: Houghton Mifflin, 1962) as the critical juncture at which the public began mobilizing on issues of environmental pollution and the costs of Western development.
2 See, for instance, D.H. Meadows, D.L. Meadows, J. Randers, and W.W. Behrens III, *The Limits to Growth* (New York: New American Library, 1972), the seminal report commissioned by the Club of Rome that explores the implications of an exponentially increasing human population paired with limited resources.
3 J. Robinson, "Squaring the Circle? Some Thoughts on the Idea of Sustainable Development," *Ecological Economics* 48, no. 4 (2004): 369–84.
4 Recently, Professor John Robinson of the University of British Columbia has developed this perspective on the damage of a conversation about sustainability and climate change that focuses exclusively on limits and human activities. See, for example, J. Robinson, T. Berkhout, A. Cayuela, and A. Campbell, "Next Generation Sustainability at the University of British Columbia: The University as Societal Test-Bed for Sustainability," in *Regenerative Sustainable Development of Universities and Cities: The Role of Living Laboratories*, ed. A. König (Cheltenham, UK: Edward Elgar, 2013).
5 Ibid.
6 R.K. Pachauri and A Reisinger, eds., *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Geneva: IPCC, 2007).
7 M.T. Boykoff, and J.M. Boykoff, "Balance as Bias: Global Warming and the US Prestige Press," *Global Environment Change* 14, no. 2 (2004): 126–36.

8 T. Satterfield, C. Mertz, and P. Slovic, "Discrimination, Vulnerability, and Justice in the Face of Risk," *Risk Analysis* 24, no. 1 (2004): 115–29.
9 D.M. Kahan, E. Peters, M. Wittlin, P. Slovic, L. Larrimore Ouellette, D. Braman, and O. Mandel, G., "The Polarizing Impact of Science Literacy and Numeracy on Perceived Climate Change Risks," *Nature Climate Change* 2 (2012): 732–5.
10 A. Kollmuss and M. Agyeman, "Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-environmental Behaviour?" *Environmental Education Research* 3 (2002): 239–60.
11 P. Slovic, M.L. Finucane, E. Peters, and D.G. MacGregor, "The Affect Heuristic," *European Journal of Operational Research* 177, no. 3 (2002): 1333–52.
12 J. Eaton, "Eleven nations with large fossil-fuel subsidies," National Geographic Daily News, 18 June 2102; available online at http://news.nationalgeographic.com/news/energy/2012/06/pictures/120618-large-fossil-fuel-subsidies/, accessed 25 January 2014.
13 Ratification is the formal confirmation or adoption of (in this case) an international treaty. Although a "simple signature" by a state indicates that it agrees with the content of the treaty, ratification means that the state is willing to be legally bound by the treaty. Ratification requires domestic support for adherence to the treaty, as well as domestic legislation to enforce it (since the treaty cannot be enforced at the international level).
14 "The outcome at Copenhagen was disappointing. But if we work hard, there is still a way forward," *Observer*, 20 December 2009; available online at http://www.theguardian.com/commentisfree/2009/dec/20/leader-copenhagen-accord, accessed 9 October 2013.
15 United Nations Framework Convention on Climate Change, "Cancun Climate Change Conference – November 2010" (Bonn, Germany: UNFCCC, 2013); available online at http://unfccc.int/meetings/cancun_nov_2010/meeting/6266.php, accessed 9 October 2013.

2. Basic System Dynamics

1 Much of the systems terminology we use throughout this chapter is from Donella Meadows' excellent and accessible book, *Thinking in Systems: A Primer* (White River Junction, VT: Chelsea Green Publishing, 2008), which is highly recommended for further reading about systems.
2 See M.J. Molina and F.S. Rowland, "Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom-catalysed Destruction of Ozone," *Nature* 249 (1974): 810–12; for a historical review, see Susan Solomon, "Stratospheric