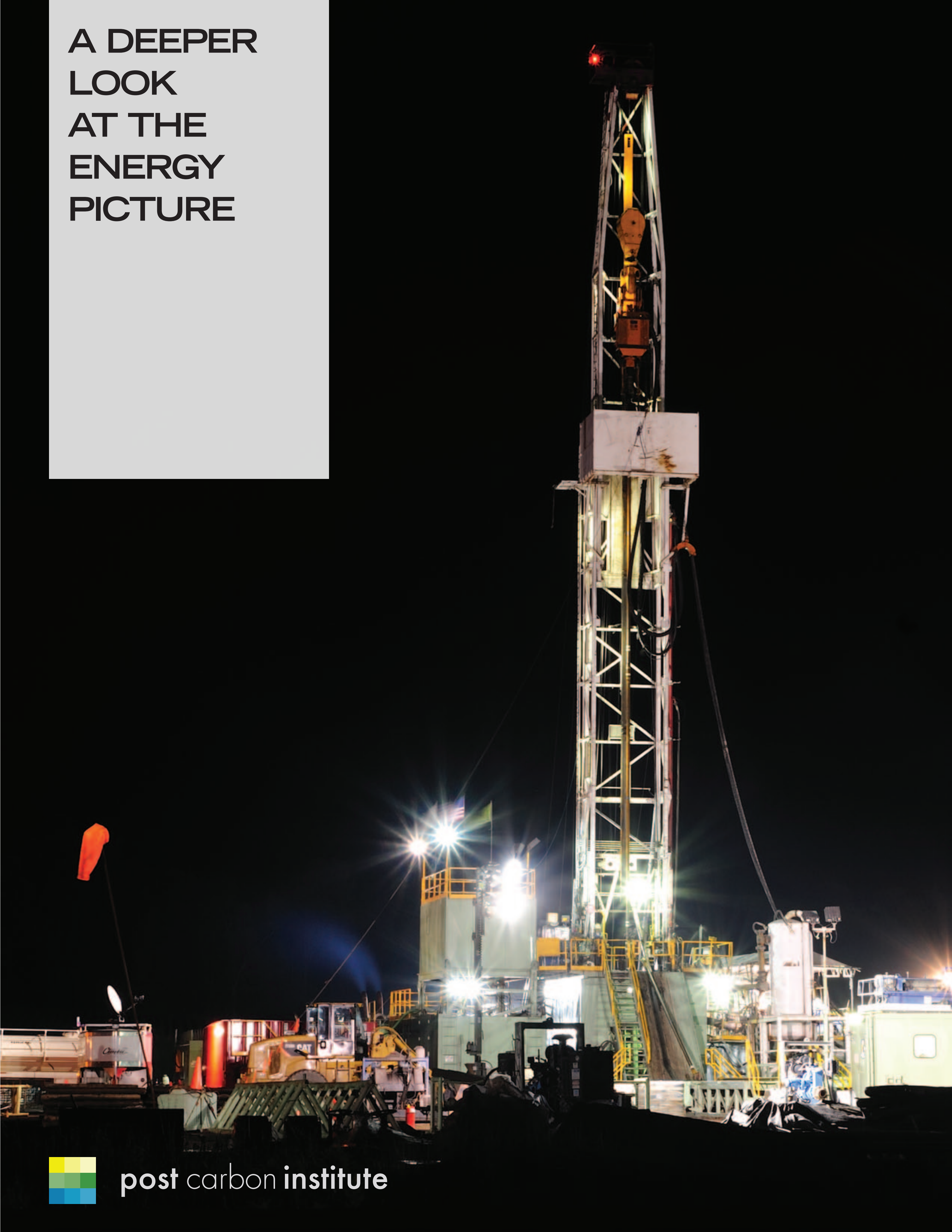
# A DEEPER LOOK AT THE ENERGY PICTURE



post carbon institute

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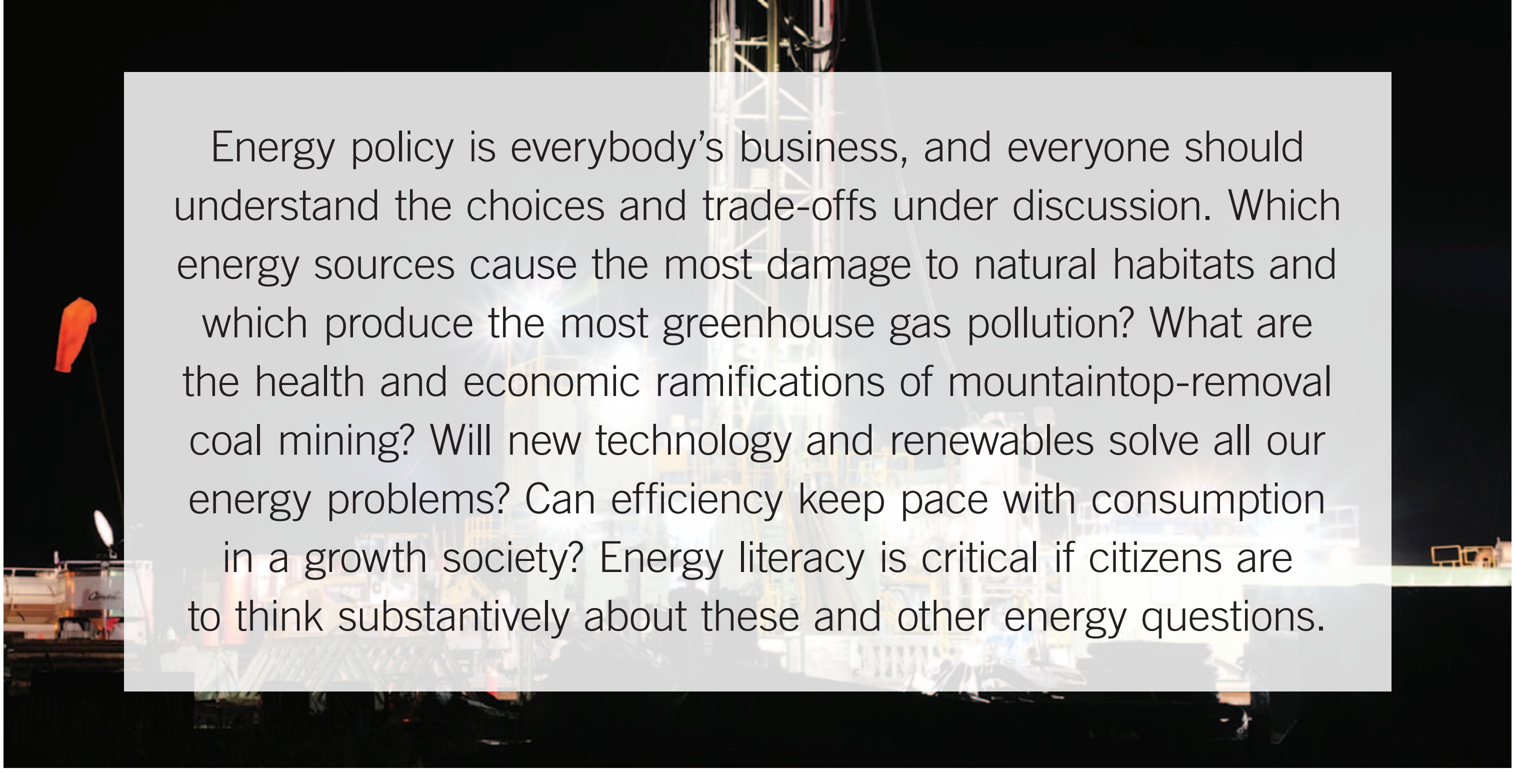


Energy policy is everybody's business, and everyone should understand the choices and trade-offs under discussion. Which energy sources cause the most damage to natural habitats and which produce the most greenhouse gas pollution? What are the health and economic ramifications of mountaintop-removal coal mining? Will new technology and renewables solve all our energy problems? Can efficiency keep pace with consumption in a growth society? Energy literacy is critical if citizens are to think substantively about these and other energy questions.

## INTRODUCTION: *Energy Literacy*

Just as a person doesn't need to be a doctor to recognize sickness in a family member, one doesn't need to be an expert to see the most blatant negative effects of the current energy system. Many of the photos in *Energy* starkly depict the garish wounds that industrial growth society, through its incessant demand for more power, is inflicting on the natural world. Anyone who takes a moment to look can see these threats to wildlife habitat, free-flowing rivers, air and water quality, and human welfare.

But some consequences of the current energy economy are subtle and require a closer look to discern. Even less visible is the range of ideas and assumptions—the worldview—behind our energy choices. These choices collectively shape the society that we live in and the range of options available to future generations. Will our energy economy foster beauty, promote social equity, and leave enough room for wild nature to flourish? Or will it produce more ugliness, political corruption, habitat destruction, and commodification of nature? Will it unleash climate chaos, trigger mass extinction of our fellow creatures, and make human habitation untenable across large swaths of the globe?

These are the big questions that undergird any discussion of energy policy. People living in the overdeveloped world have become accustomed to consistent and affordable power; few citizens give much thought to energy matters until there is a supply interruption or price hike. With human population increasing rapidly and the "easy" fossil energy resources already exploited, per capita energy availability is almost certain to decrease in the coming decades. More landscapes and seascapes will be disfigured in the mad rush to continue powering economic growth. Costs will rise, and various parts of the energy system may become unstable.

Today, energy policy is everybody's business, and everyone should understand the policy choices and trade-offs under discussion. Which energy sources cause the most damage to natural habitats and which produce the most greenhouse gas pollution? What are the health and economic ramifications of mountaintop-removal coal mining? Will new technology and renewables solve all our energy problems? Can efficiency keep pace with consumption in a growth society?

*Energy literacy* is critical if citizens are to think substantively about these and other energy policy questions. It is necessary both to understand the key concepts that inform energy debates and to be familiar with the current terrain of the energy landscape. This entails some study on the part of individuals, but it is crucial if society is to move beyond sloganeering ("drill, baby, drill") in our public discourse.

A solid grounding in energy fundamentals is the first step toward thinking more deeply about root causes and systemic problems in the current energy economy. For the health of wild nature and human communities, there is no task more urgent than promoting widespread energy literacy so that we can begin charting a course that moves civilization toward a durable, nature-friendly energy future.

## ENERGY AND THE SCAFFOLDING OF CIVILIZATION

Virtually every aspect of modern society—manufacturing, transportation, construction, heating, lighting, communication, computing, farming, preparing for and waging war—depends on a continuous supply of abundant, inexpensive energy. In essence, energy supports the entire scaffolding of civilization.

Societies with complex social organization have existed for thousands of years, but until the discovery and widespread exploitation of fossil fuels, human economies were powered by the productive capacity of local ecosystems, augmented by regional trading networks. Today, a hyper-complex web of mining, manufacturing, distribution, and marketing systems is the foundation of commercial enterprise. The everyday products of mass consumption in affluent countries would disappear without these interdependent systems, all of which require energy.

A development model that demands economic growth depends upon ever-increasing energy consumption. Since the Industrial Revolution, exploitation of fossil fuels—the onetime windfall of ancient biological capital processed by geological forces—has precipitated exponential population and economic growth. But if the scaffolding of civilization is constructed on a flawed foundation—the idea that perpetual growth is possible on a finite planet—then it cannot remain standing indefinitely.

## WHAT IS ENERGY?

Though we cannot hold a jar of pure energy in our hands or describe its shape or color, it is nevertheless the basis of everything. Without energy, nothing could happen; matter itself could not exist in any meaningful sense. But because energy as such is so elusive, physicists and engineers define it not in terms of what it *is*, but what it *does*—as "the ability to do work," or "the capacity to move or change matter."

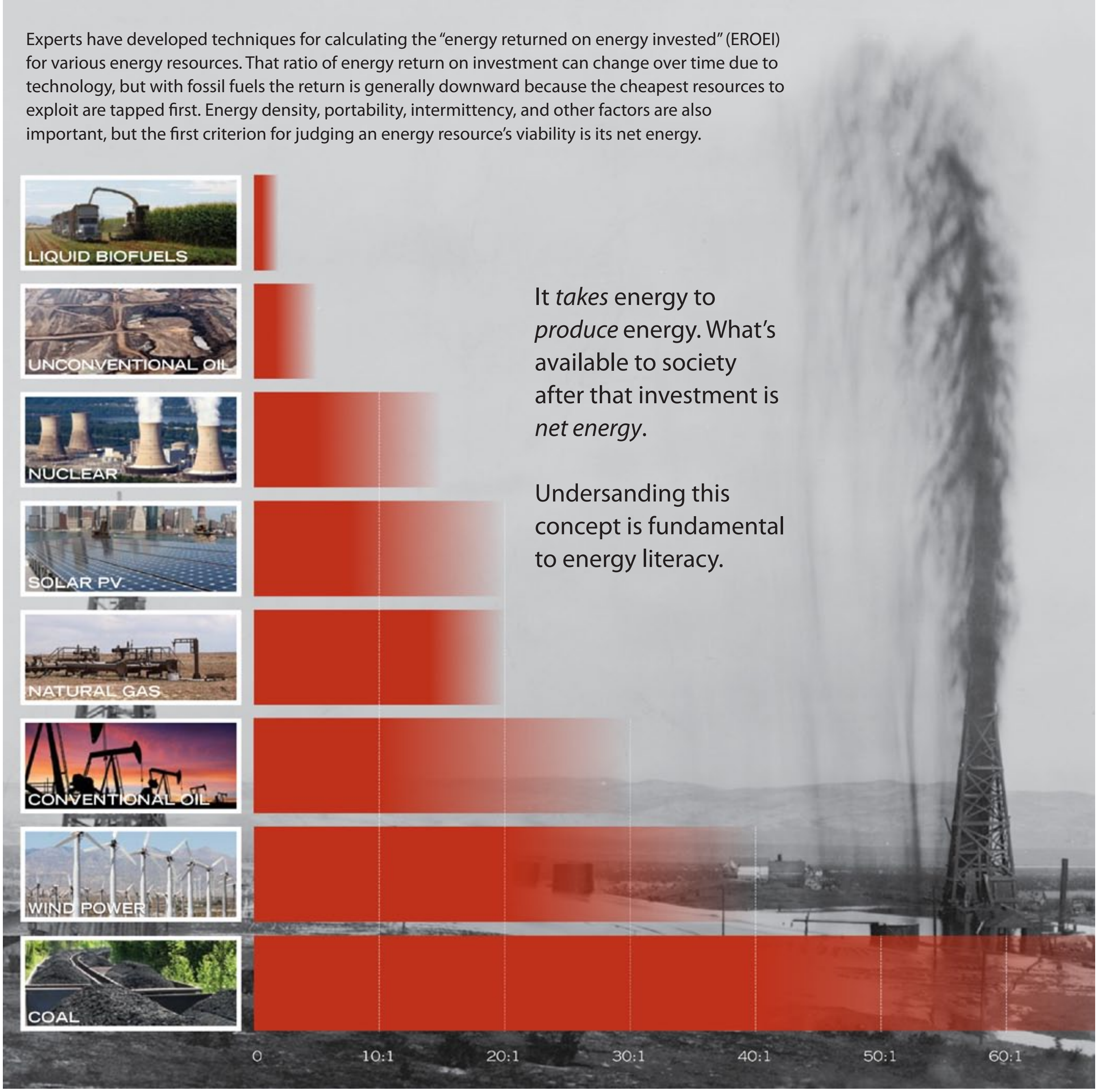
In traditional societies, most useful energy came from the sunlight annually captured by food crops and forests; people exerted energy through muscle power and obtained heat from firewood. Modern industrial societies obtain enormously greater amounts of energy from fossil fuels, nuclear power, and hydroelectric dams, and they exert energy through a vast array of machinery. Industrial energy production is essential to every aspect of modern life, but no matter how far our technology for capturing or using energy advances, energy itself always remains the same.

In the nineteenth century, physicists formulated two fundamental laws of energy that appear to be true for all times and places. These are known as the First and Second Laws of Thermodynamics. The First Law is known as the law of *conservation*. It states that energy cannot be created or destroyed, only transformed. Think of energy as a singular reality that manifests itself in various forms—nuclear, mechanical, chemical, thermal, electromagnetic, and gravitational—and that can be converted from one form to another.

The Second Law states that in every energy conversion, some energy is dissipated (typically as heat). When the gas gauge in a car moves from "full" to "empty," it may appear that the energy that is chemically stored in gasoline is being *consumed*. But all the energy that was originally present in the gasoline still exists. In reality, the stored energy is merely being released and doing some work as it moves from a condition of higher concentration to one of lower concentration. It is converted from chemical storage (via the atomic electromagnetic bonds within hydrocarbon molecules) to mechanical motion and heat (as combustion within the engine's cylinders pushes the car forward and also increases the rate of motion of molecules in the cylinder and the surrounding environment).

We might be able to get some work out of the "wasted" heat being given off by the burning of gasoline in the car engine; but heat tends to radiate quickly into the general environment, so we would have to use that heat both immediately and close to the engine. If we could gather up all the heat and mechanical energy that was released by burning the tankful of gasoline, it could do just as much work for us yet again; but the act of recon–

# NET ENERGY



Experts have developed techniques for calculating the "energy returned on energy invested" (EROEI) for various energy resources. That ratio of energy return on investment can change over time due to technology, but with fossil fuels the return is generally downward because the cheapest resources to exploit are tapped first. Energy density, portability, intermittency, and other factors are also important, but the first criterion for judging an energy resource's viability is its net energy.

It *takes* energy to *produce* energy. What's available to society after that investment is *net energy*.

Undersanding this concept is fundamental to energy literacy.

(Net energy values shown here are from *The ENERGY Reader*, Part Three: The Landscape of Energy.)

centrating and storing it would require more energy than we could regather. Thus, in effect, available energy is always being lost.

The Second Law is known as the law of *entropy* (entropy is a measure of the amount of energy no longer practically capable of conversion into work). The Second Law tells us that the entropy within an isolated system inevitably increases over time. Energy that is sufficiently concentrated (relative to background energy levels) so that it can do work for us is called a *source*. There are two kinds of energy sources: *flows* (examples include sunlight, winds, and rivers) and *stocks* (a word that in this context refers to energy chemically stored in substances such as wood or fossil fuels). Flows tend to be variable, whereas stocks deplete.

## NET ENERGY

A business may have high gross receipts and still go broke; it is the net, the profit after costs are subtracted, that determines viability. For any potential energy resource, the fundamentals are the same. How much energy is available after subtracting the energy costs to extract, process, and deliver the resource? To know how much energy from a particular source can actually be deployed by society, we must factor in both the production costs and the system costs—that is, the energy required to make energy available to the end user. With gasoline, for instance, this calculation would include energy costs related to oil exploration, drilling, refining, transportation, and the infrastructure that supports each step of the process. With coal-derived electricity, the calculation would include the life cycle from mine to power plant to electric grid.

Experts who study this use the terms "net energy ratio" or "energy returned on energy invested" (EROEI). Decades ago when the most accessible reserves were drilled, an oil company might produce 100 barrels of oil or more for each barrel's worth of energy invested. Declining oil field productivity has brought the average net energy ratio for conventional oil down to approximately 20:1 globally, with more remote or hard-to-refine oil significantly worse. For fossil energy generally, the trend is downward despite technological advances in exploration and drilling. For biofuels, the net energy ratio is lower still. Some studies suggest that corn-derived ethanol actually has a *negative* net energy ratio—that is, more energy than a gallon of ethanol can deliver is used to produce a gallon of ethanol. Sugarcane-based ethanol has a superior net energy ratio, but it is still low compared to fossil fuels.

Any produced energy resource can be analyzed for its net energy ratio, although the process raises a difficult question: What are the boundaries of consideration? For example, when tallying the energy required to build a solar photovoltaic panel, what should be included in the accounting? The energy needed to mine the bauxite for the aluminum frame? The energy needed to manufacture the heavy equipment that did the mining? The energy needed to construct the factory that produced the panel? Where the boundaries are drawn affects the final net energy ratios.

A society that depends on inexpensive energy to maintain a high standard of living and constant growth faces a predicament—it cannot maintain itself over the long run without high net energy fuels. Oil, natural gas, and coal have provided a huge, high-quality energy subsidy to the modern world. That subsidy, which has enabled human population and wealth to grow exponentially, is based on finite resources and cannot continue indefinitely. Renewable energy sources, excluding hydropower, are generally more diffuse and have lower net energy ratios than fossil fuels. If high net energy sources are in decline, and no reasonable replacements are available, the result may be a painful restructuring as society rearranges economic activity to fit a diminishing energy supply.

## ENERGY DENSITY

Different fuels contain more or less potential energy per unit of weight or volume, and even within fuel types, such as wood or coal, the heat value varies. Anthracite packs more energy than bituminous coal, and putting oak rather than pine in the woodstove before bedtime makes a big difference in how warm the house will feel on a winter morning. The fossil fuel age has been such a bonanza because oil and coal are extremely energy-dense fuels. They have benefited from the long work of geological processes to concentrate the carbon molecules from ancient plant and animal matter.

On average, coal has approximately twice the energy density of wood. Liquid fuels refined from petroleum including gasoline, kerosene, diesel, and heating oil all contain more than three times the energy value of wood. It is no accident that when human societies have had the opportunity to transition from locally harvested biomass to concentrated fossil energy fuels they have chosen to do so.

The miraculous quality of fossil fuel energy density is easy to understand if one imagines trying to push an automobile for twenty miles. Given enough time, and some help from athletic friends, it would be possible to push a 3,000-pound car that distance. But it would require a tremendous amount of effort. And yet a mere gallon of gasoline (which, despite recent price increases, still costs far less in the United States than an equivalent amount of good coffee) can easily power a car that far in the time it takes to drink a mocha latte. The fact that renewable energy is, in general, more diffuse than fossil fuel presents the primary challenge to transitioning from the current energy economy to a renewables-powered future.

## EMBODIED ENERGY

Every material artifact—a carrot bought at the grocery store, the cooler where it was displayed, the supermarket building, the car driven there, and the road network it travels—requires a certain amount of energy in its manufacture, maintenance, and eventual disposal. The methods used to analyze the total embodied energy of manufactured objects vary, but in general, studies over the decades have used life-cycle analysis to quantify embodied energy in computers, household appliances, automobiles, and other common products.

The embodied energy in our physical infrastructure—from water mains and buildings to superhighways and airports—is immense, and thus infrastructure is one of the most important areas where energy use (and associated greenhouse gas pollution) could be reduced. In addition to building smaller, or building less, we can also build differently. Wood, for example, has the lowest embodied energy of common building materials; plastic has approximately six times as much embodied energy by weight, glass 16 times as much, steel 24 times as much, and aluminum a whopping 126 times as much embodied energy as wood. Erecting the scaffolding of civilization took a great deal of energy, and maintaining and expanding it takes more all the time. This vast amount of embodied energy, along with psychological and financial investments in the current energy distribution system, is a key obstacle to fundamental changes in that system.

Another useful metaphor that communicates the idea of embodied energy across a product's life cycle is the "energy train." Take for example that ubiquitous artifact of modern civilization, the mobile phone. To its owner, a cell phone is simply a handy gadget that offers convenience and a feeling of connection. But the phone does not exist in isolation—it isn't a single locomotive chugging down the tracks; rather, it pulls a train of cars behind it, all of which have ecological and energetic costs. Those metaphorical railroad cars are filled with packaging to ship the phone; an advertising industry to inculcate desire for it; a retail store to sell it; a communications network that allows it to function; an assembly plant to build it; factories to manufacture plastic cases and computer chips and other components; mines where copper, silver, and rare earth elements are dug from the ground; the transportation infrastructure to move raw materials; and of course the energy system (oil wells, coal mines, power plants, hydroelectric dams, etc.) that support the entire operation. It is a very long train, and every car being pulled along must be in place for even one mobile phone to make its first call.

## ENERGY SLAVES

During the vast majority of our species' history, all work was done by human muscles (sometimes the muscles of human beings enslaved by others). After people learned to domesticate wild creatures, beasts of burden such as oxen and horses added to our ability to harness the Sun's energy—captured by plants and channeled into the muscles of work animals. This relationship between domestic animals and the machines we use today is enshrined in the "horsepower" rating of modern engines. More recently, people began using wind and waterpower to amplify human labor. But with the dawn of the fossil fuel age, the average person was able to command amounts of energy previously available only to kings and commanders of armies.

Where people or work animals fomerly toiled in the fields, the petroleum-powered machines of industrial agriculture now do the work of growing food. Need to be on the other side of the planet tomorrow? Jet travel can get you there. Want to sit in the sunshine, gamble, and overeat with a few thousand strangers in a gigantic floating hotel? The cruise "industry" can make your dreams come true. Energy-dense fossil fuels make the seemingly impossible or ridiculously extravagant whims of people a reality.

In effect, the modern energy economy provides power equivalent to that of vast numbers of human or animal servants. That is the idea behind the concept of "energy slaves." Although top athletes can do far better, a typical adult male at sustained labor is estimated to produce 75 to 100 watts of power. Calculate the total energy use of an average American and it seems that there are the energetic equivalent of more than 100 energy slaves working around the clock to prop up the easy lifestyle offered by modern civilization.

## ENERGY-FUELED POPULATION GROWTH

Humanity's current population explosion is an aberration. During the vast majority of human history, population levels were low and quite stable. Demographer Joel Cohen estimates that from the time our species emerged until roughly twelve thousand years ago, when local agriculture appeared, the population growth rate was less than 1/500th of 1 percent. After the widespread adoption of farming the growth rate ticked up by a factor of ten or more, but for thousands of years thereafter remained at around 1/50th of 1 percent. It took all of human history until the early eighteen hundreds for global population to reach one billion. Then the population doubled—a second billon was added—in just a century or so. Adding the next billion humans to the planet took only thirty years. The next billion, fourteen years. The next, twelve years. After another dozen years, in 1999, world population reached six billion, and the seven billion mark was passed in 2011.

When charted graphically, the human demographic explosion takes the familiar "hockey stick" shape of a classic exponential growth curve. Many factors contributed to demographic expansion, including: the global agricultural revolution in the sixteen hundreds when new foods were shared between continents; the dispersal of scientific and public health knowledge; and increasing urbanization. But central to the runaway population growth of the past two centuries is the incredible windfall of energy that fossil fuels presented to humanity. The ability to command energy, especially highly energy-dense fuels like coal, precipitated the Industrial Revolution and allowed its descendant, the techno-industrial growth culture, to flourish. Food could now be produced in far larger quantities, and local scarcity could be overcome through global transport networks.

Leading ecologists agree that humanity has already surpassed Earth's ecological carrying capacity. Exploiting the onetime reserve of fossil energy has allowed us to temporarily escape the constraints that kept early human population levels in check. Today's global extinction crisis, massive poverty and malnutrition, rising social inequity, and unraveling ecosystems around the globe suggest that the age of abundance is nearly over. As economist Lisi Krall tells her students, "The defining fact of this historical moment is the reality of exponential growth. With exponential growth, if you do the same things as your parents, you'll get entirely different results." Confronting the population problem is the preeminent challenge of our time.

## ENERGY-FUELED ECONOMIC GROWTH

World economic activity has historically grown slowly. From the Middle Ages up to the early eighteen hundreds, average per capita income rose only about 50 percent. But since the advent of the Industrial Revolution the pace has picked up, with global per capita income rising more than eightfold in just the last two hundred years.

Energy consumption has also risen dramatically, from under 20 gigajoules (GJ) per person per year in the pre-industrial era to over 75 GJ per person today (and more than 300 GJ per person in the United States). During this period, energy consumption and economic activity have stoked each other in a self-reinforcing feedback loop. Once the fossil fuel tap was opened for the modern world in eighteenth-century Britain, the high-energy content of coal (and, later, oil) enabled unprecedented productivity—spurring more consumption, more demand for energy, and better technology to get at yet more fossil fuels.

Despite the clear link between energy and economic growth, economists have interpreted and normalized growth as resulting from factors such as "market efficiency" and "labor productivity," which (it is assumed) can be counted upon to produce more and more growth, ad infinitum. Policy makers have therefore built dependence on growth into the design of our economic system. Investors demand constant growth and high rates of return. Future growth is assumed to wipe away the debts taken on today by governments, businesses, and households. Most Americans are even betting their retirement savings, sitting in mutual funds on Wall Street, on continued growth.

As the global bonanza of cheap fossil fuels winds down, what will happen to economic growth? Certainly it's possible to get more benefit per joule through smarter use of energy, but using energy efficiency to "decouple" economic growth from energy consumption can only go so far. After the easy efficiencies are found, further efficiency measures often require greater cost for less benefit; and while greater efficiency may reduce costs at first, it can have the effect of spurring yet more consumption.

It's intuitively clear that it takes energy to do things, and modern civilization has exploited high-energy-content fossil fuels to dramatically reshape the living conditions and experiences of billions of people. (Altering the climate and destroying natural ecosystems around the globe were unintended consequences.) In the future, humanity will need to cope with both more expensive energy and less energy available per capita. Maintaining an acceptable level of productivity—let alone growth—may constitute one of society's foremost social, political, technical, and economic challenges.

## PEAK OIL AND RESOURCE DEPLETION

Every individual gas or oil well, every oil field, and every oil-producing country experiences a similar life-cycle. After a well is drilled, extraction ramps up to its maximum sustained output and eventually begins to decline as the reservoir is depleted. Then we search for the next well, which is generally a little harder to find, a little more expensive to produce. The price of any fossil energy determines what reserves are economically recoverable, and technological innovations can temporarily reverse the decline or extend well life. But as with any finite, nonrenewable resource—coal, natural gas, uranium, etc.—depletion is inevitable at some point.

In recent years, a large body of literature has begun exploring the many ramifications of "peak oil"—the moment when aggregate global oil production reaches its apex. The late American geologist M. King Hubbert predicted in the mid-1950s that U.S. oil production would reach the top of its production curve around 1970 and then begin to decline. That assessment was remarkably prescient: America's production of crude did peak in 1970 and has been generally declining since, despite the addition of new sources on the Alaska North Slope and in the Gulf of Mexico. The United States, the first great power of the oil age, was also the first nation to explore, exploit, and begin to deplete its conventional oil reserves.

Oil of course is a global commodity. From a global perspective, reaching Hubbert's peak means that roughly half of the world's total oil resources are still in the ground, waiting to be tapped. Practically, however, the second half of the global oil resource is more difficult to access, making it less profitable (in terms of net energy) and more environmentally destructive than the earlier-exploited reserves.

The exact timing of the global oil production peak will be recognizable only in hindsight. Some energy experts predict that the peak will occur sometime during the first two decades of the twenty-first century. Others project continued growth in oil extraction through 2050. Based on data published by the International Energy Agency, global conventional oil production has been essentially flat since 2004, despite record-high prices, and likely peaked in 2006. Increased production of unconventional oil (deepwater oil, tar sands, oil shale, and shale oil) is officially projected to help meet growth in demand in the near future, but some energy experts insist that new production from these sources will be unable to make up for accelerating declines in production from conventional oil fields. Whether peak oil has occurred, is imminent, or remains years or decades off makes little difference to the salient fact: The era of abundant, inexpensive oil is closing, and all the systems for modern life designed around that earlier reality are bound to be affected.

## ENERGY SPRAWL

The foremost criterion by which to judge any existing or potential energy source is its systemic ecological impact. A key subset of this analysis is its physical footprint. The useful term "energy sprawl" refers to the ever-increasing area—on land and offshore—that is devoted to energy production. Quantifying the area affected by different energy sources raises challenging methodological questions. It's obvious, for instance, to take into account the drilling pad when considering the energy sprawl impact of oil and gas development. But one should also include the land affected by pipelines, access roads, refining facilities, and other related infrastructure in the calculation. Nuclear power plants occupy a small area relative to their electrical generation output, the smallest physical footprint of any major energy source. That energy sprawl impact grows considerably, however, when one factors in uranium prospecting, mining, processing, nuclear waste disposal, and any new power lines needed for an expanded nuclear industry. Moreover, as past accidents have demonstrated, when nuclear power plants fail, a large area can be contaminated.

Because of their high energy densities, coal, oil, and natural gas have a medium-size footprint if judged on an energy-output-per-acre ratio; but in practice these extractive industries affect a huge and growing area because they dominate energy production, and because of the enormous quantities of energy being consumed. Oil shale development in the American West is a potential area of fossil fuel exploitation that would create massive energy sprawl. Renewables, which harness the diffuse energy sources of wind and solar power, can have a large physical footprint relative to energy produced; they constitute such a small part of the current energy mix in North America that their aggregate energy sprawl impact at present is modest but growing. Because wind turbines require minimum spacing distances to maximize wind energy capture, the physical footprint of wind power is extensive but can be mitigated, whereas decapitated mountains in Appalachia sacrificed for surface coal mining will never grow back. Siting wind turbines in existing agricultural landscapes need not fragment any additional wildlife habitat. Putting solar arrays on rooftops, parking lots, and urban brownfields need not contribute to energy sprawl at all while generating significant energy close to where it is needed, eliminating the sprawl precipitated by new transmission lines.

Devoting land to growing feedstock for liquid biofuels, or growing biomass for generating electricity, augurs the greatest potential energy sprawl of the major energy alternatives under discussion. The energy density of these fuels is low and the amount of land that must be effectively industrialized, even for relatively small quantities of biofuels or biomass-derived electricity, is massive. In the end, the most effective strategy for fighting energy sprawl is to reduce energy consumption.

## VISUAL BLIGHT

The rampant air and water pollution resulting from fossil fuel use has garnered considerable attention in recent years, with landmark studies on the human health effects and other costs of coal burning, and alarming accounts of declining air quality in gas-and-oil-drilling boomtowns. Toxic accidents such as the 2010 Deepwater Horizon oil rig blowout in the Gulf of Mexico, and the massive 2008 spill of coal-combustion waste into the Clinch and Emory rivers in Tennessee, temporarily galvanize public attention before fading from the news. But the everyday nicks and cuts caused by energy development that mar the beauty and health of the Earth's ecosystems do not make headlines.

The creeping cancer of visual pollution is difficult to quantify but everywhere apparent. From strip mines and power lines to oil spills and sprawling wind power developments, energy-related visual blight is rampant. It is no accident that the great conservationist Aldo Leopold included aesthetics in his oft-quoted summation of the land ethic: "A thing is right when it tends to support the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." Ecological integrity and beauty are connected. Wild, intact landscapes are intrinsically beautiful. Degraded, despoiled landscapes are ugly.

Beauty matters greatly to human health and happiness but is frequently discounted. Conservationists fighting industrial-scale wind projects because of their visual impacts are mocked by wind power boosters as being overly concerned about "scenery." This is an old refrain; legendary congressman Joe Cannon, the Speaker of the U.S. House of Representatives who frequently opposed President Teddy Roosevelt's progressive conservation policies, once quipped, "Not one cent for scenery." Boosters of economic growth have been echoing that ignorant sentiment for the past century.

An energy economy that truly supported the health of the land community would not degrade beauty but foster it. It would promote ecological integrity on land and sea. A central criterion by which to measure any proposed energy development would be its contribution to visual pollution.

## CLIMATE CHANGE

The mechanism by which certain gases, especially carbon dioxide and methane, hold additional heat in Earth's atmosphere that would otherwise be radiated off the planet's surface has been known since the nineteenth century. Global "greenhouse gas" pollution has been increasing significantly since the dawn of the Industrial Revolution, and the current level of carbon dioxide in the atmosphere is higher than at any time in at least eight hundred thousand years.

Unfortunately for the community of life that has evolved within the climatic conditions of the past few hundred thousand years—a community that includes humans—the consequences of these human-caused disruptions to the planet's climate are likely to be grim. Record droughts and floods are already being felt around the globe and are projected to worsen in coming decades, even if a miraculous cessation of greenhouse gas emissions were to occur. The authoritative (and conservative) Intergovernmental Panel on Climate Change, which reflects the view of the world's leading climate scientists, has documented various impacts of anthropogenic climate change including rising sea level, diminishing sea ice and melting glaciers, and increased ocean acidification. Unprecedented heat waves from Pakistan to Moscow and unusually severe storms in North America—the kinds of events expected as a consequence of global warming—have affected many millions of people. And these dramatic indicators of climate chaos are linked to an increased global temperature of a mere 1.4°F over the past century. Many experts believe that these changes are merely a hint of what is to come as the global climate reaches a tipping point, where feedback loops such as methane release from melting permafrost and reduced reflectivity from disappearing Arctic ice cause runaway overheating. Climate chaos threatens to amplify the existing species extinction crisis, and to overwhelm the world's economies with increasing costs and declining productivity.

Although a global movement of citizen activists concerned about climate change has emerged, governmental action at all levels has been inadequate to confront the magnitude of the problem. The fastest-ever growth in carbon dioxide emissions was recorded in 2010. Year after year, global greenhouse gas pollution records are broken as the surging economies of India and China strive to catch up with the old-guard polluters. The challenge is formidable because the interconnected factors of overpopulation, economic growth, development philosophy, and the current energy economy must all be addressed if there is any hope to forestall the worst effects of climate change.

## ENERGY CONSERVATION

Americans comprise a mere 4.5 percent of the global population but consume about 20 percent of energy output annually. The silver lining in that dark cloud of profligacy is that the present energy economy is so wasteful and inefficient that it offers extraordinary potential for energy savings through conservation and efficiency efforts.

In common parlance *conservation* means using less energy, which can be accomplished through *curtailment* (turning off the lights when you leave the room) and *efficiency* (leaving the lights on but replacing old bulbs with high-efficiency LED bulbs).

In the 1970s, following the OPEC oil embargo when fuel prices spiked, America briefly got interested in energy conservation. Jimmy Carter donned a sweater on national TV and put solar panels on the While House roof. But Ronald Reagan took the solar panels down, and two decades of low fossil fuel prices spawned living patterns that used vast amounts of energy, including suburban and exurban housing developments serviced by fleets of SUVs. In hindsight, these choices look foolish—although the present era of high oil prices hasn't yet prompted a major political party's national convention to erupt in cheers of "Save, Baby, Save."

Supply-side boosterism has long kept conservation the ugly stepchild of energy policy, but as energy becomes less affordable, Americans may again be ready to consider the compelling reasons why conservation should become the centerpiece of national energy policy. Those reasons include conservation's contribution to increasing national security, as well as to creating jobs, stimulating innovation, saving money, reducing carbon emissions, and lessening the energy economy's impacts on wild nature. Numerous studies have analyzed various sectors of the energy economy and outlined the huge potential for intelligent conservation programs to reduce energy consumption while maintaining, and often improving, quality of life.

## EFFICIENCY

Global energy consumption has spiked along with population growth and increasing affluence, but there are vast disparities in energy use between people living in the leading industrialized countries and those in less-industrialized nations. And even in the overdeveloped nations, significant disparity exists; the average American, for instance, uses twice as much energy as a typical European to achieve an equivalent lifestyle. That ratio can be viewed as dangerously unsustainable, or as an opportunity to begin picking the low-hanging fruit offered by energy conservation programs.

With so much waste and inefficiency built into its current energy system, the United States has tremendous potential to harvest "negawatts" through efficiency and curtailment. A 2009 report by consulting giant McKinsey and Company outlined readily achievable efficiency measures for the non-transportation part of U.S. energy economy that, if aggressively implemented over the next decade, could reduce projected 2020 energy demand by roughly 23 percent—saving more than $1.2 trillion in energy costs. Pioneering efficiency advocates at the Rocky Mountain Institute have developed an even more ambitious agenda for massive potential savings, in energy and dollars, of efficiency. RMI's Reinventing Fire blueprint outlines a path to a U.S. economy larger by 158 percent in the year 2050 that would require no oil, coal, or nuclear energy, and would save trillions of dollars, thus enhancing business profitability.

California, which has the world's eighth largest economy, is an often-cited example of real-world success in conservation programs that have reduced load growth over time. Following the energy crisis in the 1970s, the state instituted a suite of policies to promote efficiency, including letting electricity costs rise significantly. In the following decades, per capita electricity use in the state remained essentially flat, while the national average increased some 50 percent. These measures helped decouple growth in electricity consumption from population and economic growth, although aggregate electricity use did increase by an average of 1.6 percent annually in the twenty-five years following 1980. Growth at even that modest rate means a doubling of energy use in less than forty-four years, which is not sustainable in a world bumping up against resource constraints.

In essence, the California experience shows what can happen when people in a very wasteful system get serious about harvesting low-hanging fruit. The initial efficiency gains are the easiest, but then the law of diminishing returns kicks in. As the waste is worked out of the system and it nears maximum efficiency, there is less fruit available to pick and it becomes more difficult to reach. At its maximum efficiency, a system is right at the edge of its breaking point. The overarching reality is that continuous growth on a finite planet is physically impossible. Efficiency programs have tremendous potential and are extremely cost effective, but ultimately they cannot keep up if exponential population and economic growth continues.

## CURTAILMENT WRIT LARGE

Ask a roomful of energy experts about the future and you'll get a wide range of opinions: Peaking oil production will necessitate a shift to less energy dense fuels and cause energy costs to spike. Resource scarcity will precipitate additional conflict between nations. Climate change will cause mass dislocations and civilizational collapse. Or, on the opposite side of the spectrum, human creativity and the power of the marketplace will unleash innovations that will provide plentiful, low-cost, low-carbon energy.

The precise future is unknown, but the present is certain: Our current energy economy is destructive to nature and dangerous to democratic institutions, community life, and human health. It is a toxic system that requires fundamental reform. The political, philosophical, economic, and physical barriers to rebuilding the energy economy make the task difficult. But it is achievable.

Barring some breakthrough in energy technology or a global pandemic that decimates human numbers (two scenarios that are possible but unlikely), over the next century there will be less energy per capita available than during the last. Thus, a policy of curtailment—ending frivolous and wasteful uses of energy, deploying existing renewable power technologies in the most effective manner, and ratcheting down fossil fuel use quickly and dramatically so that the planetary fever goes no higher—is the overarching task for our times.

Americans, who have become accustomed to the idea that anyone should be able to use as much energy as they want, whenever they want, for whatever purpose (and it should be cheap!), will face a different reality in an energy-constrained future. In a sane world, we would not blow the tops off mountains in Appalachia to keep coal-burning power plants belching pollution so that office towers can leave the lights on all night. From motorized paper-towel dispensers and illuminated, empty parking lots to the worst inefficiencies of suburban sprawl, there are worlds of energy-wasting products, activities, and living arrangements that can and should simply be abandoned. Curtailment achieved through outright abolition of energy-wasting machines or activities would be controversial. Nevertheless, in an energy-constrained world with a bad case of human-induced hemorrhagic fever, the sooner citizens voluntarily begin curtailment efforts, the more options remain open to transition toward a more durable, ecologically sustainable energy system.

# ENERGY

## Overdevelopment and the Delusion of Endless Growth

Edited by Tom Butler and George Wuerthner

*We have reached a point of crisis with regard to energy… The essential problem is not just that we are tapping the wrong energy sources (though we are), or that we are wasteful and inefficient (though we are), but that we are overpowered, and we are overpowering nature.*
— from the Introduction, by Richard Heinberg

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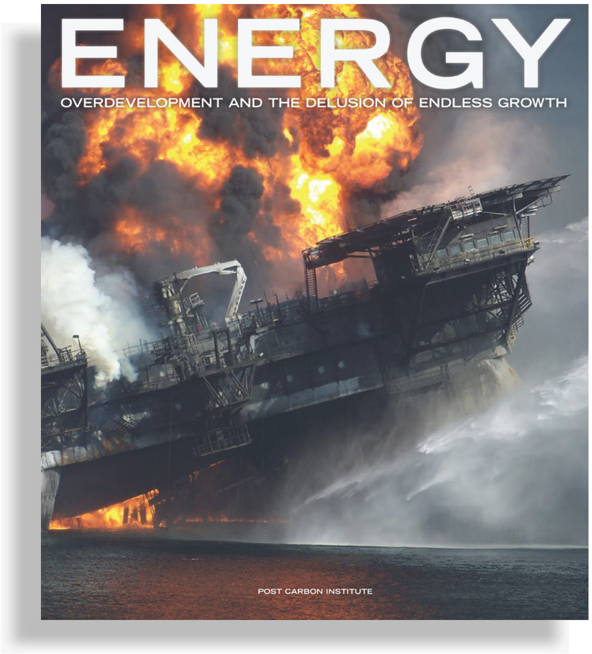

# The ENERGY Reader

Edited by Tom Butler, Daniel Lerch, and George Wuerthner

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