CHAPTER 9

ENERGY CONSUMPTION TRENDS ACROSS THE GLOBE

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ALL societies, like all living things, require energy. Therefore, finding energy sources has been an unavoidable concern of all societies, be they Paleolithic tribes that sought out wood to cook with, or twenty-first-century post-industrial nations that build wind farms to power their Internet servers. In many respects, societies can be characterized by how much energy they consume and the sources of energy they utilize. In our era of anthropogenic climate change, caused in major part by the burning of fossil fuels, the degradation of most major river systems around the world from hydroelectric dams, and radioactive contamination from nuclear waste and accidents at nuclear power plants, understanding the energy use of societies could not be more important.

In this chapter, I examine global and national-level trends in how much energy societies use and what sources of energy are exploited. In my presentation, I offer some explanations for the political and economic forces driving trends in energy use. I begin with a brief summary of long-term changes in energy use, and then I focus on examining three major features of energy use in recent decades and their implications. First, I examine the growth of energy use and electricity consumption around the world, and note the striking diversity across nations. Second, I review trends in aggregate energy efficiency of national economies, and I show how improvements in efficiency have not been particularly effective at suppressing energy use. Third, I look at the development of renewable energy sources and consider the degree to which this development has affected fossil-fuel use.

HISTORICAL ENERGY TRENDS

One remarkable thing about humans is the extraordinary variability of energy consumption across societies. This variability generally increased over the course of human history, and became especially dramatic following the Industrial Revolution, when some societies came to consume vast quantities of energy, while other societies subsisted on very modest levels of energy consumption (Smil, 1994). Although coal and peat have been exploited sporadically since at least antiquity, fossil fuels did not start to become major global energy sources until the end of the eighteenth century, after which coal consumption grew exponentially (Smil, 1994). By the time petroleum became a major energy source toward the end the nineteenth century, fossil fuels were the dominant energy sources in industrializing nations. Biomass, such as wood and animal- and vegetable-based oils, became less important as sources of energy as fossil-fuel use grew explosively, although in an absolute sense biomass consumption levels remained high and grew over the industrial era, though their proportion of the energy supply declined rapidly. Animal power, for industry (where, for example, oxen turned wheels for energy) and for transportation (e.g., horses), declined rapidly in economic importance with the expansion of the coal-powered steam engine, the train, and the automobile.

Over the course of the twentieth century, electricity became an especially important form of energy for industrializing societies, powering cities and factories. Power plants fueled by fossil sources, particularly coal, provided much of this electricity. However, large dams and, starting in the latter part of the twentieth century, nuclear plants produced a large amount of electricity in many nations. More recently, wind and solar sources have begun to contribute noticeably, although typically still very modestly, to electricity production in some nations. Of course, despite the importance of electricity, energy for mechanical power (such as for engines in automobiles, planes, ships, and trains) and for heating still comes in large part from the immediate combustion of fossil fuels.

Global Shifts in Energy Consumption

Energy use and electricity consumption have grown steadily around the world and in most nations in recent decades. However, the patterns of growth have varied substantially across nations. Some nations have seen their levels of consumption plateau, and even dip slightly, while others, mostly those that are rapidly industrializing, have seen their energy consumption grow dramatically. These different patterns of change across nations have resulted in a shift in the share of energy consumption in different parts of the world in the past few decades.

Table 9.1 shows the population, gross domestic production (GDP) per capita, energy use total and per capita, and electricity consumption total and per capita for the world as a whole and for the 20 most populous nations/economies in the world in 2013, where the European Union is counted as a single economy.[1] The 20 most populous nations/economies contain 76.4% of the world population, 77.1% of global energy use, and 77.5% of global electricity consumption, and represent nations from all levels of "development," from very poor nations such as the Democratic Republic of Congo to the most affluent nations, such as the United States and Japan. Therefore, the trends in these 20 economies dominate global trends and represent the diversity of patterns across all nations. As can be seen in Table 9.1, China has the highest energy use and electricity consumption in the world, with over 3,000 megatonnes of oil equivalent (Mtoe) and over 5,000 terawatt hours (TWh), respectively, in 2013. The United States and the European Union are the other two economies with highest levels of energy use and electricity consumption. Other nations, even though populous, use a tiny fraction of world energy resources, with energy use and electricity consumption being, for example, only 21 Mtoe and 8 TWh, respectively, in the Democratic Republic of Congo and 34 Mtoe and 46 TWh, respectively, in Bangladesh.

Table 9.1 Population, Energy Use, and Electricity Consumption in the World and the 20 Most Populous Nations/Economies,[a] 2013

Nations and World	Population (millions)	GDP per capita (US$)	Energy Use[b]	Energy Use, per Capita[c]	Electricity Consumption (TWh)	Electricity Consumption p.c. (KWh)
World	7,176	9,900	13,593	1,894	22,277	3,104
China	1,357	5,652	3,022	2,226	5,107	3,762
India	1,279	1,604	775	606	979	765
European Union	508	33,844	1,626	3,200	3,067	6,036
United States	316	49,849	2,188	6,916	4,110	12,988
Indonesia	251	3,571	214	850	198	788
Brazil	204	11,797	294	1,438	517	2,529
Pakistan	181	1,087	86	475	82	450
Nigeria	173	2,462	134	773	25	142
Bangladesh	157	882	34	216	46	293
Russia	144	11,616	731	5,093	938	6,539
Japan	127	44,328	455	3,570	998	7,836
Mexico	124	9,317	191	1,546	255	2,057
Philippines	98	2,422	45	458	68	692
Ethiopia	95	423	48	507	6	65
Vietnam	90	1,522	60	668	117	1,306
Egypt	88	2,654	78	885	149	1,697
Iran	77	5,763	228	2,960	224	2,899
Turkey	76	11,103	116	1,528	209	2,745
Congo, Dem. Rep.	73	351	21	292	8	110
Thailand	67	5,613	134	1,988	167	2,471

[a] The European Union is counted as a single "nation," and its individual members are not listed separately. These 20 nations include over 76% of the world population and account for over 77% of both world energy use and world electricity consumption.

[b] Megatonnes of oil equivalent.

[c] Kilograms of oil equivalent.

Since 1990, these nations/economies have shown a variety of trends, as can be seen in Table 9.2, which presents average annual growth rates in energy use (total and per capita) and electricity consumption (total and per capita) for three periods: 1990–2001 (the end of the twentieth century); 2001–2008 (the start of the twenty-first century before the global recession); and 2008–2013 (following the onset of the global recession). It is noteworthy that rates of growth in electricity consumption are typically substantially higher than rates for energy use. This is largely due to the well-established fact that electricity consumption is more closely connected with industrialization and economic growth than energy use in general, and investments in expanding electricity production have been a central part of development plans in most nations since World War II (Mazur, 2013). Table 9.3 presents growth rates for population and GDP per capita (inflation adjusted). The trends in these factors help to explain the trends in energy use and electricity consumption, as I will discuss in the following.

Looking at the world as a whole, the effect of the global recession (generally considered to have started in December 2007) is clear, where energy use and electricity consumption, in total and per capita terms, are noticeably lower in the period 2008–2013 than in 2001–2008. However, it also is evident that there was a slower growth regime in the 1990s, when growth rates in energy use and electricity consumption were lower than they were after the global recession. Thus, growth in energy and electricity consumption accelerated in the twenty-first century.

We can gain insight into the global trends by examining how patterns differ across nations. The collapse of the Soviet Union and the Eastern Bloc around 1990 led to dramatic economic decline in those regions throughout the subsequent decade, with concomitant drops in industrial production and energy use. This is clearly apparent for Russia, where over the course of the 1990s it averaged a 3.0% annual decline in energy use (matching the decline in GDP per capita) and a 2.3% decline in electricity consumption (see Table 9.2). These declines in the former Eastern Bloc suppressed growth in global energy consumption and GDP. In the 1990s there were also intense civil wars in parts of Africa, notably Rwanda and the Democratic Republic of Congo. However, due to global inequalities, levels of energy consumption in these nations are so low as to not appreciably affect global trends. Nonetheless, it is noteworthy that the DRC saw energy use and electricity consumption drop noticeably in per capita terms over the course of the 1990s, although total national levels of these grew due to rapid population growth.

In addition to the pattern of decline and growth in the former Eastern Bloc, global trends were largely driven by two contrasting patterns across a few dominant nations/economies. On the one hand, the European Union and the United States saw their rates of growth in GDP, electricity consumption, and energy use drop in the twenty-first century, and this drop became more pronounced following 2008. This may be due in part to structural changes that occur in "advanced" economies, where internal industrial production has declined, as cheaper manufactured goods are imported from less developed nations. Japan appears to have gone through this transition somewhat earlier than the United States and the European Union, having had low rates of growth in GDP, energy use, and electricity consumption since 1990. On the other hand, China and, to a lesser extent, India shifted to explosive rates of growth in GDP, electricity consumption, and energy use in the first decade of the 2000s, having had only modest rates in the 1990s. Additionally, the global recession had a more modest effect in India and China than it did in affluent nations.

Table 9.2 Average Annual Growth Rates (%) in Energy Use and Electricity Consumption, in Total and per Capita Terms, in the World and the 20 Most Populous Nations/Economies,[a] 1990–2013

Nations and World	Energy Use			Energy Use per Capita			Electricity Consumption			Electricity Consumption per Capita		
	2008–2013	2001–2008	1990–2001	2008–2013	2001–2008	1990–2001	2008–2013	2001–2008	1990–2001	2008–2013	2001–2008	1990–2001
World	2.2	2.7	1.3	0.9	1.4	-0.1	3.0	3.9	2.5	1.8	2.6	1.0
China	7.7	8.4	2.8	7.2	7.8	1.8	9.4	13.2	8.1	8.9	12.5	7.0
India	5.2	4.2	3.5	3.9	2.6	1.6	7.8	6.9	5.4	6.3	5.2	3.4
European Union	−1.5	0.2	0.5	−1.8	−0.2	0.3	−0.8	1.3	1.5	−1.0	1.0	1.3
United States	−0.8	0.3	1.4	−1.6	−0.6	0.2	−0.2	1.6	2.2	−1.0	0.7	1.0
Indonesia	2.8	2.3	4.4	1.4	1.0	2.9	8.1	6.2	10.5	6.7	4.8	8.8
Brazil	3.4	3.8	2.9	2.4	2.6	1.3	3.8	4.7	3.3	2.8	3.4	1.7
Pakistan	0.9	3.4	3.8	−1.2	1.3	1.3	2.4	4.4	5.5	0.3	2.3	2.9
Nigeria	3.4	3.3	2.8	0.6	0.6	0.3	5.1	10.5	1.2	2.3	7.7	−1.3
Bangladesh	4.9	4.2	4.2	3.7	2.7	2.0	9.0	10.4	10.2	7.7	8.8	7.9
Russia	1.2	1.4	−3.0	1.1	1.7	−2.9	0.5	2.5	−2.3	0.4	2.8	−2.1

Japan	−1.7	−0.4	1.4	−1.6	−0.5	1.1	−0.6	0.5	2.0	−0.5	0.4	1.7
Mexico	1.1	2.9	1.8	−0.3	1.4	0.0	3.1	2.7	5.6	1.5	1.3	3.8
Philippines	2.1	0.7	2.7	0.6	−1.1	0.3	4.9	3.7	5.8	3.3	1.8	3.4
Ethiopia	5.0	3.3	3.3	2.3	0.4	0.0	12.4	9.4	4.8	9.6	6.4	1.5
Vietnam	4.3	6.8	5.0	3.2	5.6	3.4	11.1	14.8	13.6	9.9	13.5	11.8
Egypt	1.4	6.8	3.2	−0.7	4.9	1.2	4.9	7.2	6.0	2.7	5.2	4.0
Iran	2.2	6.3	6.1	1.0	5.1	4.5	5.1	6.9	6.8	3.8	5.7	5.1
Turkey	3.4	5.0	2.6	1.7	3.6	1.0	4.1	7.4	6.8	2.5	6.0	5.2
Congo, Dem. Rep.	2.7	3.7	1.8	-0.6	0.5	−1.3	5.5	4.1	0.2	2.1	0.8	-2.9
Thailand	4.4	5.5	5.3	4.1	4.8	4.3	3.5	5.6	8.2	3.2	4.9	7.1

[a] The European Union is counted as a single "nation," and its individual members are not listed separately. These nations include over 76% of the world population and account for over 77% of both world energy use and world electricity consumption.

Table 9.3 Average Annual Growth Rates of Population and GDP per Capita (Inflation Adjusted), 1990–2013, for the World and the 20 Most Populous (In 2013) Nations/Economies

Nations and World	Population			GDP per Capita		
	2008–2013	2001–2008	1990–2001	2008–2013	2001–2008	1990–2001
World	1.2	1.2	1.5	0.9	2.1	1.2
China	0.5	0.6	1.0	8.4	10.4	9.1
India	1.3	1.6	1.9	6.1	5.5	3.5
European Union	0.2	0.4	0.2	−0.4	1.7	2.0
United States	0.8	0.9	1.2	0.2	1.3	2.0
Indonesia	1.3	1.4	1.5	4.3	4.0	2.6
Brazil	0.9	1.3	1.6	2.2	2.7	0.9
Pakistan	2.1	2.1	2.5	0.9	3.0	1.2
Nigeria	2.7	2.6	2.5	3.1	7.2	−0.4
Bangladesh	1.2	1.5	2.1	4.7	4.2	2.5
Russia	0.2	−0.3	-0.1	0.9	7.1	−3.0
Japan	−0.2	0.1	0.3	0.4	1.1	0.8
Mexico	1.5	1.4	1.8	0.4	1.2	1.4
Philippines	1.6	1.8	2.3	3.6	3.3	0.5
Ethiopia	2.6	2.8	3.3	7.5	5.1	0.0
Vietnam	1.1	1.1	1.6	4.6	5.7	5.8
Egypt	2.1	1.8	1.9	1.1	3.1	2.2
Iran	1.2	1.2	1.6	−0.5	4.6	1.5
Turkey	1.6	1.3	1.6	2.1	4.5	1.1
Congo, Dem. Rep.	3.3	3.2	3.2	3.1	2.3	−8.2
Thailand	0.3	0.7	1.0	3.1	4.4	3.2

These patterns are reflected in the ongoing shift in which economies are responsible for the largest shares of energy use and electricity consumption in the world. As Table 9.4 shows, China and India combined moved from being responsible for only 13.4% of global energy use and 7.3% of global electricity consumption in 1990 to accounting for 27.9% of global energy use and 27.3% of electricity consumption in 2013. Conversely, the European Union, the United States, and Japan moved from being the sites of 45.6% of global energy use and

55.3% of global electricity consumption in 1990 to 31.4% and 36.7%, respectively. The largest part of this shift—from the three major affluent economies in the world to the two largest rapidly industrializing nations—occurred in the twenty-first century, and the rate of change is striking. Since the European Union, the United States, Japan, China, and India combined now account for nearly 60% of global energy use and close to two-thirds of global electricity consumption, these five economies stand out as being the dominant players behind global trends.

Table 9.4 World Share of Energy Use and Electricity Consumption in the European Union, United States, and Japan versus in China and India, 1990–2013

Year	Energy Use (% world total)		Electricity Consumption (% World Total)	
	China and India	EU, US, and Japan	China and India	EU, US, and Japan
2013	27.9%	31.4%	27.3%	36.7%
2001	16.2%	39.2%	12.2%	51.8%
1990	13.4%	45.6%	7.3%	55.3%

Table 9.5 Correlations with Growth in Energy Use and Electricity Consumption for the 20 Most Populous Nations/Economies (as of 2013) in the World

Period	Correlations with Population Growth Rate		Correlations with GDP per Capita Growth Rate	
	Energy Use, Total	Electricity Consumption, Total	Energy Use per Capita	Electricity Consumption per Capita
2008–2013	.220	.404	.796*	.861*
2001–2008	.166	.271	.592*	.766*
1990–2001	.447*	.169	.625*	.757*

* *p*-value <.05 (two-tailed test)

Note: *N* = 20 for each period.

Some of the key factors that explain national and global trends in energy use and electricity consumption have been alluded to earlier, most notably demographic and economic factors. Table 9.5 shows the correlations between the growth rates in population and GDP per capita and growth rates in energy use and electricity consumption for each of the three periods examined here for the 20 nations/economies listed in Tables 9.1–9.3. Population growth has a positive correlation with growth in both total energy use and total electricity consumption in each period, although these correlations are modest, and only the one for 1990–2001 for energy use is statistically significant with a two-tailed test at the .05 alpha level. There is a much closer connection between growth in GDP per capita and per capita levels of both energy use and electricity consumption. These correlations are all positive and statistically significant. Both correlations with GDP per capita are stronger in the most recent period (.796 for energy use per capita and .861 for electricity consumption per capita), and the correlations are generally somewhat stronger with electricity consumption than with energy use. These correlations are consistent with the findings from more rigorous analyses that have clearly established that population and GDP are two of the main drivers of a variety of environmental impacts, including energy use and carbon dioxide emissions (Jorgenson & Clark, 2012; Rosa et al., 2015; York, 2007). Of course, the connections between economic and demographic trends are often complex. It is also noteworthy that declines in fertility, which change the age structure of the population, can lead to growth in GDP per capita, so that growth in energy use is not infrequently higher in nations with lower population growth rates than in those with higher population growth rates. For example, in both China and India, growth in GDP per capita, energy use, and electricity consumption have been higher in the twenty-first century than at the end of the twentieth century, even though their population growth rates have been lower (see Tables 9.2 and 9.3).

Although energy use and electricity consumption growth rates have been modest in affluent nations in this century, while they have been high in many less developed nations, China most notably, it is important to not lose sight of the stark inequalities that continue to exist. Cross-national inequalities are best understood by examining per capita levels. The United States has the highest level of energy use (nearly 7,000 kg oil equivalent [kgoe]) and electricity consumption (nearly 13,000 KWh) in per capita terms among the 20 nations/economies I examine here, and these levels are many times the levels in many other nations (see Table 9.1). Even though China and India have experienced high rates of growth, their levels of energy use and electricity consumption are still much lower than those in the United States in per capita terms. In 2013, US per capita energy use and electricity consumption were, respectively, 3.1 and 3.5 times those in China and 11.4 and 17.0 times those in

India (calculated from the data presented in Table 9.1). There are contrasts that are even more extreme. For example, the United States used 32 times more energy per capita than Bangladesh and consumed 200 times more electricity per capita than Ethiopia in 2013 (see Table 9.1). So, even though patterns of growth have been changing around the world, the affluent nations of the world are still responsible for large shares, particularly in per capita terms, of global resource consumption.

It is also important to recognize that where energy is used is not the same as where the goods and services that come from that use are consumed. For decades, manufacturing has shifted from core, affluent nations to less developed nations, and the manufactured goods are to a large extent imported back into the affluent nations. In effect this is a process, sometimes called "off-shoring," whereby the pollution from industry is moved to poorer nations, allowing affluent nations to continue to maintain high levels of consumption without experiencing the concomitant environmental degradation within their borders. Ehrlich and Holdren (1971) famously referred to the erroneous assumption that the environmental impacts a nation causes are contained within its own national boundaries as the "Netherlands fallacy." This is in reference to the fact that wealthy nations like the Netherlands consume vastly more natural resources than can be produced within their borders by importing resources from elsewhere. For this reason, some analyses focus on "ecological footprints" of nations, which are estimates based on where goods and services are consumed, rather than where resources are extracted and/or transformed into final products (e.g., York, Rosa, & Dietz, 2003). Thus, we should not assume that rising energy use in poorer nations necessarily means that people in those nations are themselves consuming more for their own uses. This point suggests the importance of examining the global economy as a whole, rather than focusing on individual nations in isolation.

Efficiency and Renewables to the Rescue?

In light of the fact that global energy consumption has been growing at an accelerated pace in the twenty-first century, despite growing awareness of the large environmental impacts that stem from energy consumption (climate change, pollution, nuclear waste, etc.), a key question is whether there are processes in motion that might help to curtail energy consumption and/or reduce the impact of energy use. In particular, is there potential for improvements in energy efficiency and the expansion of clean, renewable energy sources to stem the tide of environmental degradation?

Although improvements in efficiency have been touted for a long time as holding the potential to reduce energy consumption while allowing the economy to continue to grow (Hawken, Lovins, & Lovins, 1999), the standard, and apparently paradoxical, historical trend since the dawn of the industrial era is of steady, simultaneous growth in energy consumption and energy efficiency (York & McGee, 2016). This counterintuitive relationship, where improvements in energy efficiency are associated with growth in energy consumption, has become known as the Jevons paradox, in reference to the nineteenth-century economist William Stanley Jevons, who first observed that improvements in the efficiency of steam engines were associated with increasing coal consumption, since efficiency gains made the reliance on coal-powered technologies more cost-effective (York & McGee, 2016). This paradoxical association between total consumption and efficiency has been observed on a variety of scales, from the energy use of specific technologies (e.g., steam engines) to the resource efficiency of national economies (York & McGee, 2016). For example, Grant et al. (2014) show that power plants in the United States with high thermal efficiency typically have higher carbon dioxide emissions.

The pattern characteristic of the Jevons paradox is common, although not universal, with respect to trends in energy consumption and energy efficiency in national economies. The energy efficiency of national economies is typically measured as economic output (GDP) per unit of energy consumption. Instead of efficiency, it is common to focus on the energy intensity of economies, where intensity is simply the inverse of efficiency (i.e., intensity is units of energy consumed per unit of economic output). Thus, declining intensity corresponds with rising efficiency. The Jevons paradox can be seen in energy trends in the world as a whole in recent years. Between 1990 and 2013, the energy intensity of the global economy declined (i.e., energy efficiency improved) by 18%, while total and per capita energy use grew by 55% and 14%, respectively, and the correlation between energy intensity and per capita energy use is −.746 ($N = 24$, $p < .05$, two-tailed test). The trends in China have had a substantial effect on the global pattern. From 1990 to 2013 in China, total and per capita energy use increased by nearly 250% and 190%, respectively, while energy intensity declined by over 60% (see Figure 9.1). Stated another way, over a period of less than a quarter century, per capita energy use in China increased by nearly a factor of 3, while energy intensity declined by close to a factor of 3—that is, China had a dramatic improvement in energy efficiency and yet at the same time its energy consumption grew explosively. The correlation in China between efficiency and per capita consumption, at –.734 ($N = 24$, $p < .05$, two-tailed test), is very similar to that for the world as a whole.

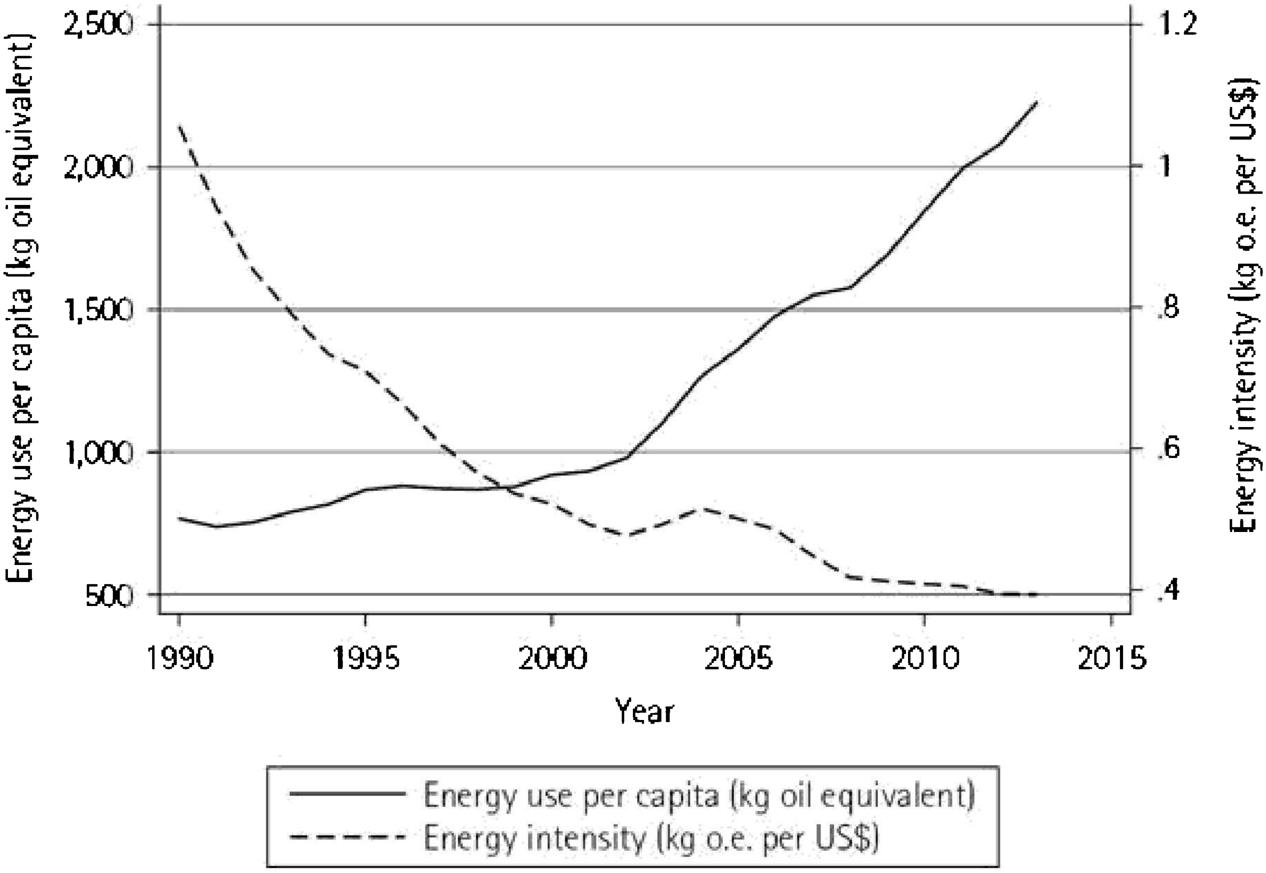

FIGURE 9.1 Trends in energy use per capita (kg of oil equivalent) and energy intensity (energy use in kg of oil equivalent per US$ inflation adjusted to year 2010) in China, 1990–2013.

These close correlations, of course, do not necessarily mean the connection is directly causal, but they do suggest that efficiency/intensity is not a good indicator of energy conservation or environmental performance. There are likely multiple processes that explain the Jevons paradox, and these processes likely vary over time and across different circumstances. In a basic mathematical sense, this pattern emerges due to different growth rates in GDP and energy use. If energy use is growing, but GDP is growing faster, intensity is declining in parallel with expanding energy use. This highlights the fact that declining intensity (i.e., rising efficiency) does not necessarily imply a trend toward absolute reductions in energy use. It is important to note, of course, that the pattern in China, although common around the world, is not seen everywhere. Japan provides a clear example, where from 1990 to 2013 energy intensity and per capita energy use tracked each other fairly closely (see Figure 9.2) and were positively correlated at .652 (N = 24, p <.05, two-tailed test). A key point to take from these patterns is that intensity/efficiency tells us little about total or per capita energy use, and we should not assume that improvements in efficiency are necessarily indicative of a "greening" of the economy.

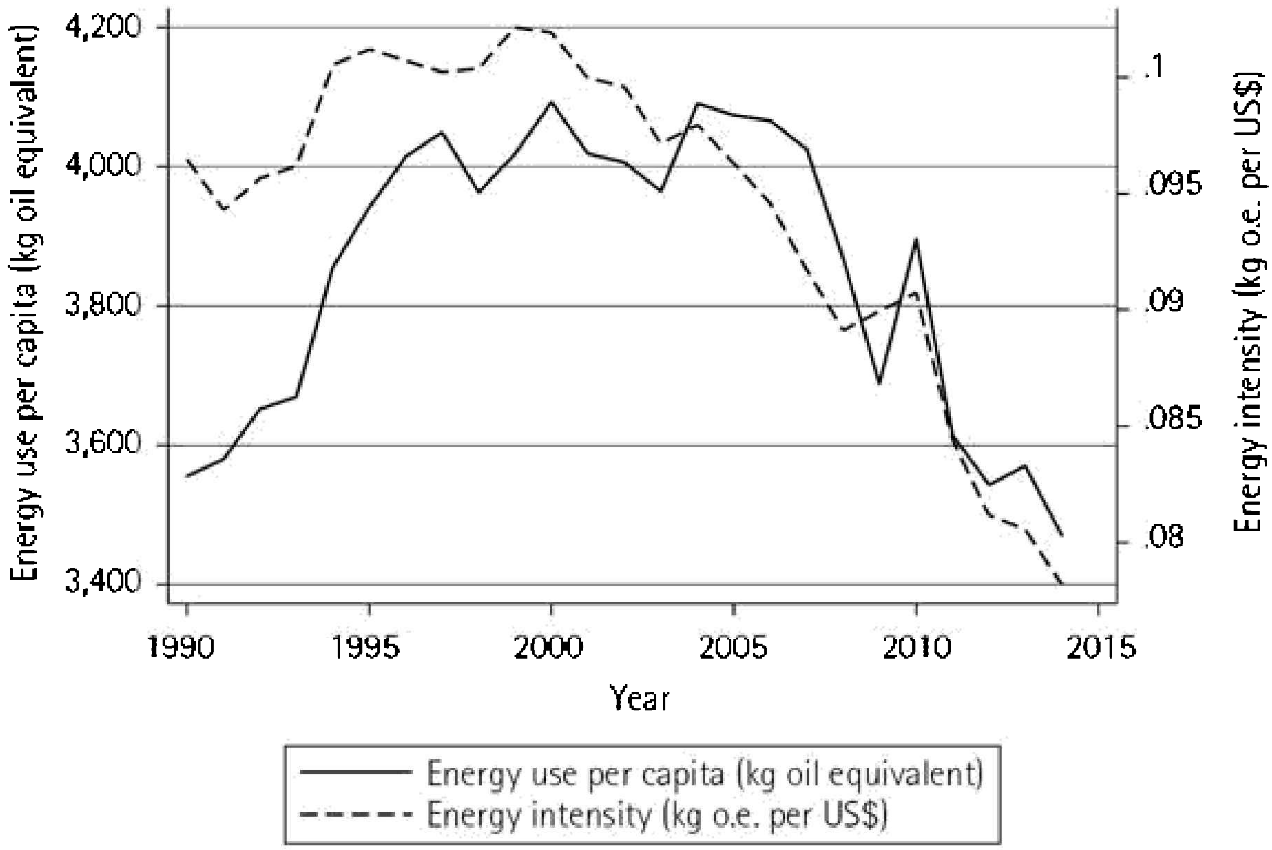

FIGURE 9.2 Trends in energy use per capita (kg of oil equivalent) and energy intensity (energy use in kg of oil equivalent per US$ inflation adjusted to year 2010) in Japan, 1990–2013.

The quantity of energy consumed is, of course, not the only aspect of energy use that is of interest. The composition of energy production is obviously very important as well. Given their contribution to global climate change, fossil fuels are an especially problematic energy source, and there is understandably widespread interest in shifting energy production to non-carbon and renewable energy sources. Here I focus on the electrical sector, since that is where non-fossil fuel sources have the greatest potential to be used, and I examine trends in four sources of electricity production: fossil fuels, nuclear, hydro, and non-hydro renewables (henceforward, I'll refer to the latter simply as "renewables"). Renewables have expanded dramatically in recent years, accelerating in the twenty-first century. From 1990 to 2001, worldwide electricity production from renewables grew more than 40%, from about 160 TWh to 230 TWH, but by 2013 it had reached roughly 1,300 TWh, more than five times what it was in 2001. However, despite this rapid growth, (non-hydro) renewables provided little more than 5% of world electricity production in 2013 (although this is up from about 1.5% in 2001) (see Figure 9.3).

The rise in renewables has failed to suppress fossil fuel use. In fact, the share of world electricity that comes from fossil fuel sources *increased* in the twenty-first century, from 64% in 2001 to over 66% in 2013 (see Figure 9.3), and this represents a large increase in absolute terms (over 50% growth) since, as I noted earlier, total electricity consumption grew substantially over this period. The persistence of fossil fuel use is consistent with York's (2012) finding that non-fossil energy sources do not effectively displace fossil fuel sources, but rather to a substantial degree are added to them, rather than replacing them. If anything, it appears that renewables were more prone to take the place of nuclear energy, which fell from about 17% of world electricity production in 2001 (which is approximately the same share it had throughout the 1990s), to less than 11% in 2013 (see Figure 9.3). This drop in the percentage of electricity production does not indicate that nuclear electricity generation declined markedly, but rather it remained approximately constant over this period, while production from other energy sources grew. Hydroelectric power grew at roughly the same pace as total electricity production, retaining approximately the same share (around 16%) of world electricity production throughout the beginning of the twenty-first century (see Figure 9.3).

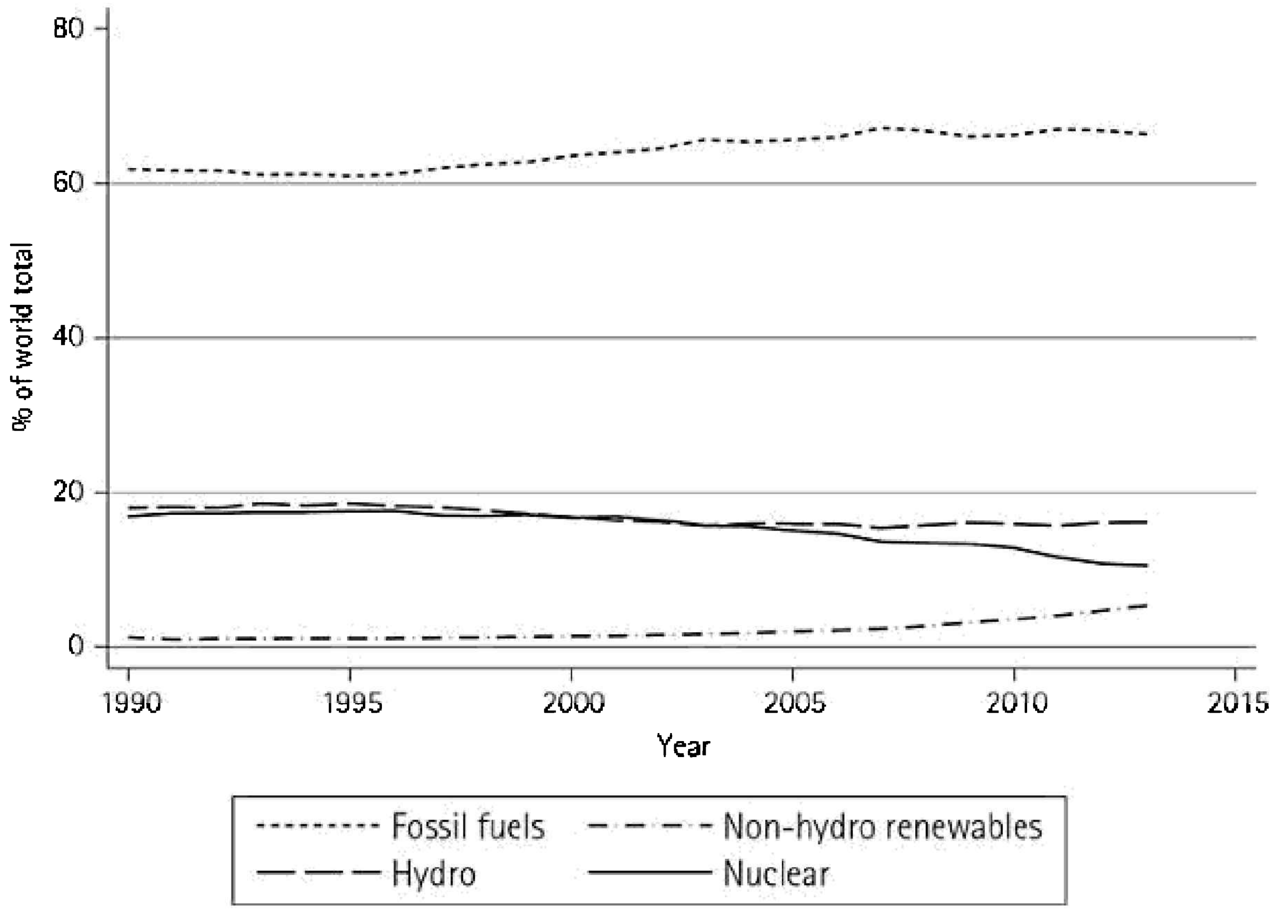

FIGURE 9.3 Sources of world electricity production, 1990–2013.

Despite the rapid growth in renewables, it does not appear that the world is on a trend away from dirty energy. In fact, not only do fossil fuels remain the dominant energy source in the world, the impacts associated with their extraction appear to be escalating. Davidson and Andrews (2013) observe that the "ecological footprint" of energy extraction has increased since the mid-twentieth century. Because the most easily accessible and highest-grade resources are typically extracted first, as time goes on the exploitation of more "extreme" forms of energy becomes necessary to maintain growing energy consumption. For example, increasing amounts of oil come from tar sands, which are particularly energy intensive to extract, there has been a rise in mountaintop-removal coal mining, which devastates ecosystems, and there is more offshore, ocean-floor oil drilling (Bell, 2014). Technological advances in the fossil-fuel industry, such as high-volume hydraulic fracturing ("fracking"), have allowed for more unconventional gas and oil development, but there are high environmental costs associated with these new technologies, especially fracking, including pollution of groundwater, leaks of methane (a more potent greenhouse gas than carbon dioxide), and increases in earthquakes (Ladd, 2017).

Thus, there does not seem to be a general overall trend to cleaner energy.

It is also worth noting that even renewable energy sources have substantial environmental impacts (Sovacool & Dworkin, 2014; Zehner, 2012). For example, hydroelectric dams destroy river ecosystems and can increase methane emissions, wind turbines require a substantial amount of material to manufacture and they (and the access roads and other infrastructure that goes with them) take up land, and the manufacture of solar panels requires a lot of energy and produces a substantial amount of toxic waste. There is no unproblematic energy source, which highlights the importance of total amounts of energy consumption.

Conclusion

In general terms, the trends and patterns discussed here can be summarized in four main points. First, energy use and electricity consumption continue to rise around the world, and the rates of growth are higher in the twenty-first century than they were at the end of the twentieth century, even following the onset of the global recession in 2008. Second, in recent years rates of growth in energy use and electricity consumption declined in the most affluent nations and accelerated in some developing nations, most notably China and India. This has led to a major geographic shift in the locations where energy resources are consumed. Third, the energy efficiency of the global economy and that of many nations has generally improved steadily in recent decades, sometimes quite dramatically, but this typically has not led to noticeable suppression of energy consumption in most nations. Fourth, energy production from renewable energy sources has grown rapidly worldwide in the twenty-first century, but it has not substantially displaced fossil fuels, the production of which is in fact on the rise, in part due to new extraction technologies.

Note

1. All of the data presented here come from (or were calculated using) the World Development Indicators online DataBank (World Bank 2016). The energy and electricity data originate from the International Energy Agency, and the population and GDP per capita (measured in US$ inflation adjusted to the year 2010) data are World Bank estimates. Electricity consumption measures the production of power plants (including heat), less transmission, distribution, and transformation losses, from primary sources. Energy use measures all forms of primary energy before transformation to other end-

use fuels (such as electricity and refined petroleum products). A notional thermal efficiency of 33% is assumed for converting nuclear electricity into oil equivalents and 100% efficiency for converting hydroelectric power.

References

Bell, S. E. (2014). Energy, society, and the environment. In K. A. Gould & T. L. Lewis (Eds.), *Twenty lessons in environmental sociology* (2nd ed., pp. 137–158). Oxford University Press.

Davidson, D., & Andrews, J. (2013). Not all about consumption. *Science*, *339*, 1286–1287.

Ehrlich, P., & Holdren, J. (1971). Impact of population growth. *Science*, *171*, 1212–1217.

Grant, D., Bergstrand, K. J., Running, K., & York, R. (2014). A sustainable 'building block'? The paradoxical effects of thermal efficiency on U.S. power plants' CO_2 emissions. *Energy Policy*, *75*, 398–402.

Hawken, P., Lovins, A., & Lovins, L. H. (1999). *Natural capitalism: Creating the next industrial revolution.* New York: Little, Brown.

Jorgenson, A. K. & Clark, B. (2012). Are the economy and the environment decoupling? A comparative international study, 1960–2005. *American Journal of Sociology*, *18*(1), 1–44.

Ladd, A. E. (Ed.). (2017). *Fractured communities: Risk, impacts, and protest against hydraulic fracking in U.S. shale regions*. New Brunswick, NJ: Rutgers University Press.

Mazur, A. (2013). *Energy and electricity in industrial nations: The sociology and technology of energy.* London: Earthscan.

Rosa, E. A., Rudel, T. K., York, R., Jorgenson, A. K., & Dietz, T. (2015). The human (anthropogenic) driving forces of global climate change. In R. E. Dunlap and R. J. Brulle (Eds.), *Climate change and society: Sociological perspectives* (pp. 47–91). New York: Oxford University Press.

Smil, V. (1994). *Energy in world history.* Boulder, CO: Westview.

Sovacool, B. K., & Dworkin, M. H. (2014). *Global energy justice: Problems, principles, and practices.* Cambridge: Cambridge University Press.

World Bank. (2016). *World development indicators.* Retrieved from http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators

York, R., & McGee, J. A. (2016). Understanding the Jevons paradox. *Environmental Sociology*, *2*(1), 77–87.

York, R. (2012). Do alternative energy sources displace fossil fuels? *Nature Climate Change*, *2*(6), 441–443.

York, R. (2007). Demographic trends and energy consumption in European Union Nations, 1960–2025. *Social Science Research*, *36*(3), 855–872.

York, R., Rosa, E. A., & Dietz, T. (2003). Footprints on the Earth: The environmental consequences of modernity. *American Sociological Review*, *68*(2), 279–300.

Zehner, O. (2012). *Green illusions: The dirty secrets of clean energy and the future of environmentalism.* Lincoln: University of Nebraska Press.