Energy was born in plumes of coal smoke, wafting from Glaswegian shipbuilding factories and the British steamships that corralled its Victorian empire. With the so-called discovery of energy in the 1840s, scientists finally had an explanation for how coal was remaking the world. Energy was not out there in the world waiting to be found, a fact of nature finally revealed to human consciousness. Energy was an ungainly bricolage of new engines and old parts, animated by very old fossil fuels.

Because energy drew upon ancient pedigrees, it was easy to think of it as timeless and cosmic, just as thermodynamics claimed it was. For one, the word *energy* itself is old, much older than the Victorians. Like most illustrious terms in Western thought, *energy* claims an ancient Greek heritage. Second, there were multiple intuitions of energy science, or thermodynamics, prior to the nineteenth century. Many religions and philosophies devised conservation laws and attempted to understand heat, the two puzzles that energy addressed (but did not completely resolve). Third, humans have always used fuel to do work, and have studied the capacities of different fuels and machines, even if they did not refer to fuel as
energy. Finally, fossil fuel has its own deep history that predates human animals by millions of years.

Most histories of energy treat these streams—etymology, cosmology, materiality—as the early chapters of a continuous story of human energy systems. However, histories of energy have been curated only retroactively by humans already immersed in fossil-fueled systems. Energy does not travel across history, a unit free of context, but rather arose at the moment when a handful of deep historical things collided: fossil fuels, steam engines, global capitalism, human terraforming, the slave trade, climate systems, empires. From the perspective of deep history, the industrial assemblage that coalesced in the nineteenth century was not the beginning of the Anthropocene, but it was an inflection point; it was the moment in which some humans became increasingly aware of their planetary agency, and did so through the lens of their fuel consumption. The birth of energy science captured the spirit of that moment, and its mixture of hope and dread. The curation of a deep energy history by modern, usually Western, humans represents an effort to make sense of Homo pyric, humans as a species both blessed and cursed with the Promethean gift of combustible fuel.¹ Energy was the new language that made heat-work commensurate regardless of fuel source, while at the same time relating hearth fires, plowing, windmills, and steam engines to the unfolding of life in the universe.

This chapter reexamines the deeper history of energy-things prior to the nineteenth century in order to disrupt the seeming continuity, or timelessness, of energy. Disrupting energy involves two claims: First, energy as we know it in the social sciences, as a sign for fuel, is a modern invention. And second, energy has a long-standing moral and etymological connection to work, which gets imported into thermodynamics, with significant political effects (the subject of the remainder of the book).

Who, and what, is served by treating energy as a cosmic unit? As a Victorian science, thermodynamics lent natural, and even cosmological, validation to the industrial project and its celebration of work. Additionally, work, exemplified in the Victorian era by the steam engine, came to be governed as a site of energy transformation. Now that energy was no longer a philosophical abstraction, but (also) a measurable unit, problems with work could be treated as technocratic energy problems, amenable to better energy governance. The energetic model of work thus helped to obscure the political contestability of modern work, and became a technoscientific means for governing workers, both human and more-than-human.
EARLY ENERGY COSMOLOGIES

The word energy originated with Aristotle (384–322 BC). His ἐνέργεια (energeia) laid the foundations for the Latin energia, the French énergie (first used in the sixteenth century), and the English energy (also originating in the late sixteenth century). Prior to the nineteenth century, references to energy bore little resemblance to its future incarnation as a unit of thermodynamics, with one exception: work. Energy appears to have been frequently connected to work and its relationship to human virtue, a link that also became central to the ethos of the science of energy.

Energeia is a combination of the Greek en-, meaning “in” or “within” and -ergon, meaning “work.” It is often roughly translated into English as activity or actuality, though classicist Joe Sachs proposes “being-at-work” as the best sense of what Aristotle meant. Sachs writes that energeia should be a jarring and thought-provoking word for the reader of Aristotle, as it is “a special word, dear to Aristotle, at the heart of his theoretical works and giving depth to everything he writes.” Aristotle uses energeia as a way to talk about happiness and goodness; for Aristotle, goodness is an ongoing, dynamic project (being-at-work, energeia), rather than a static achievement. Importantly, energeia was used almost synonymously with ἐντελέχεια (entelékheia, or entelechy), another term coined by Aristotle and one that would later be adopted into nineteenth-century vitalist debates. If energeia is being-at-work, Sachs translates entelecheia as “being-at-work-staying-the-same” or “being-at-an-end.”

The terms are related in a circular fashion. They describe life as constant motion: things achieve their actuality through being-at-work, and this work is striving toward, or maintaining, the completion or actuality of each thing. But even if a thing reaches its completion, it has to continue to work to maintain it (thus, entelecheia, or “being-at-work-staying-the-same”). A more pessimistic way to say this is that life entails struggle; even to stay alive requires ongoing effort. Aristotle, then, invests energy from the start with a sense of dynamism and vitality. Because these terms are at the center of his philosophy, they also carry a metaphysical weight that connects activity (being-at-work) and goodness. While energeia and entelecheia, as well as the concept of work itself, are quite specific to Aristotelian philosophy and do not touch upon later principles of thermodynamics, these associations remain significant when they are adopted into the science of energy.

Following Aristotle, energy continued to be advanced with its “honorable Greco-Roman pedigree,” such that “the term entered its modern
scientific usages carrying a large freight of classical associations.”4 The Oxford English Dictionary lists five different inflections of the word, all of which retain Aristotelian connotations of vigor, actuality, motion, and change: “force or vigour of expression”; “exercise of power, actual working, operation, activity”; “vigor or intensity of action, utterance, etc.”; “power actively and efficiently displayed or exerted”; and “ability or capacity to produce an effect.” The central role of energeia in Aristotle’s metaphysics also remains influential, both in premodern usage and in the science of energy, wherein “the possible equivocations, the multivalent expressions, of such power have wired into Western languages a proverbial connection between physics and metaphysics, material effect and divine cause.”5

As a Western concept, energy combines a materialism, in the description of activity, with moralism, expressing a bias toward dynamism over stasis. The bias toward dynamism accords with what Arjun Appadurai has described as “trajectorism,” a “narrative trap” of the West that serves as the central faith of modernity. Trajectorism assumes “that there is a cumulative journey from here to there, or more exactly from now to then, in human affairs, as natural as a river and as all-encompassing as the sky.”6 Importantly, for Appadurai, trajectorism is about more than temporality, more than an awareness of time’s arrow and irreversibility. Trajectorism has political effects. As a Western imperial project and a “bad habit” of thought, trajectorism became an ideology of expansion in which time’s arrow must lead to a single destination, “the world written in the image of Europe.”7 The West, then, is unthinkable except as a trajectory, as an act of expansion from here (a region, a piecemeal dominion) to there (world as Europe). Such an expansion could be synonymous with faith in progress, but its possibilities are broader.

By the nineteenth century, not only progress, but unlimited progress, had become an almost universal faith in the modern West. What is important, above all, is the preference for constant motion, action, dynamism, growth—with the progressive effects assumed to follow post hoc. Europe, or the West, then, cannot be conceived of as a steady-state project, an entelechy whose efforts are directed at maintenance; such a notion remains difficult, if not impossible, to think. Hannah Arendt quotes Proudhon from the 1850s (just after energy has been “discovered”): “motion is ‘le fait primitif’ and ‘the laws of movement alone are eternal.’ This movement has neither beginning nor end: ‘Le movement est; voilà tout!’”8 Motion is otherwise understood as kinetic energy; the laws of motion are inscribed in energy.
All this is to show that energy, even before it became a scientific thing, was always about more than fuel or the material potential for action. Energy provided the grammar for a preference for the transformation of fuel, for putting it to use to do work and make change, and for stamping teleological activity as a virtuous achievement. Even after thermodynamics adopted the term energy as a concept for physics, these older meanings of energy continued to be used alongside, or interchanged with, energy as a scientific term, such that the metaphysical and scientific connotations inflected and supported each other. Indeed, Bruce Clarke points out that, following the advent of the science of energy, “its prior layers of meaning did not vanish. The already overdetermined term energy became even more charged with powerful semantic currents. Emotional and spiritual meanings were mingled with the letter and interpretation of physical concepts.”

Energy continues to be a slippery word, traveling easily between vigor, virtue, and fossil fuels, and implicitly disparaging its opposites: rest, stasis, stillness, lassitude.

A COSMOLOGY OF CHANGE

While energy is a Western word that derives etymologically from Aristotle, there were parallel inquiries across human civilizations that aspired to understand change in the world. The wish to locate a universal concept, or force-flow, that underlies natural transformations appears to have been widely shared across human civilizations. The Chinese had the concept of qi, which Dainian Zhang defines as “both what really exists and what has the ability to become. . . . As a philosophical category qi originally referred to the existence of whatever is of a nature to change.” Tellingly, Zhang also argues that a succinct way to understand qi would be through Albert Einstein’s matter–energy equivalence equation, $E = mc^2$, as “in places the material element may be to the fore, in others, what we term energy. Qi embraces both.” Hinduism has prana, which associated the breath with a life force that permeated the cosmos. In Stoic physics, pneuma was central; it was a mixture of fire and air, “an all-pervading medium which intelligently directs the cosmic cycle” and was at the basis of all life. Unlike Aristotle, who separated the heavens from the Earth, pneuma as a universal medium meant that the Stoics viewed the stars, planets, and cosmos as continuous with the Earth, and as involved in cyclical flows and exchanges of pneuma over time. Pneuma even anticipates some facets of the science of energy, which views the
cosmos as constituted by flows of energy, and the Earth as depending upon energetic flows from the Sun.

The philosophies of energeia, pneuma, qi, or prana advanced different visions of the cosmos. However, they all reflected an interest in understanding change and stasis experienced by living things over time, and in connecting these universal experiences to moral frameworks. The morality attached to these earlier presentiments of energy did not necessarily share the West’s bias toward dynamism and trajectorism. For example, goodness might involve understanding and sometimes governing the flows of qi or prana, while evil involved their blockage or misapplication. Good governance of qi or prana might entail balance and harmony rather than constant change.

These multiple histories of energy remain relevant today. From oil and gas corporations to yoga studios, from Buddhism to interior design, from Burning Man festivals to biological and ecological sciences, from computing to quantum physics, energy has many valences, and these are determined by the context of its articulation. However, this book narrows its focus to energy’s appearance as an object of politics, where it almost always operates as a sign for fuel. In its manifestation as energy/fuel, energy imports the physical and cultural meanings of one particularly dominant figuration of energy: that of the science of energy, or thermodynamics.

It is through thermodynamics that energy became a newly soluble problem for the state, as a unit of work that was amenable to technical governance. It is also through thermodynamics that energy became a problem for the Earth, and a crisis—global warming—that also seems to demand new human governmentalities. What distinguishes thermodynamic energy from its other cultural dimensions is its emphasis on heat-work, on the transformations made possible by burning fuel. The thermodynamic rendering of energy—as the measurement of productive, valuable work—has arguably become so dominant in the modern West as to crowd out other possible ways of imagining energy.

FIRE AND FLUX

The science of energy that emerged in the nineteenth century drew indi-
rectly upon these multiple philosophical histories, but it was not just an extension of centuries-old theories about a universal life force. What made thermodynamics so unique and successful was that it managed to marry the life-force tradition, which tended toward ideals of balance, to
an understanding of heat transformations. Heat transformations propelled the new steam engines, and these were inherently machines of change, rather than symbols of harmony.

Moreover, heat transformations challenged the concept of conservation. For alongside those long-standing intuitions of a universal life force were equally ancient theories about its conservation: in other words, if there were a life force, most philosophical traditions surmised that it was ontologically stable across time and space. But what happened to the universal life force during a fire? To the human eye, all the ingredients of a fire appeared to be radically changed, if not entirely destroyed, but if there were a universal life force, then something must be conserved across all transformations, no matter how violent. Just what that something was, however, remained mostly a mystery. The insistence upon conservation was for the most part metaphysical and tightly bound to religious and philosophical precepts. Belief in the conservation of something in nature is evident in the Greek aphorism that “nothing comes from nothing,” attributed to the thought of Parmenides (“for things that are not can never be forced to be”). Nothing can be created out of nothing, and once created nothing can be destroyed—ergo the basic forces of the universe must be conserved.

Conservation theories stretch back to at least the ancient Greeks, and Philip Mirowski observes that “the concept of a conservation principle is practically inseparable from the meaning of ‘energy.’” Heraclitus (535–475 BC), often understood as a founding inspiration for later Stoic thought, was a philosopher of “fire-and-flux,” and foreshadowed thermodynamics by over two thousand years. He argued that fire was central to all things; that the cosmos “always was, is, and will be, an ever-living fire, being kindled in measures and being quenched in measures,” and therefore that change was the central phenomenon of the natural world (later Greeks cited him as offering the famous aphorism that “you cannot step into the same river twice”). Amid this change, there are equivalences between oppositions (up and down, alive and dead, goods and gold), and in this sense Heraclitus suggested an early version of the conservation of matter across radically different forms.

“Nothing comes from nothing” was also a totemic starting point for Lucretius, another early prophet of energy, though he added a tragic twist to the notion of conservation. Lucretius insisted on the senescence of the Earth, asserting that the planet, like any living thing, would inevitably decay toward death. Conservation might just mean the conservation...
of ruin and wreckage. In his gleefully blunt style, Lucretius reminds his readers that

There is never lack
Of outer space, available to take
The exploded rampart-rubble of the world.
The doors of death are always open wide:
For sky, for sun, for Earth, for ocean’s deeps
The vast and gaping emptiness lies in wait.  

His De Rerum Natura is full of declarations that the Earth is always changing, and headed toward death, as “all that might, / All that machinery of the universe, / Upheld so proudly through so many years, / Will tumble down, crumble to ruin, die.”

Lucretius intends his brusque handling of death to have an ethical effect on his readers. If death is universal and inevitable, and far beyond human control, then we should accept it, rather than fear it. It is death, along with a host of other anxieties, that leads people to worship false gods, Lucretius insists, and to toil after possessions and luxuries, for “the brief / Capacity of pleasure for increase,” which delivers humans over and over “to the great tidal depths of storm and war.” Clearly, Lucretius, unlike so many of his peers, does not subscribe to the virtue of dynamism for the sake of dynamism, or to the pleasures of growth. He spends many lines rehearsing the pointlessness of human striving to improve agriculture, law, art, and war. Instead, Lucretius’s knowledge of the universe leads him to embrace a more restful disposition, wherein “wealth, / The greatest wealth, is living modestly, / Serene, content with little.”

Lucretius anticipated modern physics, including the science of energy, with his description of atoms moving in a void. His manuscript, lost for hundreds of years until its rediscovery in a fifteenth-century monastery, would later inspire a minoritarian tradition of political ecologists and philosophers in modern Europe, from Michel de Montaigne to Henri Bergson and Alfred North Whitehead. Readers from the late industrial world might shiver with recognition at the “great tidal depths of storm and war” that De Rerum Natura prophesied over two thousand years prior to climate change. Nevertheless, Lucretius to this day remains almost too avant-garde for Western cultures. Although his physics was strikingly modern for its time, his ethical interpretations of the cosmos are in direct opposition to the energy ethics that have come to prevail in the industrial West. Lucretius’s vision of the cosmos suggested the wisdom of serenity,
modesty, and caution, which are all at odds with the dominant Western narrative of trajectorism and dynamic change. Weirder and more disconcerting still for modern readers are his tragic ethos and unflinching rejection of religion. Lucretius’s Earth was not a harmonious planet, divinely planned for human purposes, but rather a random collection of atoms sliding toward death and completely beyond the control of humans.25

Enlightenment science embraced a variation of the former and more comforting planet. Even if the world was not divinely ordained, the hope was that human knowledge could eventually triumph over earthly complexity. This meant that scientists could not rest at asserting conservation laws; they wanted to devise mathematical equations that proved them.26 René Descartes, for instance, argued that motion was conserved in the universe; he believed that “motion, like matter, once created cannot be destroyed, because the same amount of motion has remained in the universe since creation.”27 Descartes defined the conserved quantity as mass times velocity ($mv$). Later, Gottfried Leibniz initiated a vigorous debate with Descartes by arguing that it was not motion ($mv$) that was conserved, but rather what Leibniz called vis viva, or “living force,” defined as mass times velocity squared ($mv^2$).28

The debate over vis viva, which raged through the eighteenth century, is often read as a simple misunderstanding corrected by later knowledge: without an agreement as to the meaning of terms like force or an understanding of the science of energy, Descartes was actually positing the conservation of momentum, while Leibniz was arguing for a conservation of what is now known as kinetic energy. Both were to be proved correct in a sense, as both conservation rules are now understood to be valid and not mutually exclusive. However, historians of science have pointed out that the controversy was more complex than this implies.29 Leibniz was proposing an entirely different philosophical perspective than was Descartes, one in which both time and space, and thus motion across time and space, were relative.

The idea that space was relative was an eccentric view at the time, more than two hundred years before Einstein. But if motion were relative, Leibniz concluded, then it could not serve as an absolute entity that was conserved in the universe. Instead, Leibniz proposed that there was a vital, living force that was absolute (vis viva), and this force meant that “what is real in the universe is activity; the essence of substance is action, not extension as Descartes had insisted.”30 Leibniz’s vis viva, which calculated kinetic energy, came closer to the modern notion of energy, and
thus Leibniz was adopted post hoc in the building of a pedigree for the science of energy.

Here again, there is an evident preference for activity in both the philosophical and physical precursors for the science of energy. Existence, for Leibniz, is best captured by activity, in motion and change across time, rather than by extension, the mere fact of taking up space. Energy over matter, time over space. Vis viva can be understood as a scientific descendant of Aristotelian energeia, where goodness is not a state of being (extension), but rather an ongoing effort of becoming (activity). Thermodynamics, too, continues the emphasis on dynamism rather than stasis.

By the time of Leibniz, then, almost two hundred years before the science of energy, many of the pieces were already in place to cobble together something like a conservation law, if not a fully articulated concept of energy as a universal unit of exchange. However, despite the energy pedigree claiming Leibniz’s vis viva as a forebear, there was “no simple line of descent from Leibniz’s principle of conservation of vis viva to nineteenth century energy conservation.” The problem was that, as much as vis viva was useful as a conservation law, it still could not explain how steam engines worked. And the science of energy did not emerge as a result of mathematically abstract debates about conservation. Rather, energy science arose among those with more practically minded goals: scientist-engineers whose chief interest was in solving the puzzle of steam engines. Steam engines were heat machines, and the transformative power of heat remained little understood. Ultimately, it was the merging of Leibniz-like intuitions about universal conservation with a study of steam engines that produced the modern concept of energy.

The resulting science of energy differed from the historical tradition of conservation laws. It was technological in its basis, as it was inextricably wound up with the proliferation of the steam engine, and thus with the upheavals of global industrialization. While natural change had always been of interest to humans, the changes wrought by steam engines were exponentially magnified. As the philosopher of science Bruce Clarke notes, energy was “a discipline for the production of the sort of knowledge that enables persons to seize powers previously reserved to the agency of the divine,” and so “science has often taken on the allegorical attributes of the Luciferian enterprise.” If divinity was displayed in the acts of creation, in the appearance of novelty on the Earth with each dawning day of the first week of Genesis, then steam engines brought humans closer than ever to the glory of God.
Steam engines are little creative divinities, but like many creative endeavors, they feed on death, running on the detritus of a long-lost world. As with fire, which had always seemed magical to humans, engines convert matter that is usually described in terms of spatial extension—cords of wood, seams of coal, and reservoirs of oil—into motion that is best described in time—acceleration, intensity, and work. Like the host of other fossils dug up by humans in the nineteenth century, fossil fuels illuminated the Earth as a hive of constant activity, even in zones that appeared inert or lifeless. The Earth, formerly understood as an extension in space, gained a new dimension: Earth as historical, as a duration in time, and thus as a potential reservoir for work.

Up to this point, I have elided any distinction between energy-knowledge and energy-as-fuel. Rather than hew to a material–ideational division, the aim is to recognize their mutual entanglement, as well as the multiple lifetimes and histories that were assembled into fossil-fueled systems and interpreted through the science of energy. Steam engines are modern, the word *energy* and its philosophies are ancient, but the fossil fuels are more palpably older still—expanding time capsules that originated in a world without humans. Rather than approach these histories linearly, it is more helpful to imagine time in loops and spirals, as in the U.S. Geological Survey’s depiction of Earth’s history (figure 1.1) or, more poetically, in the “widening gyre” of falcons’ flight and things falling apart in William Butler Yeats’s “Second Coming.”

Life on Earth relies almost entirely upon the nuclear reactions of the Sun (with the notable exception of geothermal energy and human-derived nuclear reactions on Earth), including the forces of wind and water as well as so-called fossil fuels. In the words of global environmental historian Rolf Peter Sieferle, “the Earth’s biosphere is a powerful solar energy system.” Fossil fuels are part of this solar energy system, as they are the remains of once-living plants and/or animals.

Coal is often made up of fossilized swamp plants, while oil and natural gas derive from mostly marine plants and animals. Coal formations began when plant life accelerated around 350 to 400 million years ago. Except for a relatively short gap at the end of the Permian (fifteen million years is short when we are talking about coal), when there was a mass extinction and 90 percent of life on Earth died out, coal formation has continued and is ongoing today. Today’s peat bogs will one day become coal, albeit
millions of years from now. Coal needs special conditions to form, and these conditions were ideal during the so-called Carboniferous period of the Late Paleozoic, from about 359 to 300 million years ago, when much of the coal mined today originated (note the term Carboniferous: even our periodization of Earth history stems from our interest in fossil fuels). Oil and natural gas are not necessarily as old as coal, although it likely takes at least several hundred thousand years for these fossil fuels to form. About 60 to 70 percent of the world’s known oil—including the oil in the Middle East—is thought to come from the Mesozoic Era, about 100 million years ago.\textsuperscript{34}

For hundreds of millions of years, the bulk of this carbon energy remained buried beneath the Earth’s surface, while life on Earth existed on more immediate circulations of solar energy. For human animals, this meant technologies that harnessed wind, water, and muscle, as well as an underlying dependence on plants. Fire offered another important source of energy, rapidly releasing the concentrated energy stored in plants as heat, a kind of fossil-fuel burning in miniature. The emergence of fire use remains unknown, but evidence has recently been found of \textit{Homo erectus} using fire one million years ago.\textsuperscript{35} The control of fire was “a crucial turning point in human evolution,”\textsuperscript{36} playing “a decisive role not only in human prehistory but in the very process of humanization itself.”\textsuperscript{37} (Although even the assumption that fire manipulation is specific to human evolution is under pressure, given research documenting raptors using fire to catch prey in Australia, a phenomenon that was already well known to indigenous peoples.)\textsuperscript{38} Much later, burning wood and charcoal was instrumental to the slow emergence of agricultural civilization, as it helped to clear forests as well as to make certain crops more digestible. The relationship between humans, domesticated animals, food, climate, and terrain—all of which could later be charted under the rubric of energy exchange—is important to understanding the rise of hierarchical human societies.\textsuperscript{39}

While early agricultural civilizations mainly tapped into immediate circulations of solar energy, there were varied attempts to take advantage of fossil fuels. The use of oil dates back at least five thousand years: asphalt was used in building in ancient Sumeria and Babylon, Ancient Egyptians and Native Americans each used oil for medicinal purposes, and Native Americans also made tar for tool construction. Ancient China developed deep drilling for natural gas, bringing it through bamboo pipes as heat to make salt, or “brine.”\textsuperscript{40} There is evidence of coal being burned as fuel as early as 1000 BCE in China, and it is also mentioned in ancient Greek texts.
and later during the Roman Empire. However, coal was unpopular due to its impurities and the dirty, black smoke it emitted. Wood was preferable for heating and cooking purposes, and people only grudgingly turned to charcoal or coal for home use, often when forced to by deforestation.41

England’s own coal consumption began as early as the thirteenth century and rose in slow fits and starts. There were important geographic influences: England had easily accessible coal mines in combination with a river and forest system that made it comparatively more difficult to transport wood than it was to ship coal by sea.42 The substitution of coal for wood freed up land for other commercial purposes, such as raising sheep for textiles. Those goods could then be traded to import more food than the land could have produced. The density of coal, whose power was determined by duration rather than extension, thus helped to increase the ecological footprint of Great Britain, which was now effectively importing food energy to feed its growing population.43 By the sixteenth century, Britain experienced an “Elizabethan leap” in its coal consumption, which has been widely chalked up to a timber shortage alongside increased fuel demand by a rising urban population. Andreas Malm, however, also points to the human forces at work that made coal production profitable, and thus desirable, in the first place: a royal edict in 1566 transformed mineral resources from Crown property to private property, leading to an acceleration in elite land appropriations and tenant evictions. Coal became increasingly good business. A self-reinforcing cycle of mineral privatization and land enclosure, which pushed more people into swelling cities where fuel demands outstripped the nearby organic material, set the stage for the eventual intensification of fossil fuel economies.44

Britain’s early flirtation with fossil fuels was further accelerated by a technological innovation. Coal and oil had not yet been used to power what Vaclav Smil, an energy historian, calls a prime mover technology.45 The eventual marriage of coal to an increasingly effective prime mover—the steam engine—played a decisive role in industrialization by tying together many areas of the economy that had already been moving toward increasing mechanization, including textiles, agriculture, and chemical industries.46 Global coal use catapulted exponentially in a short period of time, from just under ten million tons at the start of the nineteenth century to almost 100 million tons in the middle of the century, and then to 1,000 million tons by the first decades of the twentieth century.47 The rise of coal also amplified the global circulation of metals like aluminum, nickel, pig iron, and lead. Sieferle, an environmental historian, reflects
that “with the utilization of coal the bottleneck that had until then slowed down all technical economic innovations was overcome.”

Despite the centrality of coal to the story, the coal–steam engine apparatus should not be overstated as a determining factor in the Industrial Revolution. The dramatic rise in coal consumption occurred only toward the last half of the nineteenth century, at the tail end of industrialization. It was through the convergence of a number of processes—technologies, scientific cultures, forestry practices, river flows, the geology of coal deposits, slavery, and the global circulations of resources and money—that coal “gained its strategic importance.” Nevertheless, “the central importance of coal as the energy basis of the Industrial Revolution” is undeniable, even if Sieferle argues that “it has been almost completely ignored by economic history.”

Emphasizing coal also helps to downplay the Western miracle narrative of industrialization. For instance, historian Kenneth Pomeranz has convincingly shown how a host of material and imperial vectors, rather than the presumed superiority of Western culture and science, were important in understanding the “great divergence,” and why Europe and not, for instance, China, industrialized when it did.

But as with the Elizabethan leap, supply, demand, and technological innovation are insufficient to explain the rise of coal. Malm goes further than Pomeranz in overturning the consensus explanation of the fossil-fuel transition, which generally holds that humans naturally hunger for more and more energy, that their hunger was stymied by fuel shortages, and that coal offered a breakthrough technological advantage. Instead, Malm points out that coal-fired machines were neither cheaper nor obviously superior in this period. Nor were other possible energy sources absent at the time. In fact, water power was a viable, and often more affordable, alternative for the new factories of the nineteenth century.

So why did capitalists end up preferring steam to water? While coal may not have been cheaper, Malm argues that it was more conducive to the relations of power that sustained capitalism. More specifically, steam power opened up better opportunities for capitalist owners to dodge the growing demands of laborers for shorter work hours, higher pay, and other social protections—in Malm’s pithy phrasing, “steam won because it augmented the power of some over others.” Water power, with its seasonal variability, required cooperation among factory owners and public institutions, and it also rooted industries to specific sites alongside waterways. If those sites were rural, as many were, mill owners might be responsible for managing labor colonies, and would also be reliant upon a
relatively static pool of workers.\textsuperscript{56} In contrast, steam power was certainly cheapest near coal pits, but it could be consumed anywhere, and did not need to be coordinated with others. It satisfied a competitive, individualist style of profit making.\textsuperscript{57} Coal’s mobility meant it could also feed urban factories located near large pools of expendable labor. Urban laborers did not need to be fed or housed by their bosses, and it was much easier to replace resistant or unruly workers in a city teeming with people who had been uprooted from land and family.\textsuperscript{58} If the “logic of water” was more communistic, the logic of fossil fuels was conducive to predatory and violent economic relations.\textsuperscript{59}

By reading fossil fuels through the lens of human power, Malm reverses Marx’s famous dictum—that the hand mill gives us the feudal lord, while the steam mill gives us the industrial capitalist.\textsuperscript{60} Instead, Malm contends, the industrial capitalist led to the dominance of steam power. Capitalism was ill-matched to water power—so much so that “the anarchy of capital had to become fossil,”\textsuperscript{61} given that “the more capital tries to extract itself from the absolute, concrete qualities of space and time, the deeper must be its exploitation of the stock of energy located in their exterior.”\textsuperscript{62} The demand for profit by some at the expense of others drove capitalists toward a fuel that could be mobile, privatized, highly controlled, and burned all night in tireless prime movers. In other words, the advantages of coal had more to do with human power than with mechanical power.

While coal girded the explosion of industrialization and remains a significant source of fuel for electricity needs worldwide, oil emerged in the latter half of the nineteenth century and quickly rose to prominence by the early twentieth century. As with coal, humans had used oil for centuries, but it was not until the mid-nineteenth century that kerosene was distilled from petroleum and proposed as an attractive fuel for lamps. When Edwin Drake found oil in Pennsylvania in 1859, the petroleum business was still perceived as a risky venture, but within a couple of decades, the U.S. oil industry took shape and oil consumption expanded.\textsuperscript{63} Here, too, the transition from coal to oil had as much to do with human power as it did mechanical power. Timothy Mitchell has shown how the urge to escape the demands of labor—in this case the demands of organized coal miners—became a significant factor in the turn toward oil.\textsuperscript{64} By the late 1800s, the oil industry was truly global, with European companies drilling for oil abroad, including Royal Dutch Shell in the Caucasus and British Petroleum in Persia. By the early twentieth century, with the advent of
diesel engines that ran on petroleum, oil began to overtake coal in fueling transportation technologies. The rise of crude oil production was even more sudden and dramatic than the rise of coal, building as it did upon the socio-energetic demands already inculcated by coal systems: oil grew from only one million tons globally in 1870 to over ten million tons in 1900 and over 100 million tons in the 1930s.

The consequent spike in industrial expansion and consumption following the spread of fossil-fuel systems is hardly surprising if one considers that some humans suddenly had a superabundance of fuel at their disposal, far beyond the transitory flows that could be captured from the Sun’s daily allowance. John Tyndall, an early scientist of energy, marveled at the power of coal, “vast truly in relation to the life and wants of an individual, but exceedingly minute in comparison with the Earth’s primitive store.”65 Sieferle notes that human societies might have been confronted with similar energy abundances in the past, as when pioneers clear-cut ancient forests. However, these moments provided only temporary spikes when compared with fossil fuels, which might supply abundant energy for a few centuries.

Unlike solar regimes, though, fossil fuel society is necessarily “transitional,”66 given that fossil fuels are both practically nonrenewable and ecologically disastrous. In effect, burning fossil fuels is somewhat like sparking the spontaneous decomposition of a large number of long-dead plants and animals all at once, thus garnering an exponentially denser amount of energy than if these plants and animals had decayed over a shorter period of time and were in less compact form. William Stanley Jevons, who famously warned of the exhaustion of Great Britain’s coal in 1865, described coal as “like a spring, wound up during geological ages for us to let down,”67 a metaphor that conceives of the Earth as a grand apparatus waiting for human operators to release its potential animation. As such, fossil fuels are also, technically, renewable energy—the spring can be wound back up again, so long as plants and animals keep living and dying—but only over the course of hundreds of millions of years. Whether energy is renewable, then, is less a material description of fuels than it is a human judgment about time. The fossil fuel interlude in human life will likely prove to be extremely short-lived when compared to solar agricultural regimes, which prevailed for over 10,000 years, and certainly when compared to the hybrid subsistence methods of hunter-gatherers, which determined human life for about 95 percent of its existence, for nearly 190,000 of the 200,000-year history of Homo sapiens.68
CONCLUSION: TOWARD A VICTORIAN ENERGY

Having teased out some of energy’s historical forebears, from Carboniferous swamps to ancient human philosophers, we are better situated to understand why the energy/fuel/machine assemblage swerves in the nineteenth century, generating energy as we now know it, as a sign for fuel. There are no clean edges in history, nothing born de novo without precedent, but in an important way our world was shaped in the nineteenth century, where industrial assemblages crossed a threshold of perception, a term adopted from Gilles Deleuze and Félix Guattari’s topographical, rather than linear, approach to history. Some economic historians have pointed out that industrialization was slow to take root, and that the “Industrial Revolution” was less a sudden big bang and more a multivalent, complex, and slowly unfolding set of processes. Nevertheless, by the mid-nineteenth century, the European public perceived the “dawning of a new age” that provoked as much anticipation as trepidation.