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Something New Under the Sun: An Environmental History of the Twentieth-Century World

CHAPTER 10

Fuels, Tools, and Economics

> Men are too eager to tread underfoot what they have once too much feared.
> —Lucretius, *De Rerum Natura*

Over the course of the twentieth century, more and more people acquired greater and greater leverage over the environment, through new energy sources, new tools, and new market connections. Energy, technology, and economic systems were tightly interlocked. They coevolved, each one influencing the paths of the others. At times, new combinations of energy sources, machines, and ways of organizing production came together, meshed well, and reoriented society and economy. Borrowing from the vocabulary of the history of technology, I will call these combinations of simultaneous technical, organizational, and social innovations "clusters." Early industrial clusters were built around water-powered textile mills and then factories and steam engines. After the mid-nineteenth century the dominant cluster emerged as coal, iron, steel, and railroads: heavy-engineering industries centered in smokestack cities. Call it the "coketown cluster" in honor of Charles Dickens's Coketown in his novel *Hard Times* (1854). The next cluster coalesced in the 1920s and 1930s and predominated from the 1940s (helped along by World War II) until the 1990s: assembly lines, oil, electricity, automobiles and aircraft, chemicals, plastics, and fertilizers—all organized by big corporations. I will dub that the "motown cluster" in honor of Detroit, the world center of motor vehicle manufacture. The coketown cluster and the motown cluster each spurred the emergence of giant corporations in North America, Europe, and Japan, and the relative efficiency and returns to scale enjoyed by these corporations in turn helped to advance each cluster; technological systems and business structures coevolved.

These clusters, and the rapid changes to society, economics, and environment that came with them, affected the whole world, but unevenly. The

dominant innovations came disproportionately from the United States, Europe, and Japan, and the wealth and power they helped to create were concentrated there. But the ecological ramifications of these clusters were felt everywhere, if not in the same ways.

Energy Regimes and the Environment

Every society has its "energy regime," the collection of arrangements whereby energy is harvested from the sun (or uranium atoms), directed, stored, bought, sold, used for work or wasted, and ultimately dissipated. Most twentieth-century societies had complex energy regimes involving several different energy sources, modes of conversion, storage, and use. Oil, hydroelectricity, and nuclear fission joined coal, wind, and muscles in powering the twentieth century.

For the most part, the twentieth-century world ran on fossil fuels, mainly coal and oil. Both lay scattered unevenly around the world, so a huge business emerged to extract, transport, process, and deliver fossil fuels to final users. Extraction of both coal and oil were dirty affairs. Transport of oil may have been messier than coal transport. In its final use—combustion—coal was much the grimier of the two fuels. Coal mining, combustion, and disposal of slag and cinder[1] had pronounced effects on land, air, and water. But because oil had so many more applications and could be distributed cost-effectively more widely, it spread pollution more broadly around the globe, whereas coal had concentrated it around a few thousand mines, furnaces, and steam engines. The pollution derived from fossil fuel burning is treated in Chapters 3 and 4. Here I will treat only the extraction and transport of one fossil fuel: oil.

After 1820 the world's economy became increasingly based on work done by nonmuscular energy. By 1950 any society that did not deploy copious energy was doomed to poverty. The scale of energy use grew so vast that the choice of energy regime became a prime determinant of the world's environmental condition. After 1820 an energy transition to fossil fuels took place. Within that, a transition within a transition, from coal to oil, occurred. By 1930, oil replaced coal as the world's main fuel in transport; by the late 1950s it usurped king coal's position in industry. The United States pioneered this energy path between 1901 and 1925. For world environmental history, few if any things mattered more than the triumph of oil.

OIL EXTRACTION. At the turn of the century, oil scarcely mattered at all. Its main use was as kerosene for lamps. But soon cars, ships, and eventually airplanes and trains came to run on oil products. A goodly share of heating fuel came from oil, as later still did the feedstocks for plastics, synthetic fibers, and chemicals. By and large, the United States shifted to oil first, between 1910 and 1950. Western Europe and Japan, which had stronger political attachments to coal, followed in about 1950 to 1970.[2] High prices from 1973 to 1984 made oil extraction especially attractive. All this provoked a determined search for oil deposits around the world and the construction of a vast network of wells, pipelines, tankers, and refineries designed to carry and process crude oil.

Although hard-rock drilling for oil began in Pennsylvania, the first big gushers came in the 1870s around Baku on the Caspian Sea. The Russian Empire led the world in oil production at the turn of the century. Derricks also sprouted in Rumania and the Dutch East Indies (Sumatra). Then, on the tenth day of the new century, at Spindletop in east Texas, came the first big American oil strike. American oilmen drilled for oil widely, first in Texas, Oklahoma, and California and then all over the world. A new age slowly dawned.

Drilling was a dirty business in those days, not least in Mexico. Oil lay under the rainforests of Veracruz along the shores of the Gulf of Mexico.[3] Here the capital came from American and British firms, the equipment often secondhand from Texas, and the labor from Texas and from the local indigenous population, Huastec and Totonac Indians. To oilmen and to successive Mexican governments, their rainforest ways seemed backward and pointless, an anachronism in the new century. Widespread drilling began in 1906.

With the Mexican Revolution (1910–1920), ambitious new leaders saw in oil a way to propel Mexico forward. Boosters thought that northern Veracruz could support 40 million people, if only trees and Indians would make way for oil and oilmen. World War I helped in the regard Lord Curzon noted: "The Allies floated to victory on a wave of oil."[4] Much of it flowed from Tampico. Mexico stood third in world oil production by 1915, and second by 1919, thanks to the wartime boom and to revolution and chaos in Russia. The Mexican boom peaked in 1921.

Oil recast both ecology and society in northern Veracruz, and almost overnight. Tampico was a sleepy, swampy port in 1897. By 1921 it had 58 oil companies, 16 refineries, 24 law firms, 6 bakeries, 77 liquor stores, and

nearly 100,000 people.[5] The surrounding region had (by 1924) thousands of oil wells and pools, and enough pipeline (4,000 km) to stretch to Hudson Bay or Chile. Spills, leaks, blowouts, and fires, while wrenching for the Huastec and Totonac, were a necessary cost of doing business for oilmen. Indeed, they positively rejoiced in a gusher. But according to the Minister of the Interior, the oil business "ruined" the land.[6]

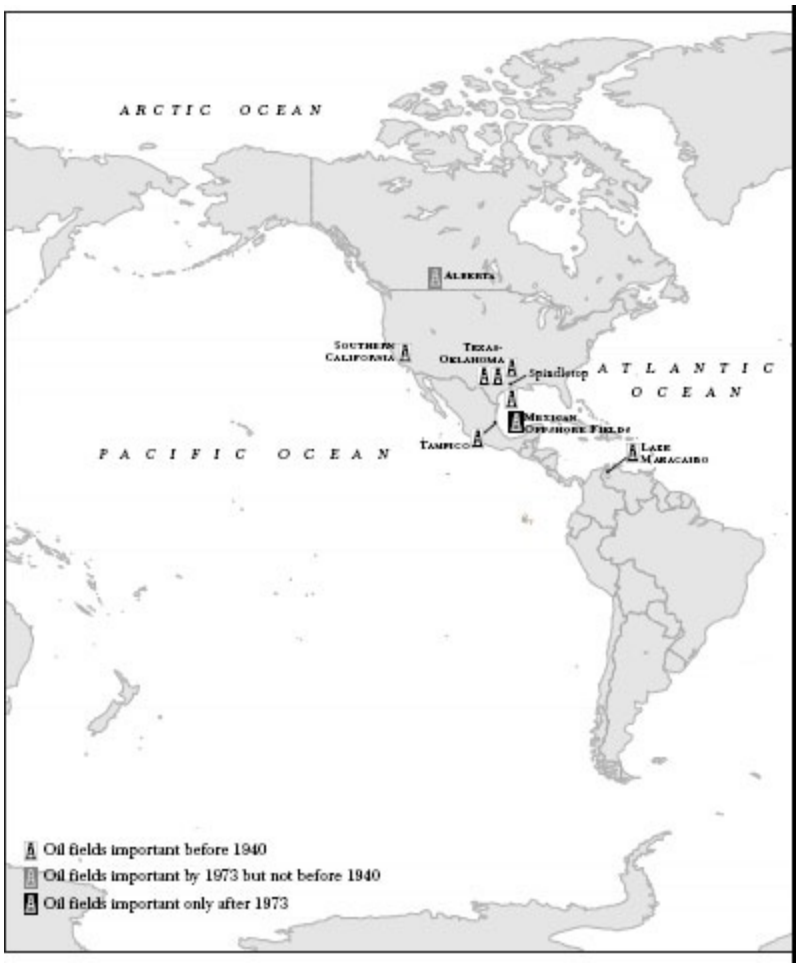
The bonanza subsided in the early 1920s. Salt water seeped into the oil fields, complicating production. Then United States and Venezuelan oil fields began producing more than the market could absorb. The Mexican government nationalized the oil industry in 1938 and forbade exports of crude. Foreign companies, indignant at expropriation, boycotted Mexican oil anyway. Production plummeted and low forest slowly recolonized much of the oil fields. Old derricks stood out here and there like Mayan pyramids amid the jungle.

Variations on this pattern of boom and bust played out around the world. The oil patches of the United States polluted land and water in Texas and Oklahoma merrily, impeded only slightly by an antipollution law of 1924.[7] Venezuela became the world's number two oil producer in 1928 and leading exporter by 1946. Lake Maracaibo, the largest lake in South America and the focus of Venezuelan production and refining after 1918, became an oily morass.[8] The early Russian fields around Baku (Azerbaijan) eventually became an oily backwater when the Soviet Union tapped its huge Siberian oil reserves. Northern Azerbaijan was left with a grimy residue of polluted water and abandoned derricks. But the world's mother lode of oil lay in the vicinity of the Persian Gulf. Here extraction took place in environments with few people and indeed comparatively little life of any sort, which helped lower the ecological costs of spills and leaks.

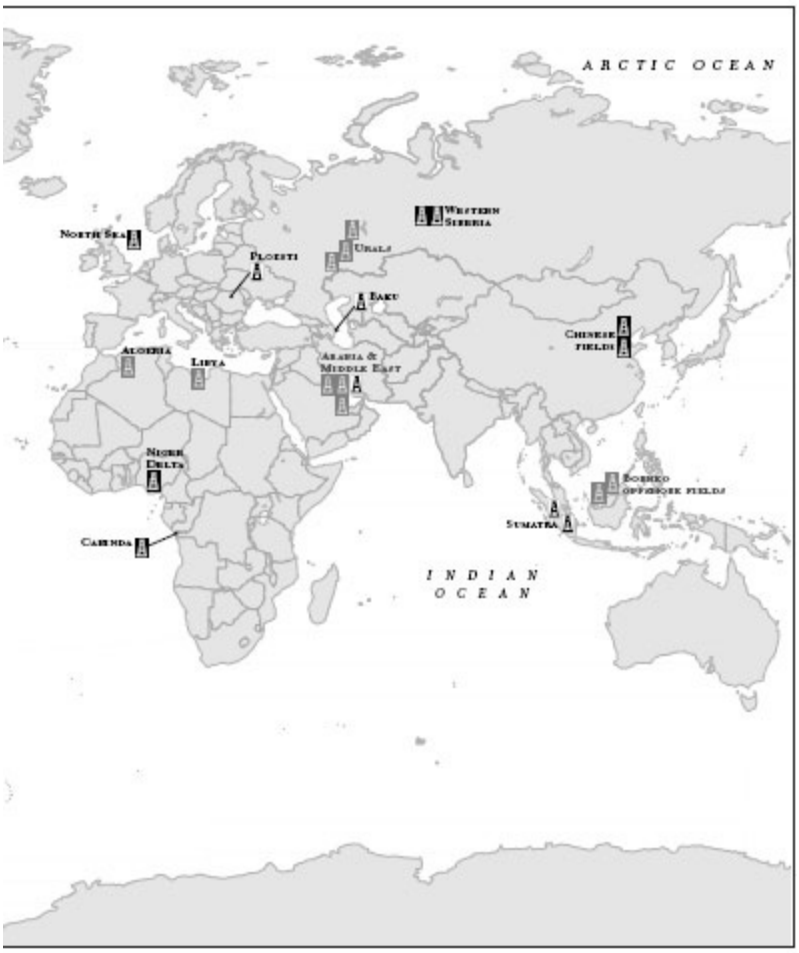
In 1973 the Organization of Petroleum Exporting Countries (OPEC) restricted production, inadvertently opening a new era in oil exploration and extraction. High crude prices, pushed higher by the Iranian Revolution of 1979, quickened exploration and production in nonmember countries and encouraged oil operations in Alaska, Alberta, the Gulf of Mexico, the North Sea, Angola, Ecuador, and on a gigantic scale in western Siberia.[9] OPEC's high prices shaped world economic history from 1973 to 1985, weakening oil-importing industrial economies and strengthening some—not all—oil exporters. High oil and natural gas prices helped prop up the Soviet Union. But OPEC's initiative

also shaped environmental history. First, it encouraged energy conservation in industrial economies, notably in Japan. Furthermore, after the 1970s, the environmental impacts of oil production—with its construction projects, its pipelines and refineries, and its leaks, spills, and fires—spread much more widely around the world. High prices also tempted those, like Nigeria, which flouted cartel rules.

Nigeria's oil lay in the Niger delta, home to about 6 million people in 1990. Royal Dutch Shell and British Petroleum (Shell-BP), which had been granted exploration licenses by the British colonial government, struck oil in 1956. Production began in the 1960s. Shell-BP built a refinery at Port Harcourt in 1965, stimulating production. Shell-BP prudently backed the victorious central government in the civil war of 1967 to 1970, in which southeastern Nigeria (Biafra) attempted to secede and take the oil revenues with it. After the price hikes of the 1970s, Shell-BP pumped out oil while Nigeria pretended to comply with the cartel's rules. Oil royalties splashed through the state's coffers, greasing the wheels of the corruption for which Nigeria became justly famous in the 1980s. Leaks, spills, and perhaps sabotage splashed oil throughout the delta, fouling the fisheries and farms of local peoples, notably the half-million-strong Ogoni.[10] Their protests and rebellions, which featured environmental grievances prominently, were met with intimidation, force, show trials, and executions of prominent Ogoni. Nigeria's military government by the 1990s derived some 80 to 90 percent of its revenue from oil, and the rulers skimmed their personal riches from it. They brooked no challenges, least of all from fisherfolk, farmers, and small ethnic minorities. In 1992 the United Nations declared the Niger to be the world's most ecologically endangered delta. Shell-BP came under unwanted scrutiny and international pressure, and in 1995 began to address environmental and other complaints.[11] Nonetheless, the Niger delta at the end of the century, like Tampico at the beginning, became a zone of sacrifice. The Ogoni, like the Huastec and Totonac, lacked the power to resist the coalition of forces that created and maintained the twentieth century's energy regime.



10. Major Oil Fields since 1900



OIL TRANSPORT. The energy regime of the twentieth century implied massive oil transport, especially after petroleum-poor European and Japanese economies converted to oil. At any given time after 1970, about 5 gallons of oil were in transit at sea for every man, woman, and child on the face of the earth. Most of it got safely to its destination. A small fraction did not.

In the first six months of the Battle of the Atlantic (January–June 1942), German U-boats sank American tankers and spilled about 600,000 tons of crude into the sea. Tankers grew in size 30-fold between 1945 and 1977, so a single spill could do serious damage, equivalent to a month's work by the U-boats. Big tanker spills on the world's seaways became commonplace after the *Torrey Canyon* broke up off of Cornwall, England, in 1967, spilling 120,000 tons of oil into the English Channel. As tankers got safer in the 1980s, the frequency of big spills abated. New rules restricted tankers from cleaning out their tanks at sea. The total human contribution to oil in the seas consequently

declined sharply by 1990. Oil cleanup techniques also improved with practice. But smaller spills like that along Alaska's coast in 1989, when the Exxon *Valdez* spilled 34,000 tons of crude, occurred about once a year in the 1990s. Moreover, most oil in the seas came not from accidents but from routine dumping and tank cleaning, which, although legally regulated, was difficult to control. All told, human action by 1990 put 10 times as much oil into the seas as did natural seeps.[12]

Tanker accidents damaged marine life for months and years. Their residual ecological effects lasted for decades in the worst cases. The same was true of offshore blowouts, the worst of which, at Ixtoc I off the Tabasco coast of Mexico in 1979, spewed 600,000 tons of oil into the Gulf of Mexico and sent an oil slick nearly the size of Connecticut drifting toward Texas. But blowouts and tanker spills were one-time events. The sun and sea eventually covered their tracks, evaporating, breaking up and dispersing the oil to inconsequential concentrations. Ongoing production, as in Veracruz or the Niger delta, or persistent pipeline leaks on land, as in Siberia, led to more enduring environmental effects—as well as more social and political frictions.[13]

Oil left a larger mark on the environment than the stains arising from drilling and transport. Petrochemicals derived from oil created new species of materials, notably plastics, that replaced wood in many uses but added to the tonnage of durable wastes. Many petrochemicals proved to be toxic pollutants themselves. Oil also gave us the car as we know it, with all its implications. It made tractors and farm mechanization possible. And because oil's price fell, especially during the interwar years (1919–1939), and again from 1948 to 1973 but also after 1984, it strongly encouraged more and more applications of energy, in various technological forms, from lawn mowers to power plants, all of which affected ecology to some degree. This energy regime allowed wealth and ease on scales quite impossible in earlier centuries for a billion or two people.[14] It had enormous social, economic, and geopolitical consequences for the twentieth century. It also polluted air and water and changed environments generally on scales equally impossible in earlier centuries.[15] Oil, on one reckoning at least, was the single most important factor in shaping environmental history after the 1950s.[16]

Technological Change and the Environment

A century ago Oscar Wilde wrote that

> civilization requires slaves. The Greeks were quite right there. Unless there are slaves to do the ugly, horrible, uninteresting work, culture and contemplation become almost impossible. Human slavery is wrong, insecure and demoralizing. On mechanical slavery, the slavery of the machine, the future of the world depends.[17]

Wilde was quite right too: the course of the twentieth century did depend on machines. The technologies of the twentieth century, intertwined with related changes in energy and economy, powerfully determined the rates and kinds of environmental changes.

As with energy paths, different technological trajectories implied different environmental outcomes. The coketown cluster meant, in particular, urban air pollution. The motown cluster meant far more because it spread so widely, so quickly, and involved such energy intensity. A given technology could magnify or minimize ecological impacts, but alone it merely modified the consequences of social forces. A technological cluster, on the other hand, could exert an influence at least as great as population or politics. Consider three technologies, one prosaic by twentieth century standards (chainsaws), one emblematic of the course of the twentieth century and the centerpiece of the motown cluster (automobiles), and one for which future millennia will remember the twentieth century (nuclear reactors).

CHAINSAWS. Before the invention of practical chainsaws, the bottleneck in logging consisted of the enormous labor demands of felling timber. In North America, armies of men filled the woods in fall and winter, swinging broadaxes and pulling crosscut saws. The lumber camps came alive only seasonally because hauling felled timber was much easier over snow and ice, and because, in eastern North America, the men, horses, and oxen mostly came from farms: after the harvest there was a slack season and labor could be spared. In parts of the world where abundant labor was harder to find, forests often survived.

The fundamental constraint was one of energy. Human muscle had its limits. The chainsaw changed social and ecological landscapes, in North America and beyond, by unleashing the energy of fossil fuels in the forests. In

an eon-straddling irony, the new machines allowed loggers to use the energy derived from ancient vegetation (the source of oil) against modern forests.

While the first chainsaw patent dates to 1858 and its first manufacture to 1917, its real impact came after World War II. The war brought vastly improved air-cooled engines and light metals (aluminum), which together allowed a practical, gasoline-powered chainsaw. Between 1950 and 1955, chainsaws revolutionized logging and pulping in North America. In eastern Canada, for example, bucksaws and axes still cut all pulpwood in 1950. By 1955, chainsaws accounted for half the total, and by 1958 all of it. Lumber and pulpwood firms had to mechanize by the 1950s, because farms had mechanized and there was no longer an available army of seasonal labor (and horses). Soon far bigger machines that looked like "giant insects from another planet" and could snip trees off at the base, took over the lumber and pulpwood business in North America. The age of the lumberjack, a distinctive figure in the cultural landscape of North America, closed.[18]

Elsewhere the chainsaw remained cutting-edge technology. It allowed men to cut trees 100 or 1,000 times faster than with axes. Without the chainsaw, the great clearance of tropical forests (see Chapter 8) would either not have happened, have happened much more slowly, or have required 100 or 1,000 times as many laborers. Hundreds of small-scale technologies, equally as prosaic as the chainsaw, altered twentieth-century environmental history in small and not-so-small ways.

FROM RAILROADS TO CARS. Transport technology made even larger differences. At the end of the nineteenth century most societies depended on combinations of railroads and animal-or human-drawn carts and carriages. Such a transport regime had its environmental consequences. American railroads, for example, demolished forests. They usually burned wood in their boilers. Boxcars were made of wood and some rails were too. Crossties, which had to be replaced every few years, consumed the most wood of all. The locomotive may have been the iron horse, but the railroad was mainly a wooden system. When the system was growing fastest (1890s), it threatened to gobble up American forests. Fears of a timber famine arose, and Theodore Roosevelt decided to create a national forest service to rationalize the use of the country's remaining timber. The same fears helped breathe life into the American conservation movement at the turn of the century and generate

political support for the system of national parks. Railroad technology put enormous strains on American forests, provoking social and political responses. But soon Americans launched new technologies, in turn provoking new responses.

Two new technologies rescued American forests from the iron horse: creosote oil and cars. By 1920, creosote oil, a wood preservative derived from coal tar, coated half of American crossties, reducing the need for new ones. Then the railroad network in the United States stopped growing in the 1920s—because of the automobile.[19]

Before it replaced the railroad in intercity travel, the automobile displaced the horse within cities. Horses, like the railroad, brought environmental problems of their own. It took about 2 hectares of land to feed a horse, as much as was needed by eight people. So in Australia, which in 1900 had one horse for every two people, much of the country's grain land went to sustain horses. In 1920 a quarter of American farmland was planted to oats, the energy source of horse-based transport. Supplying inputs was only part of the horse problem. Horses deposited thousands of tons of dung on the streets, making cities pungent, fly-ridden, filthy, and diseased. A big city had to clear 10,000 to 15,000 horse carcasses from the streets every year. Part of the automobile's manifold appeal in 1910 was its modest emissions and the liberation it promised from the urban environmental problems associated with horses. By 1930 the urban horse was on the road to extinction.[20]

The automobile is a strong candidate for the title of most socially and environmentally consequential technology of the twentieth century. Cars in 1896 were such a curiosity that they performed in circuses along with dancing bears; by 1995 the world had half a billion cars. The history of their adoption and of the air pollution consequences appears in Chapters 3 and 4. Their total ecological impact was much greater, however. Their fuel needs helped propel the oil industry. Their country cousins—tractors and small trucks—helped revolutionize agriculture (Chapter 7). Cars and car culture had many requirements and impacts.

Making a car took a lot of energy and materials. In Germany in the 1990s, the process generated about 29 tons of waste for every ton of car. Making a car emitted as much air pollution as did driving a car for 10 years. American motor vehicles (c. 1990) required about 10 to 30 percent of the metals—mainly steel, iron, and aluminum—used in the American economy. Half to two-thirds of the world's rubber went into autos. This requirement alone led to the

creation of rubber plantations in Sumatra and Malaya on a large scale; in Sri Lanka, Thailand, Cambodia, and Liberia on smaller scales; as well as failures on the grand scale in Amazonia.[21]

Making room for cars took a lot of space. The United States built a road network from a very modest start in 1900 to 5.5 million kilometers of surfaced roads by 1990, exceeding the length of railroads at their maximum by 10 or 15 times. Most of that road-building spree happened from 1920 to 1980, partly because the federal government subsidized road building from 1916 onward. In the 1930s, Franklin Roosevelt's New Deal put thousands of unemployed Americans to work on road construction. The fastest growth in the road network occurred in the late 1940s. The interstate system that now crisscrosses America dates from 1956. All these roads, especially the interstates, attracted people, settlement, and businesses like iron filings to a magnet, reorganizing America's broad spaces into new patterns, which, in turn, made car ownership almost essential for most adults. No other country achieved the same automobile saturation as the United States, although some small countries got far higher road densities. All in all, in North America, Europe, and Japan, auto space took about 5 to 10 percent of the land surface by 1990.[22] Worldwide it took perhaps 1 to 2 percent, matching the space taken by cities (and overlapping with it).

Cars also killed a lot of people. In the United States the toll ranged from 25,000 to 50,000 per year after 1925, totaling perhaps 2 million to 3 million over the century—roughly five or six times the American war dead of the twentieth century. Worldwide, auto accidents killed about 400,000 people annually by the end of the century. Nonetheless, cars were convenient and conveyed social status, so they remained irresistibly popular.[23]

THE STRANGE CAREER OF NUCLEAR POWER. Nuclear power was an unpopular and uneconomic innovation, less lethal than cars, but with mind-boggling ecological implications. Like cars, atomic power had its origins in European science, reached maturity in the United States, and subsequently spread (unevenly) around the world. Humankind's first self-sustaining nuclear reaction took place in 1942, in a squash court at the University of Chicago, amid the hectic U.S. drive to build an atomic bomb. Civilian nuclear power started up in 1954 in the USSR, 1955 in the United Kingdom, and a year later in the United States. Nuclear power held some of the same political attraction

as dam building: it signified vigor and modernity. Admiral Lewis Strauss, head of the American Atomic Energy Commission, predicted in the 1950s that by the 1970s nuclear power would be too cheap to meter. Such optimism helped inspire governments, especially in the United States, USSR, Japan, and France, to invest in civilian reactors or assist private utilities in doing so. By 1998, 29 countries operated some 437 nuclear power plants.[24] But no nuclear power plant anywhere made commercial sense: they all survived on an "insane" economics of massive subsidy.[25] In Britain, which privatized the electricity industry in the late 1980s, there were no takers for nuclear power plants. Closing down old or dangerous nuclear plants proved horribly expensive. Nervousness about accidents accounted for many closings.

Scores of mishaps beginning in 1957 (Windscale, U.K.) climaxed at Chernobyl (in Soviet Ukraine) in 1986, by far the most serious civilian nuclear accident. There, human error led to an electrical fire and explosions that nearly destroyed one reactor. Thirty-one people died quickly. Untold numbers died (and will yet die) from Chernobyl-related cancers, primarily among the 800,000 workers and soldiers dragooned into cleanup operations, but also among local children whose thyroid glands absorbed excessive radiation. About 135,000 people had to leave their homes indefinitely, although some desperate souls eventually returned. The total release of radiation, officially put at 90 million curies, was hundreds of times greater than that given off by the bombs at Hiroshima and Nagasaki, which continued to cause health problems for decades after detonation. Everyone in the Northern Hemisphere received at least a tiny dose of Chernobyl's radiation.

The accident and initial denial and cover-up knocked one of the last props out from under the Soviet Union. It completely changed the public perception of nuclear power plants around the world, but especially in Europe, making it politically unpalatable except in a few countries (such as France and Belgium). Outside of Europe, only Japan, South Korea, and Taiwan showed much interest in nuclear power after Chernobyl. When none but historians remember the USSR, the environmental imprint of its nuclear power will remain. Some nuclear wastes and part of Chernobyl's fallout will be lethal for 24,000 years —easily the most lasting human insignia of the twentieth century and the longest lien on the future that any generation of humanity has yet imposed.[26]

Nuclear power did not replace other forms of energy production, as the car did the horse. It did not find companion innovations, technical and social, to form a new cluster that would remake the world, the way oil and internal

combustion engines had done. Instead, nuclear power complemented fossil fuels; it never accounted for more than 5 percent of the world's energy supply. But it did slightly reduce air pollution by providing an alternative to fossil fuel combustion. It created a different set of environmental consequences and risks. All significant technologies carried their specific packages of environmental implications, aggravating some problems while mitigating others. No single technology, not even nuclear power, matched the motown cluster in its capacity to alter both society and nature.

ENGINEERING GENES AND BYTES—A NEW CLUSTER? A new technology cluster may be emerging, one that may also succeed in revolutionizing human life and the globe's environment. Since 1750, new clusters have come at 50-to 55-year intervals, and another was "due" in the 1990s. Genetic manipulation and information technology may be at the center of it. At the century's end, momentous changes were afoot in biotechnology, especially the fervent efforts to turn new knowledge about genes to good use (and profit). For millions of years, genetic selection dominated evolution; then, with human society, cultural evolution slowly emerged as a rival force. From the 1990s, the two began to merge as science acquired the capacity to intervene directly in the selection and propagation of genes. Genetically engineered creatures, especially tiny ones, appeared set to change procedures in pest control, fertilizers, mining, recycling, sewage treatment, and other realms with direct connections to the environment. Scientists in Scotland cloned sheep; colleagues in Japan cloned cattle. Brave new worlds loomed, or beckoned.

Once expected to save paper, minimize commuting, and so forth, computers by 1999 had negligible environmental consequences but, like genetic manipulation, limitless possibilities. The Internet, still in its infancy, promised untold changes wherever electricity and computers reached. Some of these presumably would yield unpredictable environmental consequences. But the eventual impact of information technology and the new cluster (if it is that) remained opaque.

Technologies, energy regimes, and economic systems coevolved, occasionally forming revolutionary clusters, but this was only part of the picture. These clusters in turn coevolved with society and the environment in the twentieth

century, as at all times. Successful, widely adopted clusters must fit with contemporaneous conditions and trends in society and environment. At the same time, society and environment were affected by and adjusted to successful clusters. Thus, while all three codetermined one another, their relative roles changed. In prior centuries, the environment played a stronger role in influencing society and technologies, whereas in the twentieth century, technology's role, especially within the motown cluster, expanded and shaped society and environment more than in the past. But if certain environmental perturbations—such as significant global warming or biodiversity loss—prove fundamental, then the equation will be revised again in the direction of a stronger determinative role for the (new) environment. Paradoxically, if humanity is to escape projected environmental crises, then technology, which helped bring them on, will be asked to lead us out. A new cluster of related technologies, with or without a new energy system and economic order, could lead almost anywhere.

Economic Changes and the Environment

The three dominant features of twentieth-century economic history were industrialization, "Fordism," and economic integration. They were all intertwined, and together intermingled with the spread of fossil fuels and technological change. They, too, helped spread disruption and prosperity, foment the economic miracles of the twentieth century, and provoke massive environmental change.

INDUSTRIALIZATION. In the late eighteenth century in Britain, industrialization took off, quickly reaching an intensity never before approached, not even in Song China. From there it spread by leaps and bounds, intensified further, and changed form several times. Industrial labor efficiency increased about 200-fold between 1750 and 1990, so that modern workers produce as much in a week as their eighteenth-century forbears did in four years. In the twentieth century alone, global industrial output grew 40-fold.[27]

The coketown cluster centered in the United States and northwestern Europe. It spread to Japan early in the century, the USSR in the 1930s, and to Soviet satellite countries in the 1950s, some of which already had pockets of it, in Bohemia and Silesia. The motown cluster first took shape in the United

States but quickly crystallized in Canada, western Europe, Japan, Australia, and New Zealand. It extended only partially to the USSR (where innovations often met stern resistance after Stalin's consolidation of power) and to Latin America, and scarcely at all to Africa and southern Asia. China in effect attempted to create a version of the coketown cluster overnight with the backyard steel furnaces of the Great Leap Forward of 1958 to 1960. Despite the geographic spread of industrialization, since the 1920s about two-thirds of industrial production (by value) occurred in the core areas: the United States, Canada, Japan, and western Europe.

Like urbanization, industrialization changed the structure and pace of energy and material flows. Industry too has metabolisms. Here I will pass over specifics and examples and offer only two generalizations, one obvious and one hidden. First, industrialization everywhere and at all times increased resource use and pollution. The coketown cluster was especially dirty, even in some of its late-twentieth century incarnations (such as Silesia). The 40-fold increase in industrial output in the twentieth century implied a vast rise in raw material use and industrial pollution.[28] Vast but not 40-fold.

Second and less obviously, industries over time grew less dirty and less demanding. Their energy efficiency improved, and so they emitted less carbon into the atmosphere per unit of production, allowing industrial economies to "decarbonize." Industries also learned to use less raw material per unit of output, permitting "dematerialization." The energy intensity (ratio of energy use to GDP) of the British economy peaked around 1850 to 1880; it was probably the most inefficient, energy-guzzling economy in world history.[29] Energy intensity in Canada declined after about 1910, in the United States and Germany after about 1918, in Japan after 1970, in China 1980, and Brazil 1985. The United States used half as much energy and emitted less than half as much carbon per (constant) dollar of industrial output in 1988 as in 1958. South Korea achieved the same efficiency gains in half the time, between 1972 and 1986. In the world as a whole, energy intensity peaked around 1925 and by 1990 had fallen by nearly half. This meant far less pollution (and resource use) than would otherwise have been the case in the twentieth century. But this happy trend was masked by the strong overall expansion of the scale of industry.[30]

FORDISM AND MASS CONSUMPTION. Fordism here refers to both assembly-line

production and the historic compromise of the twentieth century between industrial workers and employers. As a result of a myriad of managerial developments, including Henry Ford's electrified assembly line, inaugurated in 1912, and Taylorism, the so-called scientific management involving the choreography of each laborer's motions, industrial economies achieved enormous productivity gains in the early twentieth century. Henry Ford saw that sharing these gains with his workforce suited his own interests, and from January 5, 1914—the birthday of consumer society—he paid laborers enough that they could hope to buy a Model-T. In 1923 his workers could buy one with 58 days' wages.[31] Millions of Americans did buy cars, radios, phonographs, then refrigerators and washing machines. They enjoyed an affluence and leisure that in the nineteenth century would have required an army of household servants. Fordism amounted to a renegotiation of the social contract of industrial society.

The production systems pioneered by Ford in the United States spread to Canada, Europe, Japan, the Soviet Union, and outposts elsewhere. The social compromise that converted the gains of mass production into mass consumption took many different forms and took varying lengths of time. In Europe the state brokered Fordism, striking bargains between unions and employers. (In France and Italy the employer was often the state itself.) In Japan, Fordism made rapid headway after 1945, when both factories and society were reconfigured under the American occupation (1945–1952). Mass consumption arrived in the 1960s. In the USSR the state was in effect the sole employer, and its rulers from the 1920s were much smitten by American factory efficiency. The Soviet Union committed itself ideologically to sharing its gains with industrial workers, but it did so in the form of secure employment, not mass consumption, creating a variant of Fordism in which industry produced mainly for the state, not the citizen. Whatever their prevailing ideology and political economy, industrialized societies spread the wealth sufficiently to keep the machines humming, the workers working—and usually buying. In short, outside the Soviet sphere, the enormous revolutions in production permitted—and required—enormous revolutions in consumption.

Social arrangements, from family relations to class structure, changed accordingly. Intergenerational and gender relations had to change with the demands of mass production and the delights of mass consumption. Young people tolerated the clanking inferno of early assembly lines better than did their elders, whose venerable skills no longer counted for much. For tasks that

emphasized precision and endurance, employers often preferred women to men. Affordable household appliances changed the lives of millions of wives and daughters. Old, usually unspoken, social contracts were abrogated and renegotiated within families and within societies, sometimes bitterly. Fordism's social impact was felt first in the United States around 1912 to 1945, in western Europe about 1925 to 1960, in Japan around 1950 to 1970, and in South Korea and Taiwan after 1980. The social changes involved a fair amount of strife because some people enjoyed the benefits of Fordism while others felt left out in the cold, buffeted by the brutally efficient competition of assembly-line production. Small businessmen and artisans in Germany, for instance, crushed by the efficiency of assembly lines, often turned to radical politics in the late 1920s, especially Nazism because Hitler explained their troubles comfortingly and expressed their anger compellingly. Revolutions of production and consumption can tear apart societies as completely, if not as quickly, as political revolutions.

Ecological arrangements had to change too. To sustain the new social arrangements, fields, factories, and offices needed more fuels, fertilizers, water, wood, paper, cement, ores—more of almost everything except horses, oats, whalebone, and a handful of other raw materials consigned to the dustbin of history. All these inputs were converted into energy, food, goods, pollution, and garbage. Without Fordism, without mass consumption, the environmental history of the twentieth century would have been much calmer.

Fordism extended few tendrils into Africa, Latin America, or South Asia in the twentieth century. Some isolated pockets of Fordist production techniques developed, such as the Tata family's iron and steel mill near Calcutta, long the largest one in the British Empire. But nowhere did these translate into the social compromise that yielded mass consumption. Had they done so, the environmental history of the twentieth century would have been even more tumultuous than it was. Should mass consumption society emerge in China, India, Nigeria, and Brazil in the next century—a prospect that remains uncertain—further excitement lies in store.

ECONOMIC INTEGRATION. Now often called globalization, economic integration has a long history of fits and starts. In modern times it got boosts from the explorations and trade links pioneered mainly by Europeans and Chinese between 1405 and 1779,[32] then from colonialism, and new transport and

communications technologies—railroad, steamship, telegraph—in the nineteenth century. Indeed the era 1870 to 1914 was one of great integration and consolidation in the world economy, observable in flows of trade, migration, and capital. World War I and the Russian Revolution stopped this trend. Soviet Russia veered toward an ideal of autarky, followed by fascist Italy in the 1920s. Then international trade and investment flows plummeted during the Great Depression and World War II.

That disastrous experience weighed on the minds of the architects of the postwar economic order. They understood that prosperity depended on trade, and fashioned a new regime of monetary and trade agreements under American leadership. This regime promoted and achieved rapid integration of western Europe and North America from the late 1940s, Japan from the time of the Korean War (1950–1953), the big oil exporters of the Middle East by the mid-1950s, South Korea and Taiwan from about 1970, and, less thoroughly and less quickly, Latin America, Africa, and South Asia. Meanwhile the USSR organized a much smaller and less well integrated rival system including eastern Europe and, briefly, China. In the 1970s the two blocs began to integrate as Moscow weakened its commitments to economic autarky, seizing the opportunity to sell oil and gas, and facing the necessity to buy grain.

Despite slumps and setbacks the momentum of integration continued. Indeed, it accelerated in the 1980s and 1990s, propelled by falling transport costs,[33] instant electronic communications, by assertive privatization and deregulation of financial markets and major industries, and most importantly by the ideological collapse of autarkic socialism in China (after 1978) and its political collapse in eastern Europe and the USSR (1989–1991). In terms of both the prevailing economic ideology and the prominence of international trade and finance, the post-1980 era resembled that of pre-1914.

All this, while socially disruptive everywhere and grating for those who did not enjoy American leadership, served with industrialization and Fordism as impetus for the world's amazing economic growth after 1945. The environmental consequences of this surging economic integration extended beyond those of mass consumption.

Economic integration often commodified nature suddenly. When groups of consumers, through the magic of markets, were presented with the opportunity to buy something hitherto unavailable, they often did so. If that thing was elephant ivory, rhinoceros horn, giant panda skin, alligator hide, ostrich feathers, beaver fur, tortoiseshell, whale oil, teak, or the like, then the linkup

between consumer and source of supply changed ecology in the zone of supply—often drastically. This was because supply was governed by rhythms of reproduction not subject to rapid acceleration. Rhinos will not procreate on demand. After 1970 the market for rhino horn in East Asia (for medicines) and in North Yemen (for dagger handles) overwhelmed the rate of rhino reproduction. By 1997 their numbers fell 90 percent, to about 5,000 to 7,000 worldwide.[34]

Economic integration focused the dispersed demand of millions upon limited zones of supply. These zones were often sparsely populated frontiers, where the human touch had hitherto been light and where social restraints upon rapacity were few. The result was rapid exhaustion of commodities and transformation of ecologies. While this effect was most dramatic in the case of wildlife, it extended to valuable plants and trees, such as mahogany and cedar, and to landscapes under which valuable minerals lay. The impact of nickel mining on New Caledonia (see Chapter 2) would have been negligible had New Caledonia not been integrated into an international trading system. New Zealand and Argentina converted suitable land into pasture to meet the overseas demand for meat, butter, and cheese after transport changes—in particular, refrigerated shipping, invented in the 1880s—connected these landscapes to distant urban markets. From the 1950s, Central American forests became cattle ranches to meet North American demand for beef. Malayan forests became rubber plantations, Brazilian ones coffee plantations, and Ghanaian ones cocoa plantations—all because of market integration. Even illegal trades, in cocaine or marijuana, drove ecological change in places such as Peru, Bolivia, and northern Morocco. After 1965 the borderlands of northern Mexico—a different kind of frontier—industrialized rapidly and dirtily because Mexican manufactures achieved greater access to the U.S. market. Economic integration, especially modern globalization, left fewer and fewer landscapes, seascapes, or habitats untouched by the effects of "frontier economics."[35]

Economic integration, at least when sudden, also disrupted common property regimes that checked environmental change. Around the world, fisheries, forests, pastures, aquifers, and other resources were (and are) often governed by rules of access that allow many to use the resource but none to exhaust it. Some such arrangements were old, such as those safeguarding subterranean waters in Valencia, Spain, or rotations among herder groups in the Sahel of southern Niger, whereby different groups took turns exploiting

different grazing lands. Others were new, like the lottery system organized in the 1960s by fishermen in Alanya, Turkey; to prevent the depletion of their fish stocks, the fishermen rationed access to fishing grounds and let chance determine who fished where and when. The buffeting winds of globalization brought new shocks to these small-scale social systems. In fishing, for example, bigger operators tapping distant markets introduced trawlers and overwhelmed artisanal fishermen, whose common property regimes often collapsed. Free-for-alls ensued, and the fisheries collapsed too. Such regimes easily gave way to "tragedies of the commons" when strangers selling to distant markets—and thus operating outside the usual system of sanctions for miscreants—got involved.[36]

Similar environmental effects frequently derived from insecurity of property, even without the collapse of systems of regulated access. Wherever landowners, fishermen, herders, hunters, or miners feared that access to the resources that underwrote their livings (or their fortunes) might be lost tomorrow, they had every incentive to get as much as possible out today. Such fears, while commonplace throughout history, may well have grown with the rapid ebbs and flows of colonial empires, of communist revolutions, and other political shifts that rewrote the rules of property and access to resources. Ethiopians after 1935, to take one example, faced a chain of events featuring war, colonial occupation and expropriations, revolution, and civil war. Chinese and Russians found themselves in situations of nearly equal uncertainty. People operating on the fringes of the world economy—where links to distant markets made land and resources valuable, but where property rights, and rule of law generally, were hard to enforce—faced a similar logic. In backwoods Brazil and similar "frontier" areas, cashing in quickly whenever possible was hard to resist, and the rationale of preserving a resource for the future was especially weak.

Economic integration in the late twentieth century also promoted a rapid "financialization" of the world economy. In the 1970s, the oil producers' cartel (OPEC) brought them vast windfall profits, which they deposited in the world's banks. When states abandoned efforts to regulate capital flows, which many did under the influence of the ideas and pressures of the Reagan-Thatcher era, they made it much easier to make money in finance than in, say, trade or manufacturing. International financial flows dwarfed trade flows after 1980, filling the world's banking systems with cash. This too had its ecological consequences, because banks must lend.

A fair chunk of this cash passed through development banks. The World Bank (founded in 1944), the Inter-American Development Bank (1959), the Asian Development Bank (1965), and a few others were charged with prodding economic development in poor countries. They specialized in lending for specific development projects. In some respects they were successors to the European colonial regimes which ostensibly intended to "develop" economies in Africa and Asia before decolonization. But the banks had far more money. They could borrow huge sums in the flush financial markets of New York, London, and Tokyo and lend it out to poor countries. In keeping with reigning ideas about economic development, these banks tended to invest in infrastructure and energy projects. After 1960 the World Bank was the single largest financier of road building, power plants, oil drilling, coal mining, and dam construction. Until 1987 the development banks paid virtually no attention to the ecological consequences of their lending programs, even those with far-reaching effects such as road building and settlement in Amazonia. The governments borrowing their billions, notably Brazil, India, China, and Indonesia, did not want the banks to worry about environmental effects. They, together with most bank staffs, resisted when the World Bank, after 1987 bowing to American pressures (originating with environmental groups and filtered through Congress), started to require environmental assessment of its projects. Other development banks, not subjected to the same pressures, continued to lend on strictly economic and political criteria into the 1990s. The huge sums—tens of billions of dollars a year—disbursed by the development banks allowed eager states to transform their environments with irrigation schemes, power plants, roads through rainforests, and much more. A discouraging proportion of these projects were ecological fiascos because their promoters gave no thought to ecological contexts.[37]

Conclusion

The changes in energy regime, technology, and economy in the twentieth century were closely linked. Together as clusters of innovation, these changes propelled environmental history, both in pace and direction, in the industrialized world. Their impact elsewhere, while great enough, was limited by the fact that technological change and energy-intensive economies made a fainter imprint. Indeed, the coketown and motown clusters affected many lands only indirectly, through economic linkages with Europe, Japan, and North America. Most people in Mongolia, Borneo, Chad, and Bolivia experienced

little change in the way of automobile use, industrialization, and Fordism, but oil and new transport technology helped connect them to industrial heartlands in the USSR, Japan, Europe, and the United States, bringing environmental alterations through new crops or intensified resource extraction. The patterns of technological change and energy use shaped the international division of labor, and thus the international distribution of environmental effects. The rich countries, with their energy-and technology-intensive economies, suffered more from air and water pollution, whereas the poor countries, with their low-energy and low-technology economies, got more deforestation, soil erosion, or desertification. Some big and diverse countries, like Russia and China, suffered from all of these effects because their areas were so vast as to allow them to turn their backs on the world economy and thereby reproduce its division of labor within their own borders.

The strongly linked trajectories of energy, technology, and economy together exercised paramount influence over twentieth century environmental history. They were tied less tightly to trends in population and urbanization. And they interlocked, often strongly, with ideological and political currents, which they helped cause and which helped cause them.