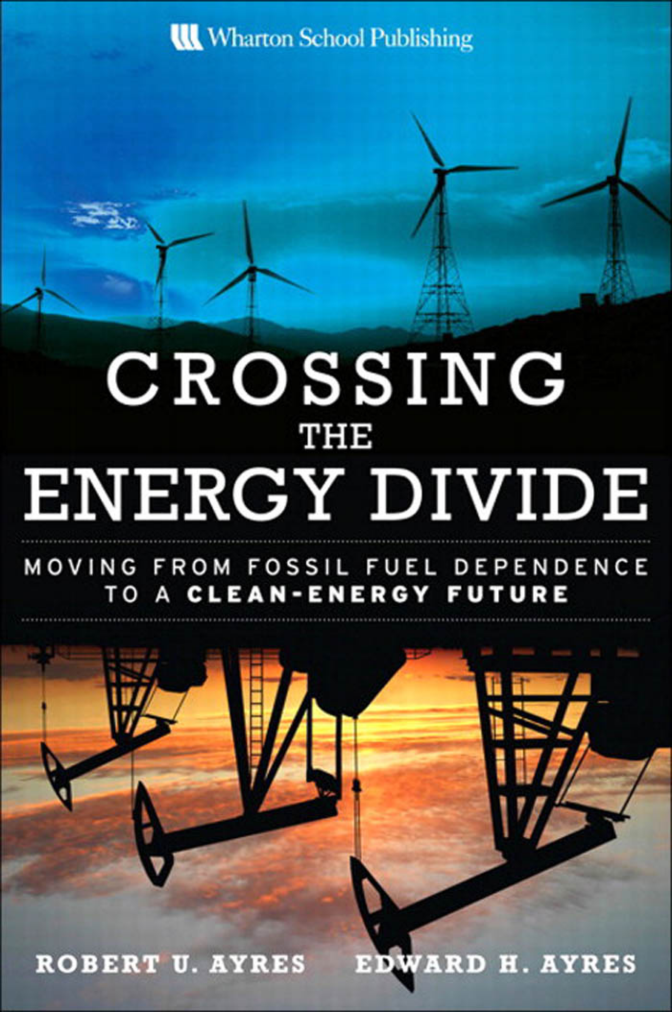

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CROSSING THE ENERGY DIVIDE

MOVING FROM FOSSIL FUEL DEPENDENCE TO A **CLEAN-ENERGY FUTURE**

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Introduction: The Chasm to Be Crossed

This book makes two paradigm-challenging claims.

First, physical energy plays a far more fundamental role in economic productivity and growth than most of the economists advising business and government have ever acknowledged. The implications for everyone who breathes, especially during the coming period of hoped-for recovery and transition to the clean-energy economy of the future, are enormous. Energy services aren't just a large part of the economy; they're a major part of what *drives* the economy. And if that is so, both the economic recovery and the energy transition will take far longer than the Obama administration has counted on—*unless* investment is targeted to the very specific technologies and industries that make energy services cheaper. Shotgun spending won't do that.

Second, the energy economy of the industrial world is so deeply dependent on fossil fuels that even the fastest conceivable growth of wind, solar, and other renewable-energy industries cannot substantially replace oil, coal, and natural gas for at least several decades. Virtually the entire capital infrastructure of the country—roads and highways, electric power plants, transmission lines, airlines, shipping, steel, chemicals, construction, and home heating and cooling—depends on fossil fuels. Even if the use of electric cars and solar roof panels were to grow as fast as the Internet did, they would still account for only a drop in the ocean of energy we will use during the next two decades.

Alternative energy has begun to make inroads at the margins, but it has much farther to go than those who have called for a "green energy revolution" have acknowledged. In 2007, after two decades of increasingly urgent warnings by climate scientists that we must sharply reduce carbon emissions, and after more than a decade of seemingly accelerating progress toward a greener future, the total percentages of U.S. electric power produced by renewables (other than hydroelectric power, which can no longer increase) were as follows:

Biofuels	1.4
Wind	0.8
Geothermal	0.4
Solar (photovoltaic)	0.1

Recent progress in these industries has been dramatic. However, even with a crash effort comparable to the U.S. mobilization for World War II, or the Apollo program to put a man on the moon, it will take decades for these new energy industries to reach the necessary scale.

And what happens between now and then? The brutal answer is that if the United States were simply to shift most of its energy and climate attention to that long-term sustainable future we now envision, the existing energy economy would likely collapse before the country could reach that future, as surely as a heart-transplant patient would die if a new heart were not available in time.

There may seem to be a large disconnect between this perspective and the widely publicized claim of Al Gore and others that the United States can harness renewables to achieve full energy independence within ten years. Although we share Gore's sense of urgency about the need to replace fossil fuels as quickly as humanly possible, a sober review of the science and economics makes it clear that it could take half a century before the United States fully achieves this goal.

There is a logical solution to this conundrum, however, and it is the great fortune of the United States—and the world—that a viable means of achieving this solution is still within our grasp. It is not a solution that has anywhere near the idealistic appeal of the alternative-energy vision that has begun to galvanize our most progressive leaders, but it is essential to achieving what they envision.

The solution is to *radically reform our management of the existing, fossil fuel–based system* so that we essentially double the amount of energy service we get from each barrel of oil (or "oil-equivalent" of coal or natural gas) during the years it takes to bring carbon-free renewables to the point at which they can truly begin to take over. This is not to echo the heroically hopeful stance of a John F. Kennedy calling for landing a man on the moon. It is not one of those epic goals that we can achieve only by a massive mobilization of technological research and development. It is not an echo of writer Thomas Friedman's call to "get 10,000 inventors working in 10,000 companies and 10,000 garages and 10,000 laboratories to drive transformational breakthroughs," which is a terrific pipe dream of free-market ideology but at best will take a generation to pay off. To safely cross the economic chasm we now face, we need a solution that yields results more quickly. As it happens, the means to a rapid doubling of U.S. energy service (the amount of useful work done by each unit of fossil fuel burned) already exist. Some of these means are hidden from public view and have not been discussed in mainstream media, but are already being profitably used by hundreds of companies and institutions. They *could* be used by tens of thousands more.

We can appreciate how the confluence of high-profile events around the time of the Obama election brought a new sense of excitement and possibility to people who had been discouraged for years. The Phoenix-like return of Al Gore with his galvanizing film about climate change, *An Inconvenient Truth*; Tom Friedman's rallying call for a more muscular "green revolution"; and the remarkable fact that *both* presidential candidates in 2008 recognized the coming threat of global warming and the need for investment in alternative energy—it all generated tremendous eagerness to leap ahead to the clean-energy economy of the future. For nearly two decades, progressive Americans had felt dismissed and ignored at every turn: the Senate voting 95–0 to reject the Kyoto climate treaty in 1995; the second Bush administration refusing to acknowledge that global warming was real (or, later, that it was driven by human activity); vice president Dick Cheney scorning energy efficiency as a feel-good thing that did nothing for the nation's "real" energy needs; and the Iraq War being widely suspected of being mainly an oil war. For Americans who had felt gloom for half their lives, the election of a candidate who had opposed that war and who was a strong advocate of wind and solar investment seemed like a time to celebrate.

That flush of optimism soon faded as the economy continued to deteriorate in 2009. Yet the belief that big investments in renewables could help spur economic recovery remained unquestioned. In the rush of the new administration and Congress to stop the economic hemorrhage, virtually no thought was given to the possibility that a very different kind of climate and energy management might be needed, not only to bridge the chasm that separates today's world from the clean-energy economy of the future, but also to restore enough growth to ensure that the nation can reach the far side of that chasm. The country isn't ready—because the technology and infrastructure aren't ready—for us to jump with both feet onto the wind, solar, and biofuels bandwagon quite yet. There is critical business to take care of first.

For those who feel a great relief and reassurance about what now appears to be an open path to the renewable-energy future, here is an example of the kind of initially disillusioning—but ultimately liberating—assessment that is essential to taking that path safely. A few years ago, behind the gates of a large rust-belt factory in Indiana, the world's largest steel company, Mittal Steel (now Arcelor Mittal), began operating a facility that captured waste heat from one of its fossil fuel–burning processes and converted that heat to emissions-free electricity. A few miles down the road, a rival company, U.S. Steel, was using a similar strategy to generate emissions-free power from waste blast-furnace gas. In 2005, the two rust-belt rivals generated a combined 190 megawatts (MW) of carbon-free energy from their waste—*more than the entire U.S. production of solar-photovoltaic electricity that year.* That was just the waste heat from two fossil fuel–burning plants in one corner of one state.

The production of photovoltaic power has continued to grow rapidly since then. In January 2009, the California company Sempra Energy began operating a 10MW solar farm in Nevada and generating its power at a surprisingly competitive price. Another California company, BrightSource Energy, announced in 2009 that it would build a 100MW thermal solar plant in the Mojave Desert, with construction to be completed by 2013. Solar power will continue to grow dramatically, as will wind power and other carbon-free sources of energy. But renewables have started from such a tiny base (solar and wind energy together produced less than 1 percent of U.S. electric power in 2007) that, even with geometric growth, they will need 20 years or more before they can replace a big share of the millions of coal-, oil-, and natural gas–burning steam generators, factories, and engines that power our civilization—and our economy. Meanwhile, the near-term potential for ramping up the clean-energy supply by such already-proven means as the ones being exploited by the Mittal and U.S. Steel plants is far larger. For every one of the roughly 1,000 American industrial plants doing this kind of waste-energy recycling, 10 more have yet to begin. Environmentalists might be disheartened and disoriented to think that the fastest and cheapest way to cut carbon emissions and fossil fuel use is *not* to turn our backs on the dirty old industries of the past and present, but to wade into their most neglected corners and clean them up, until the more ideal alternatives are up to scale.

By using the phrase "clean them up," we're not alluding to so-called "clean-coal" processing or to elaborate schemes for capturing carbon emissions and pumping the carbon deep into the ground or the ocean. Those kinds of would-be cleanup are prohibitively costly and even less ready for prime time than solar power. And if the technology for carbon capture and sequestration eventually makes economic sense, the facilities will likely take many years to build—not a realistic option during a time when the country has entered economic survival mode. The strategy we describe in this book doesn't depend on yet-to-be-developed, we-think-it-will-work technologies. Instead, it's an *energy-management* strategy, entailing a sweeping reassessment of ideological blind spots, structural barriers, bad habits, and outdated laws that have kept the U.S. energy economy creeping along at about 13 percent overall efficiency when it could double that without any new technology or new fossil-fuel supply. (Japan achieves about 20 percent, and we see a way to exceed that.) The effect would be to essentially double the country's energy service per unit of fuel burned. Sharply cutting the supply of fossil fuel needed would accelerate the hoped-for energy independence—and would greatly heighten energy security, which isn't always the same thing as independence. And by using less fuel to do more work, this strategy will sharply reduce carbon emissions.

The economic chasm we have to cross to reach that goal has two critical dimensions. First is its sheer breadth—the number of years it will take for wind, solar, and other clean renewables to replace the bulk of the fossil fuel supply we now depend on. Second is its depth—the depth of economic depression that must be overcome by a restoration of economic growth. Is there a strategy that will shorten the transition to renewables *and* stimulate growth? The energy-transition strategy we propose will help do both: It will bridge the chasm and shorten it.

As suggested by the Mittal energy-recycling case, more intelligent management of the existing fossil fuel supply can actually boost the productivity of the energy sector faster than the renewables bandwagon can. How? Increasing the *energy service* per unit of primary energy input proportionately reduces the cost of that service. And that reduction of cost, as we explain in this book, will drive economic growth.

The prevailing economic theory holds that growth is driven by capital investment and labor plus a very large, unquantifiable, factor—"technological progress," which remains "exogenous" (outside the forecasting calculations) because economists have been unable to fully identify or explain it. As a result, the capabilities of standard models to forecast economic growth have been notoriously poor. But new research has shown that the largest driver of growth is not so mysterious after all. The real engine of economic growth, it turns out, has been *the growing use (thanks to declining costs) of energy service, decade after decade.* (The term "energy service" refers to what economists with training in physical science call "useful work.") The proof, which we summarize briefly in this book and provide in full detail on our web site, is that incorporating the energy-as-useful-work factor into the economic models dramatically improves their long-term explanatory power—and forecasting capability.

The most exciting implication of this finding is not that the standard models need to be revised (they do); it's the more pragmatic prospect that a strategy that reduces the costs of energy services (by increasing output and profit per unit of fuel) will also help drive economic growth and recovery in the coming years. Our assessment suggests that we can engineer the "bridge" to achieve these goals by implementing eight proven (although in some cases little-publicized) technologies, of which the aforementioned waste-heat recycling is just one.

Two critical and potentially world-changing implications follow. First, the largely unquestioned assumption about how the cost of the multitrillion-dollar bailouts and recovery bills of 2008–2009 will be repaid—the assumption that the economy will soon recover its robust growth, as it always has in the past, because an infusion of new capital or spending power will drive it—may be wrong. Second, if low energy-service costs are needed to drive growth, the economic prospect is more dire than most experts have thought.[1] As global oil production peaks and begins to decline while the energy demands of China and other fast-growing countries continue to rise, and as climate-change constraints on all fossil fuels continue to tighten, fossil-fuel energy prices will rise higher than ever. Consequently, economic growth will halt or be thrown into reverse—*unless* we find ways to make energy services cheaper. If the nation's energy management in the coming years can double the productivity of its present supply, getting twice as much energy service or useful work (heat, light, propulsion, and so on) per barrel of supply as it does now, the cost of that service will decrease and growth can continue.

To explain more specifically how this can happen within the time span required for the transitional bridge, we take our assessment one important step further. Beyond challenging the currently prevailing theory of economic growth, which is critical to the recovery of the energy economy, our analysis suggests that there will be an unexpected silver lining to the darkening prospect of prolonged economic struggle being worsened by climatic destabilization. Experts on the ideological left and right might differ sharply in their projections of what climate mitigation will cost, but most agree that the cost will be significant and will reduce economic growth. However, our assessment suggests that we can accomplish significant parts of the transition strategy at a *negative* cost—simultaneously reducing energy costs, fuel use, and greenhouse emissions. Other parts of the bridge will involve low net costs that the nation can fund by shifting government support from currently unproductive projects to ones that are demonstrably productive.

This is where the strategy of building a bridge to the future using proven components becomes doubly important: It avoids huge capital costs (such as the construction costs of new nuclear or coal-burning central power plants, or oil-drilling platforms) that the United States

[1] Even if short-term energy prices fall, as they did in late 2008, thinking that the long-term threat has abated is a mistake. The price of a gallon of gas or a barrel of oil reflects current stockpiles, not global reserves, which will inexorably continue to shrink.

cannot afford to pay or wait for, and it cuts energy cost and drives economic growth by quickly increasing economic output per barrel of oil or oil-equivalent. We should note that oil man T. Boone Pickens did the country a service by publicizing the need for an energy bridge in his highly publicized campaign to increase subsidies for natural gas in 2008, but what he was asking for (more money to search for natural gas) would not have provided such a bridge.

This book is about what is needed to build that transitional bridge. Little or no ingenious new technology is needed, although development of the technologies required for that safer place on the far side of the bridge should of course continue to expand. Over the next few years, what's needed most is for those who see that pristine future so clearly to look down at the increasingly unstable economic ground right under our feet—and the economic chasm ahead—and to see just as clearly the outlines of the bridge we need to build before we can get to that safer place.

2

Recapturing Lost Energy

Politically and emotionally, energy independence has become a hot issue not only for Americans, but for oil-dependent countries all over the world. In 1973, the Arab oil embargo caused long lines at American gas pumps. In winter 2009, eight European countries had to go weeks without natural gas—causing millions of people to freeze—because Russian politicians decided to cut off their supply. Only a few countries are oil or gas exporters; the rest (including the United States) are increasingly at the mercy of those few—*unless* they can find a way out.

American politicians' responses to the call for energy independence have been reflexively quick and predictably consistent with their ideological proclivities. With the gasoline price spike of 2008, Republicans aggressively renewed their call to drill for more oil off the California and Florida coasts and in the Arctic National Wildlife Refuge, areas where drilling has been prohibited for environmental reasons. They also called for reviving the nuclear industry and building many new nuclear power plants. Drilling would be consistent with the long-held conservative view that the exploration and conquest of nature has been at the heart of the American quest,[1] and that the government shouldn't tell corporations what they can or can't do. Conservatives also argue that nuclear power wouldn't generate greenhouse gases. Environmentalists and the Obama administration have called for a shift from oil to renewable energy resources as fast as possible, because of the damage done in recent years both to the climate and to the nation's reputation (and clout) around the world.

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[1] TV commercials by Exxon-Mobil in summer 2008 intoned that, in the great quest of the human experience, "we are explorers" by nature, and suggested that oil exploration on the ocean bottom is an inexorable extension of that noble quest.

Unfortunately, both of these political impulses are mistaken. The conservative call to drill for more oil in ecologically vulnerable areas is misconceived for two reasons. First, geological studies have made it clear that little oil would likely be found there[2]—the call is largely symbolic. And whatever is there will take a decade to extract, so the immediate benefit would be essentially zero. Second, it's possible to achieve U.S. energy independence *without* such drilling—and without the commensurate increases in global-warming carbon dioxide emissions that the extra oil produced would then generate. As we show in this chapter, we can make the fossil fuels that we're currently using produce more energy service—so much that, within the next 20 years, it will be possible to end oil imports from the Middle East without any new drilling off Palm Beach or La Jolla, or in the middle of a caribou migration route. The heavy lobbying for nuclear power tends to obscure the fact that, although nuclear sources provide some electric power, they don't provide a substitute for petroleum, either gasoline or petrochemicals.

Some of the environmentalists are mistaken, too. Although the need to replace oil and coal (and possibly nuclear power) could hardly be more critical, it will take at least several decades to make the full changeover. We share the goals—and the sense of urgency—of the alternative-energy advocates. But there is no politically or financially viable way to overcome the real-world constraints of capital depreciation, massive capital replacement of obsolescent fossil-fuel infrastructure (including roads and highways), and the impossibility of mobilizing new investment overnight. A gargantuan share of U.S. assets is locked into the old system; even under emergency conditions, it will take many years to free them up. On the other hand, even if the old infrastructure could be dismantled in a week, it would be a huge mistake because, paradoxically, the fastest way to achieve U.S. energy independence and sharply cut carbon emissions is to leave the old system in place a while longer—investing in short-term modifications that can greatly increase the total output of useful work with existing fuel inputs *and* simultaneously reduce the output of

[2] According to the U.S. Energy Department, the United States (including its coastal areas) has less than 3 percent of the world's known petroleum reserves.

greenhouse gas emissions. We can explain this best by looking at a real-world case.

The Hidden Gold of Energy Recycling

On the south shore of Lake Michigan, in the northwest corner of Indiana, the Mittal Steel Company has a coking facility called Cokenergy. Coke (the industrial substance, not the soft drink) is nearly pure carbon, made by heating coal in the absence of air to remove the methane, sulfur, ammonia, tar, and other impurities to make it suitable for use in a steel-making blast furnace. Some of the gas removed in this process is used to heat the ovens. In a conventional facility, the combustible coke-oven gas is captured, but the hot combustion products from heating the ovens themselves are normally blown into the air.

But Cokenergy is not conventional. In addition to recovering the gases for use elsewhere, this plant captures waste heat and uses it to generate electricity as a byproduct. This "recycled" energy is produced *without any incremental carbon dioxide emissions or other pollution.* Although the primary process (making coke) uses a fossil fuel, the subsequent production of electric power from the high-temperature waste heat does not. The byproduct electricity is as clean as if it were made by solar collectors. This carbon-free electricity is then used to run the rolling machines in Mittal's adjacent steel plant.

In 2005, the Mittal coking plant generated 90 megawatts (MW) of emissions-free electric power. As we noted in the Introduction, that output, combined with the 100MW of recycled energy that nearby rival U.S. Steel produced, exceeded the entire U.S. output of solar-photovoltaic (PV) energy that year. Combined with the more than 900MW of recycled waste-energy streams other American plants harnessed, the nation's recycled-energy output was about *seven times* the U.S. solar-photovoltaic production that year. Moreover, the companies that recycle their waste energy haven't needed to buy this power from local utilities. This eliminates all the carbon dioxide emissions (and other pollutants) that the utilities' production of that amount of power would otherwise generate. Yet the total U.S. production of emissions-free "bonus" electricity by this method is still only about 10 percent of the amount that currently operating American plants *could* produce—without burning any additional fossil fuel.

Solar PV has gained rapidly since 2005, but even if it continues to expand at a meteoric rate, it has started from such a small base that it will take many years to replace a large share of the fossil fuel we now depend on. Wind power is further along, but it, too, will need many years. And it's those "bridge" years we need to be concerned about. Companies can install facilities such as the one at Mittal Steel's Cokenergy plant within three or four years. And those facilities are profitable. The electricity from Mittal's recycling operation costs only half of what the local utility charges its customers.

It's a bizarre, perhaps ironic situation, to be sure. From an aesthetic or emotional standpoint, a progressive environmentalist might find it hard to accept that *using fossil fuel more effectively* is preferable to just switching as soon as possible to renewables, as so many people seem to suggest. But from the standpoint of physical science and engineering, it's indisputable: If our goal is to reduce carbon emissions on a large scale as quickly as possible, the most effective way is to invest in "cogeneration." This means recycling the high-temperature waste heat energy not just from coking, but from a spectrum of existing fossil fuel–burning industrial processes—such as smelting, oil refining, carbon-black production, and chemical processing—into electricity that's as clean as if it had been produced by wind or the sun. And this energy is cheaper.

That last point is critical: Recycling waste-energy streams from industrial uses of fossil fuels is still far *cheaper* than energy from solar-photovoltaic generation or wind turbines, and far cleaner than energy from biomass. The day will come when the renewables will be competitive without subsidies, and civilization will be on safer ground. Wind power is sufficiently developed to compete with nuclear power or fossil fuels in some windy places, but solar power (both thermal and photovoltaic) still has a long way to go. For the next few years, even with the 2009 financial rescue plan's boost for alternative energy, a dollar invested in waste-energy recycling such as the program at the Mittal plant will produce more emissions-free new power—and carbon dioxide reduction—than a dollar invested in renewables.

We must quickly add that this does *not* mean investors should have second thoughts about investing in renewable energy. For the strategy outlined here to make any sense, investment in solar, wind, and hydrogen sources should continue to increase. Energy recycling such as the kind Mittal Steel is doing is a short-term strategy intended to hold the fort until renewable output is big enough to take over. Until then, recycling the heat from the coke plant is the smartest thing Mittal Steel can do.

Unfortunately, this doesn't mean that such low-cost, emissions-free energy can provide the power for your home or office—yet. Mittal Steel distributes its 90MW from Cokenergy only to its own steel plant, not to the people of East Chicago, Indiana, where the plant is located. However, supplying clean electricity to the enormously energy-consuming steel-making process in this way not only reduces the need for Mittal to buy electricity from its local utility, but also greatly reduces the amount of carbon dioxide that the utility pumps into the air over northern Indiana.

In addition to high-temperature heat, we can recycle several other kinds of waste-energy streams that thousands of American industrial plants generate. We can inexpensively convert much of this waste to electric power that would otherwise need to be generated by coal- or natural gas–burning power plants or by nuclear plants.[3]

In Rochester, New York, the Kodak Corporation has a complex that stretches 5 miles end-to-end. A steam-pressure system that powers its chemical processing now recycles 3 million pounds of what would otherwise be waste *steam* per hour, generating electric power that, at last count, was eliminating 3.6 million barrels of oil-equivalent per year and saving Kodak $80 million on its electric bill.

A third category of waste-energy stream is flammable *gas,* which petroleum refineries and some chemical plants often simply burn off (flare) into the sky. If you've ever driven along a certain stretch of the New Jersey Turnpike at night, along I-95 near Philadelphia, or in the "Cancer Alley" area of Louisiana, you've seen (and smelled) a lot of gas flaring. In principle, companies could have used all that wasted energy to make cheap electricity.

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[3] Nuclear plants don't emit carbon dioxide, but they pose an entirely different energy-security problem because of safety concerns that have persisted since the Chernobyl disaster (and that have been intensified by perceived vulnerabilities to terrorist attacks) and because of the difficulty of safely burying radioactive waste that remains lethal for thousands of years.

At a U.S. Steel plant in Gary, Indiana, and in steel plants all over the world, a byproduct of the iron-smelting process is "blast-furnace gas," which consists mostly of carbon monoxide and nitrogen, with some hydrogen and carbon dioxide. The monoxide and hydrogen make it flammable (and toxic), so it must be flared if a beneficial use cannot be found. But in this plant, the blast-furnace gas is captured to produce steam, which drives a steam turbine powering a generator with an annual output of 100MW—even more than at the Mittal coking plant a few miles to the west.

A fourth kind of waste-energy stream is produced by decompression. About 8 percent of the natural gas shipped by pipeline is used for compression of the gas itself, to drive it through the pipelines. At the delivery point, this compression energy is lost. Yet a simple back-pressure turbine, costing a few hundred dollars per kilowatt, can convert that pressure to useful electricity. This process alone could add another 6,500MW of carbon-free electricity in the United States, saving roughly 1 percent of U.S. fossil-fuel consumption and the greenhouse gas emissions.

The Biggest Energy Drain

A fifth, and very different, waste-energy stream is *low*-temperature heat, which is dumped into the air or water in enormous quantities by—of all people—the big centralized electric utilities. You might wonder, why would a company that's in the business of selling energy *dump* energy? The reason is that, unlike high-temperature waste heat, low-temperature heat can't be used to make electricity, so the central power plants just blow it into the sky or into a nearby river or pond.

However, that doesn't mean that low-temperature heat can't be used. It's just that it can't be used in the places where most central power plants are located—far from the cities or towns they serve. Although electricity can be transmitted many miles over wires, hot air or hot water can't be sent any distance without cooling. But if the heat can be used just a short distance from the power plant, it has an immediate energy-saving and carbon dioxide–reducing benefit.

The main use of low-temperature heat is for warming homes or buildings. In most U.S. communities, space heating is provided by burning oil, natural gas, or propane, or by purchasing electricity from a utility that burns coal or natural gas. In other words, nearly all U.S. homes and buildings (with a few solar or wood-burning exceptions) are heated by fossil-fuel combustion, directly or indirectly. If they could be heated by the low-temperature waste heat from electric-power production, the fossil-fuel combustion now used to produce that heat could be completely eliminated.

The potential for that saving is enormous. With the conventional U.S. electric-power system operating at an average efficiency of just 33 percent (including transmission losses), only one of every three units of energy going into those plants ends up being delivered to consumers in the form of electricity. The other two units are discarded as waste heat. The obvious question is, how can we get the heat to where it can be used?

One answer is a strategy called CHP. Among energy experts, CHP refers not to the California Highway Patrol, but to something that could make an arrest with more stopping power than most policemen ever get to use: It could arrest what is perhaps the single largest of the many leaks that are draining America's energy supply. CHP is the strategy of combined heat and power—producing both heat and power in the same plant as saleable products. Because a conventional electric-power plant produces only electric power in a facility that is typically located in the boondocks, the power must be transmitted over costly (and ugly) power lines to cities. But suppose the power is generated right in the basements (or rooftops) of apartment houses, shopping districts, university campuses, or industrial parks where it is needed, and where the buildings can then use the waste heat for heating and hot water. That kind of system, called *decentralized* CHP, or DCHP, eliminates not just the financial and environmental costs of buying power from so-called central plants, but also the substantial costs of transmitting power at high voltages over long distances.

The Mittal and Kodak cases previously described are limited forms of CHP because both heat and power are produced and used. Unfortunately, it's not as easy to cite current examples of DCHP used for a shopping mall or office park in the United States because DCHP is, for most purposes, illegal in every one of the 50 states. You can generate electricity for your own use or sell it back to your utility monopoly (at a price it decides), but you can't sell it to your neighbors. It is actually illegal in every state to send electricity through a private wire across a public street. That's why Mittal Steel can't sell clean, cheap electricity to its neighbors in East Chicago, for example. We return to this topic in Chapter 5, but for now let's just say that the laws blocking DCHP need to be modified. If politicians and policymakers are serious about energy independence, the laws that created those utility monopolies in the 1920s, under very different circumstances, will have to be changed.

DCHP is now used routinely in other countries. In much of Europe, a form of CHP called "district heating" has been implemented for decades. Otherwise-waste heat from local power generation is distributed short distances through pipes to nearby users (typically, apartment buildings). It saves fossil fuel that would otherwise be burned just to produce heat, and it replaces the highly inefficient system of conventional space heating by means of a furnace in the basement. But it's practical only in very densely developed areas with power plants nearby. District heating isn't of much use in the United States, with our sprawling cities, suburbs, exurbs, and scattered small towns.

More advanced systems of DCHP, in which gas turbines or diesel engines (or eventually high-temperature fuel cells) generate both heat and power in the same building, are already up to speed in some of the more technologically advanced countries. CHP accounts for more than 50 percent of the electricity produced in Denmark, 39 percent in the Netherlands, 37 percent in Finland, and 18 percent in China. Governments have achieved these results mainly by requiring the utilities to reduce carbon emissions and, consequently, find markets for their heat, which has meant locating new electricity generation right in the places where heating is needed.

Not incidentally, those countries (except China) rank among the top countries in living standards—places where in-house power generation would be unacceptable if it weren't unobtrusive, quiet, and clean. If power and heat could be cogenerated in individual buildings in the United States *while retaining connections to the grid,* virtually all new additional capacity could be decentralized. That possibility is not a sci-fi dream; it's a right-now reality. Only the laws protecting utility monopolies need to be changed. One of the rules of this book is that everything we propose for the next decade (and most of what we forecast for beyond) can be achieved with existing technology—already in use somewhere in the world—using domestic energy resources. In a 2008 report, the International Energy Agency (IEA) projected that if future demands for new capacity were to be met by adopting CHP, but without significant changes in the laws, global savings in capital costs would be $795 billion. Given the current U.S. share of global energy consumption, the U.S. share of that saving could be between $100 billion and $200 billion. We think the actual potential is higher.

The initial reaction of many legislators, bureaucrats, economic advisors, utility commissioners, and city planners to this idea of decentralized heat and power might be quick dismissal, due to that pervasive belief that central power plants are optimally efficient and that small-scale production could never compete. In the early twentieth century, that was true—and that's how utilities got the legally protected monopolies they now control. But while central power plants have not significantly improved the efficiency with which they generate and deliver power in 40 years, small systems have improved dramatically. Small gas turbines and diesel engines today are almost as efficient for electricity generation as the large steam-generating systems in the central power plants, especially when transmission and distribution losses are taken into account. And when the potential for local use of waste heat is added in, they are far *more* efficient because they eliminate much of the need for fuel currently burned for space heating and water heating.

End-Use Inefficiency Shock

To put the potential of combined heat and power in perspective, it's important to remember that when we say the efficiency of the present electric utility system is 33 percent, that's just the efficiency with which it generates and delivers power to the consumers. Only one-third of the energy contained in a barrel of petroleum or oil-equivalent ends up as electric energy arriving at the meter. To calculate the overall efficiency of the actual energy *service* (lighting, heating, and so on), you need to multiply that 33 percent efficiency by the efficiency with which the consumer *uses* that delivered power, whether it's to run a motor or to turn on a light.

Everyone knows now that an incandescent light bulb (that familiar "bright idea" symbol of the past century) has very poor end-use efficiency in terms of lumens per watt, and that compact fluorescents are far better. But although fluorescent lighting gets about three times the efficiency of incandescent (about 15 percent versus 5 percent), when multiplied by the 33 percent of the power delivered to it (.33 × .15), the total efficiency of the compact fluorescent light is still just 5 percent.

Similarly, we might be encouraged by the advent of plug-in electric cars, but although the average mechanical efficiency of an electric motor is between 60 and 95 percent (depending on size, speed, and so on), the charge–discharge cycle for the battery itself loses about 20 percent each way (in and out). A car using plug-in electricity from a 33 percent–efficiency central power plant might have an overall efficiency of power to the wheel of 16–18 percent. That's more efficient than a conventional gasoline-powered vehicle operating in city traffic, but it still wastes the energy embodied in more than five of every six barrels of oil-equivalent.

Then consider the *payload* efficiency you get when you drive a car. Set aside the question of whether it makes sense, in a country where energy is no longer cheap, to move more than a ton of steel, glass, and rubber (plus fuel in the tank) to transport your 200 pounds, or whatever you and your briefcase or shopping bags weigh. If the efficiency of moving the car itself is 10 percent—typical in the United States—the payload efficiency of what's being transported (assuming it's one-tenth the weight of the car) is a tenth of that, or about 1 percent. If you carry a second person, or have a lot of luggage, the payload efficiency might be 2 or 3 percent. If the car is hybrid or electric, you might get up to 4 percent. For stationary uses, a comparable inefficiency prevails. Someday historians will shake their heads in wonder.

If you add up all the different kinds of energy use in the United States, the overall efficiency just for producing useful work is currently around 13 percent (and that's before taking payload inefficiency into account). It's as if a father goes out to buy seven ice cream cones for his kid's birthday party, and six of them fall on the ground as he's walking out of the store. The bad news is that a lot of ice cream is lost. The good news is that the dad's dexterity has lots of room for improvement.

When President George W. Bush and his would-be successor John McCain urged America to address its energy independence problem by drilling more holes in the ocean floor, they might not have been aware that they were recommending a course of action that would do nothing to improve the country's truly crippling energy inefficiency—nothing to relieve either near-term dependence on Middle Eastern oil or the longer-term problem of global warming. If the country were to adopt then–Vice President Dick Cheney's nightmarish scheme to build 1,300 new coal-fired central power plants, the effects would be even more devastating: The energy efficiency of the country would be barely on life support, and carbon dioxide emissions would rise to even more dangerous levels. Or if we followed the "clean-coal" route being promoted by the coal lobbyists and utilities, the carbon dioxide would continue to climb at approximately the same rate, but the cost of power would rise sharply—and the economy would be further crippled. ("Clean coal" might sound reasonable to people who don't get a kick out of oxymorons, but the process of converting the coal to gas—which gets rid of the fly ash and sulfur—makes the coal energy about twice as costly to deliver, and the process of capturing and storing the carbon dioxide produced by combustion doubles the cost again.)

Suppose that, instead of following the reflexive impulses of politicians pandering to an electorate fearing for its energy security, the Obama administration were to systematically put together a strategy combining just the two major opportunities outlined in this chapter: (1) Recycle high-temperature waste heat, steam, or flare gas in industrial plants, and (2) encourage the shift of mainstream electric-power production from centralized to decentralized heat-and-power production. How much would the country's need for fossil fuels be reduced, and how far would that take us toward full energy independence?

First look at recycling waste energy. We noted that the U.S. Steel plant in Gary, Indiana, produced about 100MW in 2004, and Mittal's Cokenergy plant produced 90MW. Approximately 1,000 other U.S. plants are already doing waste-energy recycling. Most of them are smaller than the Indiana giants, but together they were contributing 10,000MW of electric power per year to the national total, according to the latest available data. Yet according to a recent study for the U.S.

Environmental Protection Agency, 19 different U.S. industries could have profitably generated more than 10 times that amount by recycling wasted heat. Even accepting a more conservative estimate by the Department of Energy, the profitable potential for energy recycling is six or seven times greater than the current level of recycling. Most of it would be clean electricity replacing power currently purchased from coal- or natural gas–burning utilities.

The approximate capacity of conventional (fossil fuel–burning) power plants in the United States in 2007 was 900,000MW, or 900 gigawatts (GW). The installed capacity of waste-energy stream recycling was 10GW. And the solar-photovoltaic (PV) capacity was 0.1GW. By 2009, PV had grown to nearly 0.2GW, and President Obama projected that the solar energy industry would double again in the following three years. As an industry grows larger, it's unrealistic to expect it to continue expanding at the same rate, but suppose the solar-PV industry continued doubling every three years. That would bring it to roughly 1GW by 2015—still just a fraction of 1 percent of U.S. electricity production. But in the meantime, if energy waste-stream recycling doubled at the same rate, it would reach 40GW—with more room to grow. If the *full* potential of energy recycling is exploited, we can generate up to 10 percent of U.S. electricity without generating carbon emissions or burning any additional fossil fuel. Granted that solar-PV is the golden future and cleaning up dirty fossil fuel is the prosaic present, a hard reality in the present business climate is investment cost. And the reality is that the waste-energy recycling option is much cheaper.

For wind power, the near-term prospects are stronger, but not yet strong enough. U.S. wind capacity reached 0.8GW in 2006, and wind is economically competitive on a per-kilowatt basis in some locations. But the actual output of wind facilities is intermittent, so the real output is less than that of a plant that is operating continuously. Even assuming a very optimistic growth trajectory for wind power, the recycling of waste streams from aging fossil coal– or natural gas–burning facilities will have greater potential for affordable carbon-free power, at least until 2013. Beyond that, the capacity for solar and wind power to continue growing geometrically becomes unrealistic.[4] But even at the most rapid continued growth conceivable, it would be many years before solar-PV and wind power could replace more than half of the nation's fossil-fuel power. To keep the economy adequately functioning for that time and beyond while continuing to reduce carbon dioxide emissions, large investments in renewables must be joined by equally large (and initially more productive) investments in energy recycling.

Then consider the central power plants and the potential for ramping up U.S. power production by phasing out of "centralized" into decentralized CHP. Approximately 3,855 utility-owned or municipal electricity–only power plants currently exist in the United States. Studies by energy engineers show that the 33 percent efficiency of those plants plus their massive transmission and distribution infrastructure could be increased to around 60 percent efficiency if all new and replacement capacity were decentralized. That shift could take many years, but if the laws that prevent it were changed quickly, a substantial bump in electric power production—while achieving a net *reduction* in fossil-fuel use—could be achieved within a few years. If no new central plants are built and half of the old ones are phased out and replaced by CHP, half of the industry's 900GW capacity could shift from 33 to 60 percent efficiency—increasing total U.S. electric power by roughly one-third, while cutting emissions by one-third and using no additional fossil fuel.

That two-part strategy—recycling industrial waste energy and beginning to decentralize electric power generation—would constitute a huge stride toward energy independence *and* toward the parallel goal of sharply cutting carbon emissions. But it's not the whole story by a long shot; it's just the first chapter after the wake-up call.

In comparing the strategy we've just outlined with the option of drilling for more oil off the American coasts, we like to use an analogy. Suppose you have a farm in upstate New York where you keep seven wild mustangs in a corral. One day you discover that six of them have

[4] Suppose you decide to save a penny today and double the savings every day. Keep doubling every day by working hard, and you'll have $20 million in a month, but you probably can't keep it up for more than the first ten or twelve days.

escaped. Do you immediately plan a costly new expedition to find replacements in wild-horse country 2,000 miles away, or do you try to retrieve the ones that escaped into neighboring fields and can't have gone far? Thinking of horses as units of potential work (horsepower-hours), and keeping in mind that six of every seven units of U.S. energy extracted from coal mines or oil wells escape before they can produce useful work or heat, doesn't the same question about retrieval versus replacement apply? It will be vastly cheaper to retrieve a barrel's worth of energy from a waste-energy stream that already exists in Allentown, Pennsylvania, and use it for electricity that's needed right there, than to retrieve that barrel's worth from a hole a mile deep under the Pacific Ocean off the coast of Santa Barbara and then refine it and ship it 3,000 miles.

To take this analogy one step further, we like to recall that before European explorers arrived in North America, no horses lived there. Horses originated in Central Asia and the Middle East. Later, those formerly Arabian imports became an indispensable part of the pioneer American culture and economy. Now as energy pioneers of the twenty-first century, we have an opportunity to do the same with horse*power.* Our dependence on Saudi Arabia for the energy needed to run a modern economy can come to an end. *We already have the horsepower in our own country.* Like the farmers, mail carriers, and cowboys of an earlier time, we just need to learn how to harness it.

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