1 Global Energy Shifts in World Historical Perspective

In the latter part of the nineteenth century, the citizens of Great Britain faced what seemed to be a bleak energy future. Commentators argued that the country's most important energy resource—coal—was destined to run out within a generation or so. At the same time, they argued that there was no viable alternative to coal. Two primary solutions to Britain's perceived energy crunch were therefore offered: Military strategists were urged to undertake expeditions to seize control of coal reserves in foreign lands, and companies were urged to drive their workers harder to increase domestic production of the resource. But these efforts were met with resistance from other colonial powers and from unions inside Britain. Meanwhile, cities across the nation grew increasingly choked with the sulfurous pollution flowing out of factories, railroads, and homes.[1]

Accounts at the time argued that Britain was destined to lose its global preeminence as its coal reserves disappeared and as social and environmental problems originating from the industry tore at the fabric of British society. In the eyes of many commentators, the resource that had once fueled the rise of the nation's fortunes had begun to contribute to the weakening of the British Empire.

Shifting forward in time, intriguing parallels between the "coal panics" that swept through Britain in the latter part of the nineteenth century and the "oil panics" that grip the world today are clear. The world's oil infrastructure is threatened by insurgencies in many countries, and there are widespread fears that reserves of oil will be unable to meet world demand within a decade or so. At the same time, many analysts claim that there are few viable alternatives to oil. Likewise, the recommendations that flow from this view rather eerily echo those proposed in the nineteenth century. Governments across the world are again being urged to seize military or commercial control over key oil reserves, and local officials in many countries are being urged to remove constraints on domestic oil extraction to maximize production.[2]

But resistance to these efforts is even fiercer today than it was in the nineteenth century. Oil-producing countries like Saudi Arabia, Iran,

and Venezuela are protecting their independence from external pressure. Meanwhile, social chaos is engulfing countries like Iraq, Nigeria, and Russia and undermining their ability to provide oil to the wider world-economy. Given these constraints, competition for oil reserves is escalating between large consumers like the United States, the European Union, and China. Underlying these pressures is a host of growing environmental dangers. From deteriorating local air quality to the many dangers posed by climate change, there is widespread consensus in the scientific community that overreliance on fossil fuels must soon end if ecological catastrophe is to be avoided.[3]

If long-term stability is to be achieved, significant reforms must clearly be made in our global energy system. But can fundamental changes really be made in time to avoid severe strategic, commercial, social, and ecological crises? Although this is a question that cannot be definitively answered, the historical record shows that remarkable changes in the global energy system have occurred in the past, which should allow for some cautious optimism that similarly profound transformations can be achieved in the future.

Consider, again, the example of Britain. With hindsight we can see that nineteenth-century analysts were wrong to claim that there were no alternatives to coal. How were they to know that a new resource—oil—would ease Britain's energy crunch? After all, it played almost no role in providing energy in that society in the 1870s and 1880s. But by the beginning of the twentieth century, the British government and private industry were spearheading a shift toward increased reliance on this new resource. This transition was given added urgency as social and environmental tensions emerged around coal sectors. As a result of these intersecting forces, by the end of the First World War oil had become the fastest growing source of energy in Britain.

This shift toward oil was repeated in country after country, beginning in the United States and spreading to countries as diverse as France, Russia, Japan, and Australia. In fact, within a few decades the first global energy shift of the modern era—toward increased reliance on oil—was well underway. And even as the world was rocked by the First World War, the Great Depression, and the Second World War, investments in oil-based technologies and infrastructures continued doggedly ahead. Massive new fleets of ships, trucks, cars, and airplanes were built, and entire regions of the world were incorporated into a new energy system based on oil. The speed and magnitude of this shift, carried out during very turbulent decades, was quite breathtaking.

Current claims that little can be done to shift away from overreliance on oil sound rather defeatist in light of the transformations that were

achieved in the global energy system during this earlier period. Just as many nineteenth-century analysts were unable to conceive of changes that would bring oil flooding into a system dominated by coal, many contemporary analysts seem unable to imagine conditions that could foster the rapid growth of alternative energy systems and bring new forms of renewable power streaming into a system that is currently dominated by fossil fuels. They argue that alternative energy sectors are not yet viable or that the capital does not exist to fund major new infrastructures. These claims overlook the achievements of the early twentieth century, when new financial investments were undertaken in the toughest of times that propelled the development of new energy industries forward.

Although there can be no guarantees about what will happen in the coming decades, there are many reasons to believe that shifts of the magnitude and speed achieved in earlier eras can again sweep through the global energy system. As the historical analysis carried out in this study will show, entirely new systems of energy production, transportation, and consumption have repeatedly enveloped the world in a period of about fifty to sixty years. This remarkable history of transformation should give concerned citizens the confidence to move forward with efforts to reform the energy foundations of the contemporary world.

An Empirical Overview of Global Energy Shifts

In this study, an energy system is defined as originating from the naturally occurring, primary resource that is harnessed for human use. Primary energy resources include, for instance, wood, coal, oil, natural gas, radioactive energy, running water, wind, and solar power.[4] An individual energy system, then, is defined as the interconnected network of production, transportation, and consumption that delivers one of these specific energy resources to people for use in their daily lives. The global energy system, meanwhile, is the even more complicated totality of these individual energy networks. As will become clear in the coming chapters, events in one energy system can have reverberating effects throughout the other systems and can even cause long-lasting transformations in the structures of energy production and consumption on a global scale.

Over the long arc of human history, the relationship between primary energy resources and technological systems has become increasingly complex. Today it is often difficult to determine the source of the energy that powers the machines we use. Consider, for instance, the case of electricity. Although electricity occurs naturally as lightning and static, these natural forms cannot easily be captured for human use. Technologies

have therefore been devised to transform a variety of primary energy resources—like coal, natural gas, nuclear power, and running water—into electricity. These different streams of electricity are then fed into a utility grid, which distributes energy to any light, appliance, or motor connected to the network. Because electricity is clean and quiet at the end-point of consumption, its origins in coal, oil, natural gas, and uranium are hidden from view.

One way of piercing through the complexity of modern energy industries and getting at key underlying features of the global energy system is by focusing an analytic lens on the primary resources that are being harnessed for human use. Looking at the primary energy resources that are being fed into the world's energy grids will render visible important features of the global energy system that may otherwise be obscured.

For this reason, the point of departure of this study is an investigation of patterns in the extraction and consumption of primary energy resources. From this perspective, an energy shift is defined as the process whereby a new primary energy resource is harnessed for large-scale human consumption. This incorporation may occur through the creation of new technologies, or through the resource being fed into preexisting systems. But whatever the intermediate process might be, the underlying material fact is that a new source of energy is being captured for use.

Adopting this resource-based perspective allows for a straightforward depiction of successive waves of incorporation of energy over the modern period. The first modern energy system, based on coal, grew steadily in the nineteenth century and reached maturity in the twentieth century. The second modern system, based on oil, expanded rapidly during the twentieth century and is now reaching maturity. Systems based on natural gas and hydroelectricity are also in the process of attaining global reach. Meanwhile, nuclear power industries have expanded in certain regions of the world, but they are not likely to be capable of becoming truly global in scale. Finally, systems based on renewable energy sources such as wind and solar power are beginning to gain regional importance, although they are not yet near attaining a global scale.

Figure 1.1 shows shifts in the percentage of the world's commercial energy provided by the most important primary resources over the last two centuries. The figure demonstrates that, in 1800, most of the world's commercial energy came from wood and other biomass materials. Of course, since these biomass resources tended to be harvested and consumed in small-scale operations, data on their use have to be treated with caution. Once we turn to coal and other industrial resources, though, the empirical record becomes more reliable.[5]

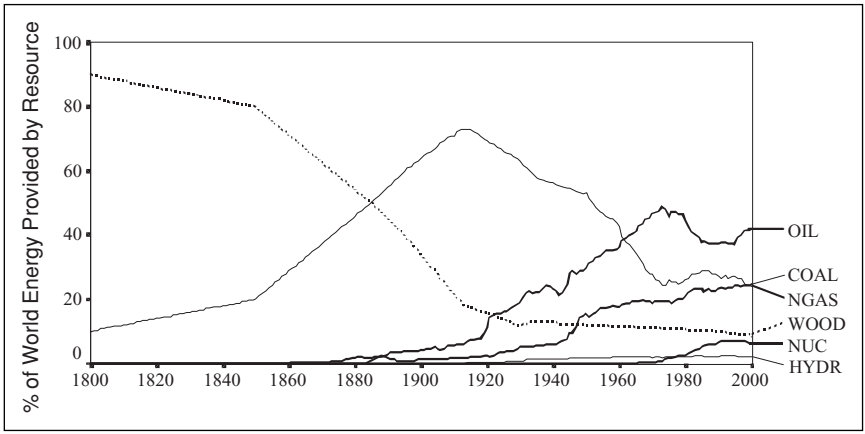

FIGURE 1.1. Global Energy Shifts, 1800–2000
Sources: See Appendix A.

According to data compiled by historians, coal went from providing approximately 10 percent of the world's commercial energy in 1800 to over 60 percent in 1913. This shift to reliance on coal was very rapid when compared to the time it took for preindustrial societies to harness the power of resources such as wood and wind. Still, the speed of the shift to coal pales in comparison with what came later.

It took over a hundred years for the coal system to mature to the point where it was providing 50 percent of the world's commercial energy supplies. The shift to reliance on oil was much more rapid. In 1910, oil provided only about 5 percent of the world's commercial energy supplies. Sixty years later, though, oil was supplying approximately 50 percent of the world's energy. Natural gas has also undergone a rapid process of growth; whereas it provided only about 6 percent of the world's commercial energy in 1946, by the year 2000 it was supplying about 24 percent (about the same as coal's contribution). A central goal of this study is to uncover the factors that allowed for the rapid expansions that have occurred in these fossil fuel industries.

Not all commercial energy industries have undergone such rapid and sustained trajectories of growth. Nuclear power experienced some expansion in the 1970s and 1980s, but by the late 1990s it had reached a plateau at about 6.5 percent of primary world energy supply. Energy from hydroelectric facilities, meanwhile, underwent slow growth throughout the twentieth century, so that by the year 2000 hydroelectricity was providing about 3 percent of the world's commercial energy. Meanwhile, all modern

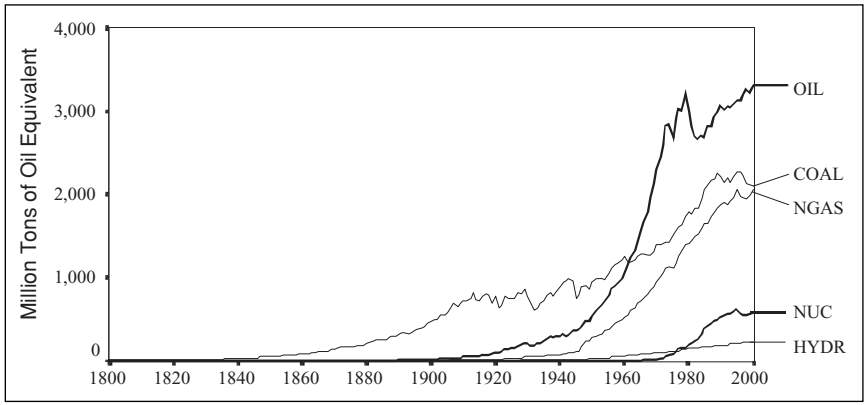

FIGURE 1.2. World Commercial Energy Production, 1800–2000
Sources: See Appendix A.

renewable energy systems (including wind, solar, geothermal, and modern biomass) combined provided only about one half of 1 percent of the world's commercial energy in the year 2000. This is, of course, a sobering statistic for anyone concerned with the environmental viability of modern society.

Another way to map these successive waves of incorporation is by looking at the volume of energy being absorbed into human societies. To create this kind of figure, though, we first need to transform the wide variety of energy resources we are examining (tons of coal, barrels of oil, and so on) into a common unit. This analysis follows many other energy studies by using one metric ton of oil equivalent as the common unit. Taking the amount of energy contained in one average metric ton of oil as a basic unit, it is a straightforward operation to calculate how many of these energetic units are contained in a given quantity of coal, natural gas, or any other resource.[6] Once this transformation is carried out, we can create a graph that depicts the volume-based growth of primary energy resources over the modern period on the basis of a common metric.

Figure 1.2 provides this alternative representation of global energy shifts. The volume of coal production (measured here in tons of oil equivalent) grew steadily up to 1913, entered into stagnation until 1945, and then resumed modest growth in subsequent decades. Oil production, on the other hand, is marked by exponential growth in the period 1945–1973 and then by volatility since that time. For its part, natural gas has achieved rapid and steady growth since the Second World War. Nuclear power output achieved significant growth in the 1970s and 1980s, but then plateaued. Hydroelectric power production has maintained a slow but steady growth

rate since the early 1900s. Meanwhile, modern renewable energy systems provide such a tiny proportion of the world's energy that they do not even register in the figure.

There are a number of important observations to be made about the patterns of evolution in energy industries that emerge from these empirical pictures. What is perhaps most remarkable is the speed with which huge volumes of energy can be incorporated into the world-economy. Oil went from providing about 44 million tons per year in 1910 to around 3 billion tons per year in 1970. This phenomenal rate of increase in oil production has almost been matched by the expansion of natural gas. In fact, from 1940 to 2000, natural gas output rose from 76 million to over 2 billion tons of oil equivalent per year. Given the right constellation of circumstances, massive volumes of new resources can clearly be incorporated into the global energy system in a handful of decades. If these new resources can be integrated into preexisting infrastructures and commodity circuits, then the rate of absorption of new resources can be accelerated even more.

It is important to point out, though, that these new energy systems have been superimposed on top of older systems that continue to expand. The shift toward greater reliance on coal that occurred in the nineteenth century, for instance, was overlaid on a world that was using ever-growing quantities of wood. Similarly, the shift toward increased dependence on oil and natural gas that took place in the twentieth century was layered on top of a still-growing coal system.

The energy shifts that have occurred in the modern era have therefore been relative rather than absolute shifts. That is, while a higher percentage of the world's energy is now coming from oil and gas, coal consumption continues to grow in absolute, volume terms. Overall, global reliance on hydrocarbon resources has increased exponentially throughout the modern era. In fact, today coal, oil, and natural gas resources combined provide approximately 90 percent of the world's commercial energy requirements. At some point in the future, however, an absolute shift will have to be achieved where systems based on coal, oil, and natural gas are replaced by something else. Since coal is very plentiful, pressures will always exist to revert back toward greater reliance on this very polluting resource. With careful preparation, though, a shift toward cleaner, more environmentally benign energy systems can be achieved.

Achieving a shift away from hydrocarbons and toward modern renewable energy resources may seem impossible from today's perspective. However, it is clear that the global energy system has gone through important periods of profound, nonlinear change in the past (Smil 2003). The key challenge is to develop an understanding of what caused these earlier

transformations, and then foster a similarly profound shift in the coming decades.

The conceptual tools of world historical analysis will illuminate the underlying societal dynamics that have generated profound transformations in the global energy system in the past and will continue to do so in the future. How this particular research tradition can help make sense out of the nonlinear transformations that are etched in the historical trajectory of the global energy system is described below.

A World Historical Interpretation of Global Energy Shifts

One of the most important research traditions in the social sciences centers on the effort to come to an understanding of the historical origins, contemporary dynamics, and likely future trends of the capitalist world-economy that has come to incorporate the entire globe. While it is readily acknowledged that there are always elements of unpredictability in human affairs, a broad number of scholars argue that there are discernible patterns of evolution that underlie the development of this world-economy. It is hoped that, by coming to a better understanding of key trajectories of societal evolution operating within the system, our ability to intervene in intentional ways to reform problematic aspects of our globalizing world can be enhanced.

The scholars who have most clearly articulated this approach operate within what has come to be known as the world-systems perspective. This perspective was first introduced in an explicit way by Immanuel Wallerstein in his influential book *The Modern World-System* (1974). Drawing on theorists such as Marx, Weber, and Braudel, Wallerstein argued that a capitalist world-system came into existence in Europe in the sixteenth century. Following its creation, this world-system expanded to incorporate ever-wider geographical areas in intensifying networks of political, economic, social, and cultural interaction. Once incorporated into the system, nations, industries, or communities could no longer be treated as independent units. They instead had to be seen to be heavily affected by changes in the broader world-system, and their actions likewise often reverberated throughout the system.

Over the last twenty-five years, researchers from such disciplines as sociology, political science, economics, and history have contributed to the effort to uncover patterns of continuity and change in the evolution of this world-system.[7] From all the insights generated in this world historical research tradition, four are particularly relevant to an analysis of global energy shifts. The first is that world events in general, and global energy

transitions in particular, are driven in part by a dynamic of geopolitical rivalry that fluctuates between periods of intense and moderate conflict. The second is that there is a process of corporate competition that also alternates between periods of radical industrial innovation and periods of more predictable growth. The third is that dynamics of social conflict likewise go through alternating phases of radical and moderate intensity.

The fourth is that these systemic dynamics of geopolitical rivalry, commercial competition, and social conflict interact in a process known as the hegemonic sequence. The modern world has repeatedly alternated between periods of relative order, during which a great power (or hegemonic state) is able to impose stability across the globe, and periods of chaos, in which powerful countries compete for dominance. During periods of relative order, international conflict is contained, commercial prospects are enhanced, and social unrest is more or less suppressed. Periods of chaos, however, are characterized by warfare, economic crisis, and radical outbreaks of social conflict.

Transitions from periods of world order to world chaos profoundly impact the global energy system. As this study will demonstrate, periods of relatively linear, predictable growth in global energy systems are achieved during times when a hegemonic state is able to contain dynamics of geopolitical, commercial, and social competition within moderate frameworks. Conversely, periods of more profound change in global energy systems occur when hegemonic stability breaks down and the pressures of warfare, economic crisis, and social conflict can no longer be contained.

This, then, is a brief summary of the key conceptual tools used in this study of global energy shifts. Below is a more detailed discussion of the ways in which each of these systemic dynamics individually impact energy industries, as well as the way they periodically interact to produce global energy shifts.

Geopolitical Rivalries and Global Energy Shifts

One of the most enduring features of the modern world-system has been that of geopolitical rivalry among nation states for military and economic primacy.[8] Since long-term military strength is intimately tied to the economic health of a given state, political leaders have often intervened in commercial matters, especially in sectors that are judged to be of strategic significance. This state intervention has been particularly common in the case of energy industries.

The efforts of empires and nation states to stimulate domestic energy production and to gain access to foreign energy resources have a very long history. As early as the fifth century B.C., the city-state of Athens employed

force to compel its hinterlands to provide wood resources for energy and construction purposes. This state-enforced exploitation of wood grew during the Roman Empire, while authorities throughout China, India, North Africa, and Western Europe also came to intervene in circuits of wood production and consumption in the classical and medieval periods.[9]

In the modern period, state intervention in energy sectors has in some ways waxed and waned. During the Napoleonic Wars, for instance, state agents in Britain and France engaged in many efforts to increase their own coal output while simultaneously attacking enemy mining operations. State intervention in coal eased once these wars came to an end, only to intensify again later in the nineteenth century as coal-powered industries became critical to modern war machines. This interventionist dynamic was further strengthened during the First and Second World Wars, when key adversaries struggled to maximize their access to coal and oil supplies for military campaigns. The current era is witnessing a renewed intensification in state intervention as powerful nations across the world struggle to secure access to affordable oil resources.

Although there has been a shift between periods of strong and moderate intervention, states have rarely retreated all the way back to laissez-faire policies in times of peace. Instead, there has been an expansion of state mechanisms for influencing energy industries. Early state action was limited to, for instance, seizing private coal reserves for use in battle or conscripting laborers to work in mines. By the eighteenth century, however, governments began using a variety of regulatory, fiscal, and procurement tools to facilitate the expansion of domestic energy operations. In the nineteenth century many governments also started funding research and development programs designed to improve the operation of specific technologies and to further the scientific understanding of energy combustion processes. By the twentieth century, leading states were regularly utilizing a range of overt and covert strategies to secure access to key energy supplies. And in recent decades, multilateral agencies such as the World Bank and the International Energy Agency have developed some capacity to influence energy industries and markets on the international level.

We can trace these dynamics of state intervention in energy sectors thanks to important work carried out by a broad number of historians and social scientists. McNeill's (1982) analysis of the industrialization of warfare, for instance, is crucial for comprehending the growing degree of state intervention in modern energy industries. Meanwhile, Fine (1990) and Fremdling (1996) provide good descriptions of government influence in coal sectors, and a host of scholars have examined state interventions in the international oil system. Of particular note are the studies offered by Yergin (1991) and Nowell (1994).[10] More recent work by Bunker and

his colleagues[11] and by Harvey (2003) and Klare (2004) demonstrates that states continue to intervene extensively in energy industries in the current period.

As important as state support is for emerging energy systems, the historical record shows that governmental interventions alone are not enough to foster the full maturation of an energy technology. In fact, this study will demonstrate that dangers emerge when state officials try to push energy industries forward irrespective of commercial and social resistance. The case of nuclear power reveals the danger of this kind of state overreach in particularly clear terms. Still, interventions by an era's most powerful nations have always played a critical role in successful global energy shifts. A future shift to more sustainable energy technologies will similarly require important levels of support from political authorities in many countries across the world.

Corporate Competition and Global Energy Shifts

Innovations in the world-economy are also propelled forward by competition among private firms for dominance in key commercial sectors.[12] During the modern era few arenas have been as profitable as those that provide energy resources to industry and consumers. As a result, the global energy system has long attracted the attention of entrepreneurs and private corporations. The resulting dynamics of commercial competition have had a profound impact on the global energy shifts that have taken place in the modern period.

Over the last two centuries, commercial energy industries have tended to shift from situations of intense corporate competition to ones of controlled, oligopolistic competition. Most coal mining regions, for instance, first saw the emergence of many small companies that engaged in cutthroat forms of competition. Over time, many of these regions went through processes of industrial consolidation that left a select group of companies dominant in regional or national industries. This shift from cutthroat to oligopolistic forms of competition was even more marked in the case of oil. A select group of oil companies were able to expand their operations to national and international levels, so that the entire oil system quickly became dominated by a small number of firms that worked together to limit intense competition. Both the coal and oil industries, however, witnessed periodic breakdowns in these industrial truces. The reintensification of corporate competition that ensued then helped set the stage for major shifts in each of these industries.

The rise of the multinational oil corporation stands as a remarkable case of entrepreneurial growth and innovation in the face of significant market

challenges. As discussed in later chapters, oil prices were higher than coal prices in most markets when oil firms began their rapid expansion. And as oil companies began penetrating into established markets, coal companies tried to mobilize public opinion and government influence against oil. The oil companies that succeeded in winning markets away from coal clearly did so in extremely competitive environments.

The ability of oil companies to grow in the midst of challenging market conditions highlights the capacity for commercial innovations to be achieved in what are often assumed to be static energy industries. The business history of energy shows that firms can overcome significant price hurdles and open up new arenas for market expansion and profit making. Understanding the forces that have allowed for major shifts in the global energy system requires examination of corporate competition and innovation in global energy industries.

Social Conflict and Global Energy Shifts

While political and commercial dynamics have long been recognized as major forces of global change, processes of social conflict have less often been accepted as being of similar significance. A growing number of scholars working within the world historical tradition, however, have come to argue that dynamics of social conflict have a central role in the evolution of the capitalist world-economy and the energy industries embedded within it.

It was, of course, Karl Marx and Friedrich Engels (1848) who most ardently maintained that human history is driven by processes of class conflict. More recent scholars, such as Hobsbawm (1962), Gordon (1980), and Mandel (1980), have lent added weight to these early claims. Recent work by Beverly Silver (2003), meanwhile, draws together historical evidence of both a qualitative and quantitative nature to demonstrate that the long-term impact of social conflict on the world-system has been as profound as the forces of geopolitics and commercial competition.

Dynamics of social conflict have had far-reaching impact on the historical evolution of large-scale energy industries. Struggles carried out by coal miners to protect their livelihoods and communities, for instance, changed work procedures, wage rates, and safety regulations in coal sectors throughout the world. Oil industries, for their part, have been transformed by labor and nationalist struggles with deep roots in civil society. Campaigns undertaken by environmental and indigenous rights movements have constrained the expansion of hydroelectric and nuclear projects.[13]

Over the course of the modern era, we can document a rise and fall in the social tensions surrounding energy industries in particular locations.

For instance, waves of labor militancy swept through coal industries in Europe and North America in the late nineteenth century and then again after the Second World War. Within oil, social tranquility was more or less maintained until the latter part of the twentieth century. But then workers and citizens in key oil-exporting nations began participating in campaigns to overturn corrupt regimes and nationalize petroleum industries. While phases of intense social conflict eventually gave way to times of compromise and moderation, they left lasting changes in their wake. Union organizations consolidated their influence in many coal regions, for example, while nationalist movements retained important degrees of control over domestic oil industries.

Over time the types of social movements impacting energy sectors and the strategies they employed have multiplied. Union campaigns have grown in sophistication, often coming to employ experts from the worlds of law, politics, and media. Nationalist movements have made even more successful use of political campaigns, while contemporary environmental and indigenous rights groups have used tactics like demonstrations, media campaigns, consumer boycotts, and legal challenges in their attempts to reform energy industries. In the current period, insurgent groups such as al Qaeda are using even more extreme tactics to destabilize operations and destroy energy infrastructures in critical regions.

Given the pervasive influence of social movements in the evolution of modern energy systems, it is surprising that the mainstream energy literature has so often treated workers and activists as irrelevant or passive agents.[14] This inattention to social dynamics of unrest is one reason why mainstream analysts have been frequently unable to forecast eras of radical change in global energy industries. One of the main goals of this study, then, is to advance our understanding of this previously underexamined dimension of global energy shifts. By documenting the various ways that social conflict has provoked periods of fundamental, nonlinear change in the past, we will be better able to understand how such dynamics are likely to operate in the future.

The Hegemonic Sequence and Global Energy Shifts

The systemic dynamics of geopolitical rivalry, commercial competition, and social conflict each partly follow their own trajectories. Indeed, as subsequent chapters will demonstrate, individual dynamics can at times move to the forefront in causing change in energy industries. However, it is my contention that for energy shifts to become truly global in scale, each of these systemic dynamics must be operating together in strongly

transformative ways. This convergence of influences is most likely to occur at times of world crisis, when great powers are in decline and all facets of the world-system are in flux. Though the rest of this study fleshes out the argument in more detail, what follows here is an overview of this relationship between the hegemonic sequence, the interaction of systemic dynamics, and the consolidation of energy shifts on a global scale.

The British and American periods of hegemonic order each rested upon the growth of each era's key energy resources. Early successes in the pioneering of new energy systems gave each rising great power important advantages over its competitors. These resource advantages were important in determining which state would emerge victorious in times of war. Once a new world order had emerged, the careful distribution of energy resources fostered alliances and enhanced the perceived legitimacy of the political order maintained by the leading state.[15] During these periods of hegemony, dynamics of commercial competition and social conflict were also kept within moderate frameworks, which provided the stability required for the maturation of the era's key energy industries.

A central characteristic of human history, however, is that no world order has ever been sustained in perpetuity. Instead, hegemonic powers have consistently lost their technological and financial leads as new competitors have emerged. Dynamics of corporate competition have become more chaotic in periods of late hegemony, and declining hegemonic powers have tended to overextend themselves militarily in efforts to retain dominance. This has intensified social unrest at home and throughout the world. Ultimately, the ability of the declining hegemon to contain chaos evaporates, and a new period of intense, often violent interstate conflict ensues.

It is during these periods of world chaos that fundamental changes most readily occur in the global energy system. This study will show, for instance, that the first era of transition in energy systems in the modern period—the shift from coal to oil that took place during the mid-twentieth century—corresponds to a period of hegemonic crisis when all three systemic dynamics became radically transformative in nature. Geopolitical tensions escalated, prompting large-scale interventions by leading states in the accelerated development of oil systems. Private corporations, which had already begun investing in new oil industries, were then able to greatly expand the scale of their operations, and an intensification of labor conflict in coal industries throughout the world undermined profits and confidence in maturing coal sectors. Given these multiple pressures, the transition toward oil was remarkably rapid and far-reaching.

A second period of significant change in the global energy system, the crisis of the 1970s, similarly corresponds to a time of hegemonic crisis.

Weakened by its military campaigns in Southeast Asia, the United States temporarily lost its ability to contain threats to the international oil system. Corporate rivalries in oil markets intensified, and social unrest in key oil-producing nations exploded. These conditions then set the stage for a wave of nationalizations and price adjustments to sweep through international oil markets. However, in the early 1980s the United States and its allies reestablished their capacity to impose order in key oil sectors, which fostered a shift back toward primary reliance on the resource. Systemic turbulence declined in the face of this retrenchment, and the global energy shift toward more sustainable technologies stalled.

The collapse of socialist regimes in Eastern Europe, the rapid defeat of Iraq in the first Persian Gulf War, and strong economic growth in the United States and East Asia were taken by many as proof that the United States had begun a second phase of hegemonic leadership in the 1990s. However, most world-systems researchers argue that the United States has remained trapped on a trajectory of decline.[16] Their arguments appear particularly prescient today, following the series of terrorist attacks and international conflicts that have again called into question the stability of a world order led by the United States. Security threats have multiplied, financial crises have rippled through the world-economy, and military campaigns spearheaded by the United States have undermined the perceived legitimacy of this nation's global project in the current period.

This contemporary period of world disorder may escalate into catastrophic crisis. If that were to occur, the stability of the global energy system would, of course, be one of the least of our concerns. However, there may be a silver lining in these times of trouble. As the historical record shows, global energy shifts occur most readily during eras of turbulence and chaos. Indeed, as the conclusion of this study will argue, the current era of crisis provides a unique opportunity for governments, corporations, and communities across the world to mobilize in favor of a shift to a more sustainable global energy system.

Human Agency and Global Energy Shifts

My interpretation of global energy shifts emphasizes the central role of human institutions and conflicts in influencing the evolution of large-scale energy industries.[17] This is an argument that departs from those that draw on more deterministic models, which are not particularly helpful in shedding light on modern energy shifts so long as they ignore the ways in which societal dynamics foster large-scale changes in the global energy system.

Early research on the historical evolution of energy industries is marked by a strong current of resource determinism. In the formulations of Jevons (1865), Ostwald (1909), and Carver (1924), for instance, shifts from one source of energy to another were seen to have been caused mainly by the effects of resource depletion. While resource depletion has played a role in some energy shifts, however, modern transitions have not generally been associated with resource scarcity effects. For instance, most shifts toward greater reliance on oil have taken place in countries that still have abundant supplies of coal. A simple model based on resource depletion cannot account for these increasingly common shifts.

Another version of resource determinism focuses on the characteristics of specific resources and maintains that these qualities are what drive energy shifts. For instance, there is a widespread belief that physical features of oil—the fact that it is a liquid or that it burns well in small engines—are what determined its eventual triumph over coal. This interpretation, however, overlooks other characteristics of oil—the fact that it explodes or that it needs to be refined—that led many people to question its usefulness in earlier eras. Instead of winning converts because of its physical properties, oil-based systems had to be aggressively marketed before they attained popular acceptance. While the physical characteristics of energy resources certainly play some role in their diffusion, analyses that focus exclusively on this dimension are prone to neglect the societal dynamics that more profoundly influence large-scale energy shifts in the modern age.

In raising questions about narrowly deterministic perspectives, I am not attempting to entirely discount the impact that resource endowments have on transformations in the global energy system. Each has a role to play in setting the material constraints within which human institutions operate. As new energy technologies are developed, material constraints are at least temporarily eased. But if available resources fail to keep up with growing demand, these constraints tighten. Over the period 1800–2000, material constraints were never rigid enough to propel large-scale energy shifts on their own. Instead, competitive dynamics within human societies were the central forces driving transformations during an era of abundant energy. But energetic constraints on human societies have not always been loose, and they are not likely to remain so in the future.

In premodern times, technological innovations occurred relatively infrequently and they added only modestly to the energy supplies available for human use. As a result, consumption generally pressed close up against the limits of resource availability. Indeed, there were cases in which premodern societies overtaxed their resource base, leading to intensified social conflict and even civilizational collapse.[18]

During the modern era, the exploitation of fossil fuel reserves allowed energy production to greatly outstrip established consumption requirements, and material constraints on the global energy system therefore became quite loose. We are now, however, entering a new phase in which fossil fuel consumption will need to be scaled back—first for environmental reasons, and then because of depletion effects—while consumption continues to grow rapidly. As a result, the global energy system is again entering a period of tightening resource constraints.

One intriguing thing about the current period is that resource constraints are drawing tighter just as the capacity for human beings to alter energy trajectories is growing stronger. In the past, social groups have generally intervened in uncoordinated ways. The history of energy shifts, therefore, has often been a tale of the unintended consequences of human intervention. Today, though, coordinated efforts are being carried out on many levels to devise solutions to our energy crises. Political elites are beginning to construct international agreements and institutions designed to facilitate the global expansion of renewable energy systems. Multinational energy corporations are increasing their investments in renewables to spread their risk and position themselves for success in emergent sectors. Environmental groups are intensifying their efforts to contain the most damaging kinds of energy projects while pushing for a more rapid expansion of renewable energy technologies. These coordinated efforts provide hope that a future global energy shift can be achieved even more quickly than those that have occurred in the past.

When analysts in nineteenth-century Britain surveyed their energy options, the horizon of possibilities they could consider were much more limited than ours are. Today we can find inspiration in the fact that a new energy system, based on oil, spread across the world during the most chaotic and violent decades of the twentieth century. This provides hope that new energy systems, based on renewable technologies, can begin similar trajectories of growth even in the turbulent era that lies ahead.

There are, of course, no certainties when it comes to forecasting what will happen in the global energy system. But it is important that concerned citizens across the world forge ahead with the knowledge that fundamental changes can be achieved. Just as the gloom of late-nineteenth-century Britain gave way to unexpected new energy horizons based on oil, the current era of crisis can similarly give way to a new era of hope as renewable energy industries are encouraged to replicate rapid expansion cycles. Advocates of this kind of future global energy shift need not be utopians. We can instead proceed with a historically grounded, realistic, and yet ambitious agenda of transformation in the coming decades.