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CHAPTER 1

Pursuing Sustainability: An Introduction

Sustainability is a term we hear all around us. Corporations brand themselves as sustainable and attempt to build sustainability goals, measures, and metrics into their business plans and supply chains. State and local governments set sustainability targets and pursue them, installing efficiency standards and practices, encouraging the use of public transportation systems, and incentivizing citizens to reduce, reuse, and recycle. Universities compete for sustainability awards that recognize efforts ranging from improving energy and water use efficiency to curricular offerings. Researchers focus their attention on the development of new knowledge and technologies to promote sustainability. Consumers consider sustainability concerns as they buy organic, or buy certified sustainable seafood or wood products. Citizens strive to reduce their environmental footprints on the planet out of a sense of responsibility to their children and grandchildren.

Sustainable development, likewise, is a widely used term. It frequently appears in high-level discussions of the United Nations, the World Bank, and non-governmental organizations (NGOs) such as CARE and WWF and is a fundamental objective of the European Union and of many nations rich and poor. The World Business Council for Sustainable Development counts many leading global companies among its members. These and similar organizations invest in efforts to help countries, companies, and communities “develop” not just in the near term but for the long-term benefit of people.

While the terms *sustainability* and *sustainable development* are often used by different communities of people, the vast majority of these uses have something very important in common: a realization that our ability to prosper now and in the future requires increased attention not just to economic and social progress but also to conserving Earth's **life support systems**: the fundamental environmental processes and natural resources on which our hopes for prosperity depend. Because of that commonality, we use the terms interchangeably. We believe that the take-home messages of this book are important for both.

THE EVOLUTION OF SUSTAINABILITY THINKING

Sustainability is an old idea. Societies for centuries have recognized the importance of demanding no more of the environment than it can supply over the long term. This recognition is evident in long-standing ideas about fallowing fields and conserving game and protecting water sources. The concept of sustainable development in its modern form, however, was most famously articulated by the United Nations World Commission on Environment and Development (WCED) in 1987. As Gro Brundtland, the commission chairwoman, wrote at the time: “Environment is where we live; and development is what we all do in attempting to improve our lot within that abode. The two are inseparable.”¹ The commission argued that *sustainable* development “meets the needs of the present without compromising the ability of future generations to meet their own needs.” And its carefully documented report left little room for doubt (among those willing to confront the evidence) that a transition toward sustainable development would have to arrest and reverse the increasingly global and accelerating degradation of Earth's environment and natural resources.

Since the Brundtland Commission's call for global action the UN has reinforced the urgency of a **sustainability transition** through numerous conferences and agreements. Over many years and several iterations, the international community has developed consensus on a wide-ranging set of sustainable-development goals,² and in pursuit of those goals, numerous efforts at the global, national, and local levels have been launched. They aim to reduce hunger and poverty; improve

access to health care, family planning, and education; increase agricultural production while reducing environmental degradation; and halt the degradation of Earth's life support systems. Today, thousands of governmental and non-governmental organizations, private firms, and individuals all over the world have adopted the idea of sustainability and have started to allocate attention and resources to sustainable development programs. Corporations have developed metrics to track the economic, social, and environmental impacts of their actions. Cities around the world have created and joined associations designed to share best practices and encourage progress. Regional and national efforts are to be found in every part of the world. Scholarly organizations such as the world's national science and engineering academies and numerous professional scientific associations have also engaged in the effort. And international consortia such as the World Business Council for Sustainable Development and the Science and Technology Alliance for Global Sustainability have built cross-sectoral communities of actors from private and public organizations to chart strategies for progress toward sustainability goals. (We provide in appendix B a short list of the Internet resources we have found most useful for keeping abreast of rapidly changing initiatives around the world that are pursuing sustainability.)

As a result of these many initiatives, people's vision of sustainable development has been rapidly evolving. It has matured from simple relationships that see human prosperity primarily in terms of economic growth, to a focus on human needs as called for by the Brundtland Commission, to the ever more encompassing and nuanced views centered on social well-being being advanced today (see chapter 2).

A benefit of this expanding framing of sustainability has been the creation of an ever-broader "tent" under which the multiple constituencies of scholarship, advocacy, and action are now working to promote sustainable development. This inclusiveness, however, creates an increasing risk of losing sight of the sustainability forest for its many individual trees and the concomitant temptation for everyone engaged to fall back into activities focused on individual disciplines or sectors. Progress toward sustainability requires commitment to such details—to the individual trees of our global system as well as the particular con-

texts in which they must be nurtured if they are to contribute to sustainable development. But progress also requires a broader perspective on how the parts of the forest depend on one another, interact, and co-evolve. We have tried to provide one such perspective with this book.

SCIENCE FOR SUSTAINABILITY

Meeting the challenges of sustainable development requires action that changes the status quo. Because too many powerful interests have a stake in resisting such change and in continuing “business as usual,” meeting the challenges of sustainable development will require a deep and broad commitment to social agitation, to stirring things up. Contributions to this agenda of agitation and action are needed not just from self-described activists but also from political and business leaders, civil society, medical professionals, educators, and individual citizens. In addition, however, sustainable development requires contributions from *scientists*, a term we use to encompass all sorts of scholars committed to figuring out how the world works—natural and social scientists, humanists, policy analysts, engineers, medical scientists, and all their many kindred.

Just what are the roles for science and scientists in promoting sustainable development? We explore many specific contributions throughout this book. In general, however, the roles of science include helping society to see where present trends are taking us, to discover or design new technologies and policies that might change our course, and to evaluate the possible trade-offs and implications for future generations of implementing such alternatives. Or, in the words of Nobel Laureate Amartya Sen, the role of science is to help assure that the social agitation seeking to promote sustainable development is *informed* agitation.

When we, the authors of this book, first began working on sustainability issues, lots of relevant science and technology were being done, but there were few places in which those who were doing them could escape their disciplinary homes to come together in collaborations centered on sustainable development. Today, things have changed. Like the fields of health or agricultural science before it, **sustainability sci-**

ence has emerged as a field focused on creating and harnessing many different kinds of knowledge to help address social problems. In particular, it is a field that tackles directly the numerous problems involved in pursuing sustainable development. To that end, sustainability science strives to integrate study and practice through use-inspired research. It includes the contributions of many different kinds of basic science and the contributions of people involved in the design and implementation of policy, technology, and practices. The field also carries out the unique and critical role of striving to integrate those knowledge bases and to build on them in new ways, developing knowledge to support decision making for sustainability goals. Ultimately, sustainability science is about increasing our knowledge of and ability to manage the interactions between environmental and social systems that set the stage on which sustainable development plays out.

We have a good deal to say later in this book about the general characteristics of such **social-environmental systems** and of the common challenges people face as they guide those systems along paths toward sustainable development. To bring specificity to those generalized discussions, however, we have found case studies useful. We introduce in the next section of this chapter four such studies that represent the kinds of challenges facing sustainable development and the types of work sustainability scientists do in helping to meet those challenges.

SUSTAINABILITY CHALLENGES IN THE REAL WORLD: FOUR CASE STUDIES

As noted in the previous section, we have selected four case studies to illustrate just how challenging it is to determine what to do to promote sustainability over the long term. The cases take place in a wide variety of settings—high-tech science laboratories, fields of small-scale farmers, neighborhoods of one of the world’s most cosmopolitan cities—but they share some central features. The cases are alike in that they showcase people trying to make good things happen for themselves and the people in their communities, struggling to deal with unintended consequences, and continuing to push for progress despite failures and setbacks. The cases show that even the most well-intentioned interventions

can go awry for many different reasons, including not considering them in the context of the full social-environmental system, not building appropriate and useful knowledge and getting it into the hands of the right decision makers, not working effectively within governance systems that allow sustainable decisions, and not having good luck. Each case has unique lessons to share, and together they give us concrete experiences through which to think about sustainability concepts.

These cases form a starting point for this book. We draw from them in all chapters of the book as we share our perspectives on what we think are the most critical lessons for those of us who are pursuing sustainability. We present short introductions to each case next and provide more detailed treatments in appendix A. We believe that most readers will find it helpful to read the fuller treatments in the appendix before getting too far along in the book.

London

The London case highlights the challenges of thinking analytically about development over the multigenerational time periods central to concerns about sustainability.

London today is widely recognized as a leading world city. It regularly scores at or near the top of surveys about sustainability and quality of life in urban areas, racking up especially high scores for its international clout, its technological savvy, and its livability; doing well on economy, governance, and many dimensions of environment; but still struggling with air pollution and social inclusion.

This has not always been the situation for London. On the contrary, London's current high but uneven prosperity rests on a history of more than a thousand years of collisions with the environment, some very like those being experienced in today's rapidly growing "new" cities. Two related themes have run through these collisions, both relevant to cities everywhere.

One involves the constant struggle to secure the basic food, fuel, and material resources needed for a growing city and at the same time to dispose of the waste products resulting from the use of those resources. Failures to handle these resource and waste flows directly resulted in multiple episodes of food shortages and consequent malnutrition for

the poor, the intermingling of human waste and drinking waters, chronic air pollution, and growing vulnerability to flooding.

The second recurrent theme in the relationship of London to its environment centers on its population's battle with communicable disease. The odds in this battle were clearly affected by repeated failures to solve the resource management issues noted previously, but they also involved the dynamics of resistance and immunity in a closely packed settlement increasingly exposed to diseases imported from remote corners of the world.

In grappling with these problems, growing numbers of Londoners pursued short-term personal gains that repeatedly inflicted long-term large-scale costs of social and environmental degradation that eventually became untenable. But with each setback, society responded with a mix of political activism, scientific discoveries, technological inventions, social adjustments, and new forms of governance that—together with events occurring in the wider world beyond London—opened the way for the next round of development initiatives. These invariably led to their own surprises and readjustments, the most recent or persistent of which are being publicly debated in the context of the London Plan, an organic document that charts the city's goals and strategies for a sustainability transition.

Nepal

The Nepal case focuses on the multiple pathways through which irrigation technology has been deployed to reduce food insecurity. It highlights the importance of involving technology users in the design and operation of technology-augmented systems.

Growing food in Nepal is a challenging prospect. With most of the country mountainous, and area for agriculture very limited, Nepali people have always been susceptible to food shortages. By the late twentieth century, the growing rural population was becoming chronically food insecure. One possible solution that had been successfully pursued elsewhere was to introduce improved irrigation technology to increase the amount of food produced on land already under agriculture. But when the Nepali government and foreign partners began to construct advanced irrigation systems to replace the more primitive

version being used by poor farmers, the results fell short of expectations. Many of the agricultural systems that received high levels of financial support and technological improvements actually saw declining food production.

What was going on here? How could these state-of-the-art engineering projects not deliver improvements to farmers in Nepal? Scientists studying the irrigation projects found the answer in key elements of farmers' social systems that the "outsider" aid providers had overlooked. Many of the systems were designed in government engineering offices and failed to incorporate local farmers' knowledge about typical stream flows and other aspects of local context. In particular, because the sophisticated equipment used to create the new irrigation works was difficult to maintain and operate, the government agencies took over from farmers full responsibility for the new irrigation systems. Farmers themselves were thus no longer in charge of maintaining these systems, as they had been for the earlier simpler ones. As a result, farmers perceived little need to cooperate with other farmers to coordinate their irrigation activities. Upstream farmers stopped worrying about maintaining good relationships with downstream farmers, withdrawing more and leaving less water for their downstream neighbors' use. Eventually, agricultural productivity within the system as a whole declined.

Over the years, researchers studying irrigation activities in Nepal have shown the important role that irrigators themselves play in making irrigation systems work. They fulfill several important functions, such as organizing contributions of labor to the construction and maintenance of field canals and regulating water allocation. And they perform the critical functions of monitoring violations and helping enforce compliance measures. Their long-term commitment to their village as well as their knowledge of the place, its resources, and its people makes an important difference in the performance of irrigation systems. However, even farmer-managed systems can benefit from expertise, experience, and financing from outside organizations. Current efforts to introduce new technologies to improve food security in Nepal are thus increasingly experimenting with hybrid models involving significant roles for both farmers and outsiders.

Yaqui Valley

The Yaqui Valley case takes a closer look at how imperfect but persistent interdisciplinary research on the coupled social-environmental system of a region can bring tangible benefits for sustainability when conducted in close consultation with local decision makers.

The Yaqui Valley, located in the state of Sonora in northern Mexico, was the home of the Green Revolution for wheat. It is where, starting in the 1950s, the international agricultural research community developed the new high-yielding cultivars of wheat and corn that have been critical to meeting the food needs of people around the world. Farming in the valley has benefited from that new knowledge and know-how, and farmers there boast some of the highest yields of wheat in the world.

Unfortunately, the valley today has a range of sustainability challenges, most of them unintended consequences of the Green Revolution. For example, water resources are used very inefficiently (through flood irrigation in the fields), and until recently, the irrigation districts lacked rules for changing water draws to sustain water resources during times of drought. The agricultural systems tend to be overfertilized, and the addition of far more nitrogen than is used by crops leads to nutrient losses (in the form of greenhouse gases, and air and water pollutants) from soils to neighboring streams, ocean, and atmosphere.

If a “breadbasket” is not developing sustainably, what is to be done? Over a fifteen-year period, an interdisciplinary research team sought ways to reduce the environmental impacts of agriculture in the valley while maintaining or even improving grain production and economic well-being. Doing so required a focus on agronomic and environmental as well as economic, social, and political aspects so as to understand the coupled social-environmental system of the Yaqui Valley and to come up with solutions that made sense in that context.

In the case of overfertilization, researchers and farmers worked together to develop and test alternative fertilizer practices that required less fertilizer input, lost less fertilizer to water and air systems, and kept grain amounts and quality high. These and other win-win management practices were shown to be capable of saving both farmers’ money and

the environment. But discovering great win-win technologies didn't mean they would be used. Ultimately, it also took an understanding of the broader decision-making and governance systems of the valley, and improved partnerships with farmers and credit unions, to turn good ideas into action on the ground.

Stratospheric Ozone

The ozone case highlights the challenges of managing useful technologies that turn out to pose threats to the global commons. It shows how careful orchestration of international scientific assessments and stakeholder engagement, coupled with a willingness to make decisions in the face of uncertainty, produced a successful global environmental regulation.

The mechanical refrigerator, invented in the mid-1800s, allowed foods and other materials to be kept cold under all conditions. Not surprisingly, this invention was a boon to human health and well-being. The main problem with it, however, was that its standard cooling fluid was ammonia, a gas with a dangerous propensity to explode! Thanks to the work of industrial chemists, a new class of industrial chemicals—called chlorofluorocarbons, or CFCs—was invented in the 1930s to replace the dangerous refrigerant. After testing, CFCs were judged to be safe, nontoxic, and nonexplosive. Their manufacture and use took off, and CFCs became an important ingredient in a variety of coolants, and later, also propellants and cleansers. By all accounts, the class of compounds was an amazingly useful technology that could help meet some of the needs and wants of people around the world.

In the 1970s scientists discovered—much to their surprise—that CFCs were accumulating in the upper atmosphere, or stratosphere, and could be found all across the planet. Moreover, by the 1980s, researchers who would later win the Nobel Prize in Chemistry had shown that CFCs have the capacity to deplete ozone in the stratosphere. This finding was important because the *ozone layer* is known to serve as a shield that protects life on Earth from health damages that would otherwise result from excessive exposure to ultraviolet (UV) radiation from the sun. People and other forms of life around the planet were at risk.

What happened to prevent humans, and all the other species who share the planet, from being “fried” by UV radiation as the ozone layer

was lost? Thanks to ongoing measurements and monitoring and scientific analysis, and the leadership and engagement of decision makers in governments, corporations, and civil society, the ozone problem was identified and addressed through a sequential set of international agreements. These agreements limited and then radically reduced the use of ozone-depleting substances, and ultimately replaced those substances with others that have fewer negative consequences. While the loss of stratospheric ozone has not been completely reversed, the decline has been arrested, and signs of a recovery are evident.

THE BIG THEMES OF THIS BOOK

Our short case studies suggest (and their longer versions in appendix A show conclusively) that pursuing sustainability is not easy. That making progress is difficult is confirmed by the unabated emissions of greenhouse gases and their consequences for people and ecosystems, by the appalling conditions in many of the world's largest and most rapidly growing cities, and by the deepening inequalities in prospects for improved well-being of individual humans around the world.

Progress is nonetheless happening in some places and sectors, and is possible elsewhere. We now know that the successful pursuit of sustainability almost always requires the participation of many different stakeholders, including those of us in the “knowledge production world” of universities, research institutes, technology innovation operations, and policy think tanks. No one person can be an expert in all the fields of knowledge that may prove essential in solving particular sustainability problems. Thus, the successful pursuit of sustainability is usually context specific and a collaborative affair. But there are a few things that our own experience suggests should be understood by *everyone* who wants to be an effective contributor to the pursuit of sustainability. That essential foundation of general knowledge about sustainable development is what we have tried to convey in the remainder of this book.

In chapter 2 we present a framework for thinking about sustainability—a framework that links sustainability goals to their ultimate determinants. In particular, we follow a growing body of scholarship and practice in arguing that the ultimate goal of sustainable develop-

ment should be focused on human well-being. Moreover, we propose that well-being should be thought of inclusively; assuring the well-being of a few people today should *not* be achieved by degrading the well-being of their neighbors or their grandchildren. We suggest that the ultimate determinants of inclusive well-being should be thought of as the stocks of assets on which people now draw and will draw on in the future to subsist and to improve their lives—stocks that include natural, social, human, manufactured, and knowledge capital. Chapter 2 also explores the status of sustainable development today in terms of measures of inclusive human well-being and of the asset base that supports well-being.

Chapter 3 suggests that pursuing sustainability is complicated by the fact that efforts to do so play out in rather challenging ways in the social-environmental systems that humans inhabit. These are not simple equilibrium systems. Instead, they are complex, dynamic, adaptive systems that involve a great variety of interactions among social and environmental components, with all kinds of trade-offs and surprises in store. Focusing on a single component—for example, a new technology, a certain tropical rainforest, a particular type of material or pollutant, or particular new policy—in isolation from the rest of the system will rarely result in successful problem solving. Diagnosing problems and developing, implementing, and evaluating solutions requires an understanding of the system as a whole.

Developing knowledge of how coupled social-environmental systems work is necessary for making progress toward sustainability, but it is not sufficient. It is also necessary to understand how people, as active, committed agents of change, can intervene in those systems to make them work differently. Almost always, such interventions require collaboration to be effective. The governance processes that are the focus of chapter 4 are how society secures such cooperation in the face of conflicting goals, temptations to free ride, and the prevalence of outright selfishness. Governance systems, working at multiple levels, influence when and how society takes actions that promote or undermine sustainable development. Chapter 4 aims to characterize the nature and importance of governance processes and to give some practical guidance to those trying to reform such processes in ways that support the effective pursuit of sustainability.

New knowledge, tools, and approaches are also crucial determinants of sustainability. Unfortunately, however, even really innovative and exciting ideas cannot promote sustainable development if they are not actually used by decision makers. Chapter 5 discusses the challenges of creating useful knowledge and of linking such knowledge with action. It outlines approaches for increasing the chances that innovations will be useful and used effectively in decision making for advancing sustainable development.

Finally, in chapter 6, we try to tie the big ideas of previous chapters to their implications for individual people as agents of change. What should these big ideas mean to each of us? How can each of us, as individual agents, contribute to the pursuit of sustainability? What are the attributes individuals need to serve as leaders in a transition to sustainability? What type of training can help prepare such leaders? What can institutions of learning do to help? What should one remember when working in the world to promote sustainability?

The conceptualization of sustainability, the framing of sustainability goals, and the perspectives on meeting the challenges of sustainable development that we present in this book are certainly not the only approaches worth considering. (We list some different approaches we have found especially thought provoking in the “Additional Resources” section of appendix B.) Rather, they simply constitute the most useful framework that we three coauthors have been able to construct from our diverse experiences as professionals who both study and engage in efforts to promote a sustainability transition. We encourage our readers to push back on us when their values or experiences lead them to conclusions different from ours. We nonetheless hope that many of you will find in this short book some building blocks that can contribute to your own pursuit of sustainability.

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