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14 Epilogue—Beyond Pollution Control and Prevention: Sustainable Development

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Currently several environmental problems face both industrialized and developing nations. These include (1) chemical pollution, (2) climate change, (3) resource and energy depletion, and (4) the loss of biodiversity and ecosystem integrity. While often addressed separately, all four of these environmental problems are related to advancing industrialization, population growth, and the globalization of production and commerce. Societies that produce and consume more also tend to deplete more natural resources, create more pollution, produce more greenhouse gases, and have a relatively greater adverse impact on the ecosystem. In addition, the interconnectedness of nations through globalization has produced "lock-in" of, and dependence on, a particular development model. We believe that this model needs thoughtful reexamination.

Environmental burdens are often felt unequally within nations, between nations, and between generations, giving rise to intranational, international, and intergenerational equity concerns that are often expressed as a concern for environmental justice. Not only do environmental problems affect different people differently, but they are also addressed differently within and between nations and between generations. At present, global climate change, with its intergenerational consequences and with different implications for industrialized and developing nations, has captured center stage, but all environmental problems raise a variety of equity concerns.

This text on environmental pollution has focused largely on the first of the environmental problems identified above and has examined a variety of policies designed

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to reduce gradual releases of chemicals into the environment and/or the sudden and accidental releases associated with chemical mishaps. Historically, the approach to reducing pollution was framed independently of the approaches to the other three kinds of environmental problems. As we have seen, national approaches in the United States and Europe for reducing pollution have been evolving in the past four decades, first emphasizing the dispersion of pollution and waste (the ''dilution solution''), then end-of-pipe control, then waste and material exchange and consolidation (industrial ecology), and now (at least to a certain extent) pollution prevention and cleaner and inherently safer technology. Only recently has attention turned to system changes and the promotion of sustainable development. In evolutionary terms, these newer approaches lie beyond changing a single industrial process, transportation vehicle, energy source, or agricultural practice, and involve a larger set of fundamental changes than either pollution control or pollution prevention are likely to bring.

Incremental or even moderate improvements in energy efficiency, ecoefficiency, and dematerialization may not be sufficient to offset trends of increased pollution and increased energy and resource consumption tied to industrial and commercial development. Significant transformations may be needed in manufacturing, housing, agriculture, transportation, energy systems, services, and consumption patterns to reduce the impacts caused by pollution. For some, sustainable development implicitly focuses on environmental sustainability. For others, sustainability includes more far-reaching changes in (1) the nature and level of goods and services produced and used by a society, (2) employment, and (3) environmental sustainability. In other words, environmental concerns are ''nested'' within, and are connected to, wider concerns of competitiveness and employment.

A. THE UNSUSTAINABLE INDUSTRIAL STATE

Those who argue that the industrialized state, whether developed or developing, is currently unsustainable emphasize several problems. These are depicted schematically in figure 14.1. In the ''economic'' realm, there may be a failure of a society to provide adequate goods and services to all of its members. This of course places enormous pressure on an economy to produce more, but this in turn may increase the ecological footprint of that society. Environmental problems stem from the activities involved with agriculture, manufacturing, extraction, transportation, housing, energy, services, and information and communication technology (ICT)—all driven by the demand of consumers, commercial entities, and government. In addition, these activities have significant effects on the amount, security, and skill of employment, on the nature and conditions of work, and on the purchasing power associated

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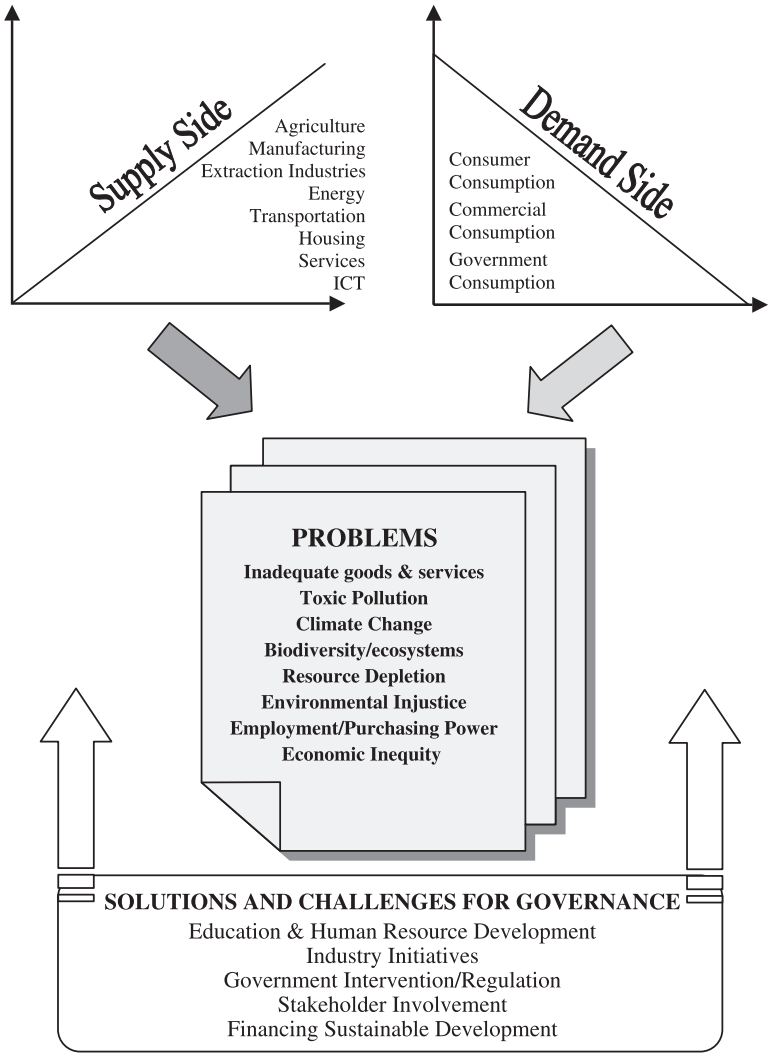

Figure 14.1
The sources and drivers of unsustainability, resulting problems, and solutions.

with wages. An increasing concern is economic inequity stemming from inadequate and unequal purchasing power within and between nations and for the workers and citizens of the future. Policies to increase employment are often fashioned in terms of producing (and consuming) more, again with adverse environmental consequences. On the other hand, reducing production to accommodate environmental pressures may create undesirable consequences for growth and employment. Is there a way out of this seeming dilemma in which one social goal must be compromised to satisfy another? Is it a question of achieving the proper balance among competing social goals? This may be the case only if a society remains technologically static.

Whether education, industrial initiatives, government intervention, stakeholder involvement, and financing will be able to solve these problems will depend on whether a number of fundamental characteristics of the modern industrial state can be corrected or overcome: (1) the fragmentation of the knowledge base, which leads to a myopic understanding of fundamental problems and the fashioning of single-purpose or narrowly fashioned solutions by technical and political decision makers, (2) the inequality of access to economic and political power, (3) the tendency toward ''gerontocracy''—governance of industrial systems by old ideas, (4) the failure of markets to correctly price the adverse consequences of industrial activity, and (5) the inherent failure of even ''perfect'' markets to deal adequately with effects that span long time horizons (for which correct pricing is not likely to be the answer).

B. CONCEPTUALIZATIONS OF SUSTAINABLE DEVELOPMENT

Whether one views sustainable development as just an environmental issue or as a multidimensional challenge in the three dimensions—economic, environmental, and social—makes quite a difference. We argue that competitiveness, environment, and employment are the operationally important dimensions of sustainability. Together these three dimensions drive sustainable development along different pathways and lead to different places than does a singular concern for environmental sustainability. The latter will almost invariably lead to tradeoffs, e.g., between environmental improvements and jobs or economic growth, that will ultimately be counterproductive. The interrelatedness of competitiveness, environment, and employment is depicted in figure 14.2.

A *sustainable development* agenda is, almost by definition, an agenda of *system* change. This is not to be confused with an *environmental policy* agenda, which is, or should be, explicitly effects-based: a program of policies and legislation directed toward environmental improvements and relying on specific goals and conditions. The sustainable development policy agenda focuses on products and processes (e.g., related to manufacturing, transport, energy, or construction), but extends to changes in technological and social systems that cut across many dimensions.

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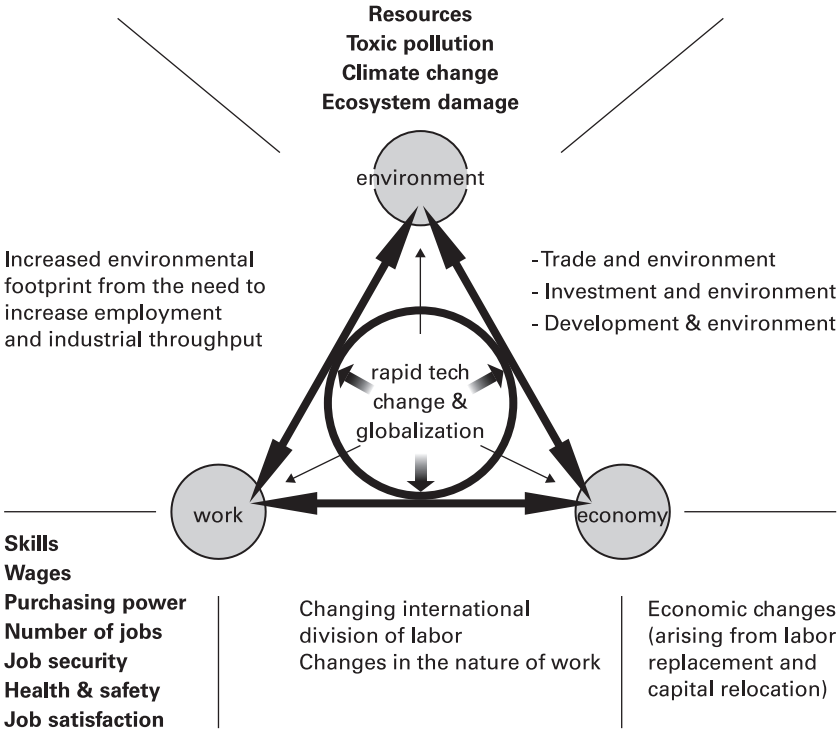

Figure 14.2
The dimensions of sustainability.

Note that *current strategy agendas*, even those that go beyond environmental goals, are focused on policies that (1) improve profit and market share by enhancing the performance of current technologies or by cutting costs, and by finding new sources of energy, (2) control pollution and/or make simple substitutions and changes and conserve energy and resources, or (3) ensure an adequate supply of appropriately skilled labor, and safe and healthy workplaces. See table 14.1. In the context of technological change, we would describe these strategies as reactive rather than proactive. Each usually is the responsibility of a different unit of government or a different department in the industrial firm, and each usually is pursued separately by different private sector stakeholders. At best, current policies affecting competitiveness, environment, and employment are *coordinated* but not integrated.

In contrast, *sustainable agendas* are those policies that are focused on (1) technological changes that alter the ways goods and services are provided, (2) the prevention

Table 14.1
The Interrelationship of Competitiveness, Environment, and Employment

Agenda	Competitiveness	Environment	Employment
Current	Improve performance/cut costs Find new sources of energy	Control pollution and make simple substitutions or changes to products and processes Conserve energy and resources	Ensure supply of adequately trained people; dialogue with workers Provide safe workplaces
Sustainable	Change nature of meeting market needs through radical or disrupting innovation (a systems change)	Prevent pollution through system changes Design safe and environmentally sound products and processes Change resource and energy dependence	Radical improvement in human–technology interfaces (a systems change)

of pollution and the reduction of energy and resource use through more far-reaching system changes, and (3) the encouragement of the development of novel sociotechnical systems—involving both technological and organizational elements—that enhance the many dimensions of meaningful employment through the integration, rather than the coordination, of policy design and implementation. Sustainable agendas address all important social goals simultaneously rather than in a piecemeal fashion.

C. INCREMENTAL CHANGE BY INCUMBENT FIRMS IS INADEQUATE FOR ACHIEVING SUSTAINABILITY

The kind of innovation likely to be managed successfully by industrial corporations is relevant to the differences between current and sustainable technology agendas. We argue that the needed transformations in products, processes, and systems may exceed the capacity of the dominant industries and firms to change easily, at least by themselves. Furthermore, industry and other sectors may not have the intellectual capacity and trained human resources to do what is necessary.

This argument is centered on the idea of ''the winds of creative destruction'' developed by Joseph Schumpeter[1] in explaining technological advance. The distinction between incremental and radical innovations—be they technological, organizational, institutional, or social—is not simply line-drawing along points on a continuum. Incremental innovation generally involves a series of continuous improvements, while

1. Joseph Schumpeter (1939) *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process*. McGraw-Hill, New York, as discussed in Jurg Niehans (1990) ''Joseph Schumpeter,'' in *A History of Economic Theory: Classic Contributions 1720–1980*. Johns Hopkins University Press, Baltimore, p. 448.

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radical innovations are discontinuous,[2] rather than evolutionary transformations, possibly involving *displacement* of dominant firms, institutions, *and ideas*. In semantic contrast, Clayton Christensen[3] distinguishes continuous improvements as "sustaining innovation" and uses the term "disrupting innovation" instead of radical innovation, arguing that both sustaining and disrupting innovations can be either incremental or radical, where the term "radical" is reserved for rapid or significant performance changes within a particular technological trajectory.

Thus in Christensen's terminology, a radical sustaining innovation is a major change in a technology *along the lines that the technology has been changing historically* (for example, a much more efficient air pollution scrubber) and is often pioneered by incumbent firms. A major innovation that represents an entirely new approach, even if it synthesizes previously invented artifacts, is termed "disrupting," and in product markets it almost always is developed by firms that are not in the prior markets or business. This is consistent with the important role of outsiders—both for existing firms and as new competitors—in bringing forth new concepts and ideas.[4]

Counting only or mainly on existing industries or on traditionally trained technical expertise for a sustainable transformation ignores increasing evidence that it is not simply willingness, opportunity, and motivation that are required for change. Another factor—the ability or capacity of firms and people to change—also is essential.[5] In some situations they may change because society or market demand sends a strong signal, but this is not true in all or even in most cases.

An essential concept in fostering innovative technical responses is that of "design space." As originally introduced by Tom Allen and his colleagues at MIT, design space is a cognitive concept that refers to the dimensions along which the designers of technical systems concern themselves.[6] Especially in industrial organizations that limit themselves to current or traditional strategies or agendas, there is a one-sided utilization of the available design space. Solutions to design problems are only sought along traditional engineering lines. In many cases unconventional

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2. Chris Freeman (1992) *The Economics of Hope*. Pinter, London.

3. Clayton Christensen (2000) *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*, 2nd ed. Harvard Business School Press, Cambridge, Mass.

4. Ibo de Poel (2000) "On the Role of Outsiders in Technical Development," *Technology Analysis and Strategic Management* 12(3): 383–397.

5. Nicholas Ashford (2000) "An Innovation-Based Strategy for a Sustainable Environment," in *Innovation-Oriented Environmental Regulation: Theoretical Approach and Empirical Analysis*, J. Hemmelskamp, K. Rennings, and F. Leone (eds.) ZEW Economic Studies. Springer Verlag, Heidelberg, New York, pp. 67–107.

6. Thomas J. Allen, James M. Utterback, Marvin A. Sirbu, Nicholas A. Ashford, and J. Herbert Hollomon (1978) "Government Influence on the Process of Innovation in Europe and Japan," *Research Policy* 7(2): 124–149.

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solutions that may or may not be hi-tech are ignored. For that reason, radical, disrupting innovations are often produced by industry mavericks or as a result of some disruptive outside influence (such as significantly new or more stringent environmental regulation, foreign competition, or the input of an outsider to the organization).

Given that a sustainable future requires technological, organizational, institutional, and social change, it is likely that an evolutionary pathway is not sufficient for achieving improvements of a factor of ten or greater in eco- and energy efficiency and reductions in the production and use of, and exposure to, toxic substances. Such improvements require more systemic, multidimensional, and disruptive changes. The capacity to change can be the limiting factor, and this is often a crucial missing factor in optimistic scenarios. Such significant industrial transformations occur less often within dominant technology firms than in new firms that displace existing products, processes, and technologies. This can be seen in examples of significant technological innovations over the past 50 years, including transistors, computers, and substitutes for PCBs.

D. THE ROLE OF GOVERNMENT

An intelligent government policy is likely to play an essential role both in encouraging the appropriate systemic responses and in assisting in the necessary educational transformations. As noted, successful management of disruptive product and process innovations often requires initiatives from outsiders to help expand the design space that limits the paths likely to be pursued by dominant technology firms. Rigid industries whose processes have remained stagnant will face considerable difficulties in any efforts to become significantly more sustainable. Shifts from products to product services will rely on transformations in the use, location, and ownership of products. Mature product manufacturers may participate in such transformations, but this will require them to make significant changes and will involve both managerial and social (customer) innovations. Changes in sociotechnical systems, such as transportation or agriculture, are likely to be even more difficult to achieve. This collection of formidable challenges, each involving one or a series of entrenched interests, suggests that the creative use of government intervention is likely to be a more promising strategic approach for achieving sustainable industrial transformations than reliance on policies that tend to emphasize firms' short-term economic self-interest.

This is not to say that enhancement of an industry's analytical and technical capabilities, and of its communication and cooperation with suppliers, customers, workers, and other industries (as well as environmental, consumer, and community groups), are not valuable adjuncts in the transformation process. In most cases, however, these means and strategies are unlikely to be sufficient by themselves to bring about significant transformations. Further, they will not work without clear, man-

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dated targets to enhance the triple goals of competitiveness, environmental quality, and employment.

Government has a significant role to play, but it cannot simply serve as a referee or arbiter of existing competing interests because neither future generations nor future technologies are adequately represented by the existing stakeholders. The government should work with stakeholders to define targets far into the future without allowing the agenda to be captured by the incumbents, and then use its position as trustee to represent future generations *and* future technologies. Through this process government should attempt to ''backcast'' the specific policies that will be necessary to produce the desired technical, organizational, and social transformations. To do this, government will need to go beyond its historical focus on coordinating public and private sector policies. Approaches for achieving sustainability must be multidimensional and must directly address the present fragmentation of governmental functions, not only at the national level but also among national, regional, and local governmental entities.

It may be unreasonable to expect that government can (or should) play too definitive a role in creating a future. Accordingly, rather than attempting tight management of the pathways necessary for the type of transformations that are sustainable in the broad sense in which we define the term here, the government role might be better conceived as one of enabling or facilitating change while at the same time *lending visionary leadership for cooptimizing competitiveness, environment, and employment*. This means that the various policies must be mutually reinforcing. This newly conceptualized leadership role—focused on opening up the problem space of the engineer and designer—will require the creative participation of more than one government department or organization. Without a collective approach, sustainable development is likely to remain an elusive goal.

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