crude

THE STORY OF OIL

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PREFACE

For the Love of Oil

> Oil creates the illusion of a completely changed life, life without work, life for free. . . . The concept of oil expresses perfectly the eternal human dream of wealth achieved through lucky accident. . . . In this sense, oil is a fairy tale and like every fairy tale a bit of a lie.
>
> —Ryszard Kapuscinski[1]

OUR SPECIES HAS basked in the strange and wonderful properties of crude oil for millennia. But it was only over the last century that we built whole ways of living upon its power, harnessing crude to make cars run, planes fly, houses warm and lit, hospitals sterile, and supermarkets stocked with fresh fruits and vegetables.

Today, one-sixth of the entire global economy is dedicated to the staggering effort of harvesting oil from its uneven accumulations within the earth's crust. From birth to death our mobility, health, and sustenance all depend, in various ways, upon crude oil and its progeny. Newborn babies slide from their mothers into gloved hands, are swaddled in petro-polyester blankets, and hurried off to be warmed by oil-burning heaters. Later, strapped into steely, oil-fed motors, their soft breakable bodies gloriously extend their reach and power.

So long as the pipelines course with crude, our reliance on oil isn't a fact we think about very often. But every so often, we are struck with a paralyzing anxiety. How much is there? How long will it last? What will come next?

There are many reasons why we might worry about our reliance on crude. After all, we use the stuff 100,000 times faster than it can accumulate underground. And we've already depleted the easiest and safest sources of oil.

But our apprehensions are generally sparked by a more mundane trigger: rising oil prices. In the wake of the oil embargo and Iranian revolution in the 1970s, the price of oil more than tripled, forcing Americans to take their first baby-steps toward moderating oil consumption. But then, in the 1980s, despite the ongoing depletion of oil, the price of a barrel of oil plummeted, and the zest for conservation faded.

And so it hit even harder when, in the middle of the first decade of the new millennium, the price of oil shocked us once again. This time, a confluence of factors threw the delicate balance between supply and demand into pandemonium. China consumed more oil than expected, while a series of hurricanes crippled oil facilities in the Gulf of Mexico. As the price of oil rose, so did the anxiety. Hollywood movies spun elaborate conspiracy theories about the oil supply. Editorialists speculated darkly on the end of oil, and webmasters warned of "Petrocalypse Now!" Talk shows discussed the possibility of an ever-growing China depriving Americans of their oily birthrights. The term "peak oil" entered the public lexicon.

The fundamental facts are not hard to understand. Every year, the world demands about 2 percent more oil than it did the year before, while the flow of oil from known oilfields declines by 3-5 percent. Since the 1960s, oil explorers' finds of new oil have been ever smaller, and since the 1980s, they've been finding those smaller accumulations less frequently. And so the oil industry slakes growing desires for crude by slurping faster on the reserves of oil discovered decades earlier. At some point, that endowment of oil will be spent, and the flow of crude will start to inexorably decline.

Some analysts say if we invest sufficient effort and money we can stave off the peak by a few decades. Others, more pessimistic, say the beginning of the end is a matter of years, or even months.

The oil industry has, indeed, been pronounced dead before. In 1909, Standard Oil was beheaded, and the oil industry was predicted to fade into oblivion. In 1960 the Organization of Petroleum Exporting Countries (OPEC) was formed, depriving Western oil companies of access to the most plentiful oilfields in the world. In the 1980s the rate of discovery of new oil started to decline. In 1997 the Kyoto Protocol was forged. And yet, the industry has survived, and thrived.

That's not to say there's been no fallout from these near-death experiences. In the beginning, oil drillers did little more than dig holes in their own backyards to produce oil. Today, oil companies must enlist the best minds of scholars and the blood of soldiers to fortify their sprawling tangle of arteries pumping oil to the world's machines. But the accumulated scar tissue would hardly be revealed through the simple pulse-read that is the price of oil. Despite the increasing difficulty of keeping the pipelines full, oil has not always become more expensive. In part, that's because it isn't consumers but distant ecosystems and future generations that suffer the lengthier pipelines, longer drills, stepped-up security, and environmental disruption that costlier oil requires.

In the coming years, the oil industry may be able to continue to keep the pipelines full with heavier oils, distant oils, and oil-like substitutes. But if the higher costs are pushed onto people and places separated from consumers by time and space, judging by the price of oil we may never know it.

If so, we may not experience oil's death throes as a prolonged period of painfully high prices for ever-scarcer oil, but rather as other kinds of seemingly disconnected disruptions. Up in the air, the century's explosion of carbon from the planet's crust hangs over us, ominously. The malignant spawn of petro-states send us cryptic messages of Armageddon. The most powerful nations on earth vie for the last forests, fresh waters, and farmlands to feed their oil-hungry economies. These—not the price of oil—may be our canaries in the coal mine.

If that is so, one could reasonably take a look around and surmise that the question isn't when the end of oil will come. We're in it already.

What next after crude? Again, there are roughly two camps. According to conventional wisdom, the West's high-tech, hydrocarbon-based society lies at the pinnacle of a natural, inevitable development path. There is no need even in the face of oil's decline, according to this view, to veer off in a new direction. We can continue using as much energy as we have over the last century of oil. We'll just get the stuff from other sources, whether coal, natural gas, nuclear power, or biomass.

An alternate view holds just the opposite: that the petro-life is an anomaly, based on the improbable discovery of relatively rare, finite accumulations of energy lurking under the ground during an era of unusually stable climatic conditions, a development as unlikely as winning the lottery. According to this view, the discovery of oil, the harnessing of its power, the rapid development of a society nourished and sustained by its short-term riches, despite its long-term and far-away costs—none of this was preordained or inevitable. If the very basis for this aberrant way of life is receding, there is no reason left to cling to its pathways. It is time, then, to adjust to radically new ones.

Whether we decide to maintain our oil-drenched society or chart a new energy future at least partly depends on how we understand the circuitous path behind us. It depends upon our story of oil, from its birth hundreds of millions of years ago to its abrupt exhumation over the last century and a half, a story told, in part, in the pages that follow.

INTRODUCTION

Oil Is Born

The story of oil is written on a time scale that humans can scarcely grasp, but it starts with something innocuous and seemingly peripheral: the slimy dregs at the bottom of the sea.

The outer crust encasing the earth is just 100 to 200 kilometers thick, a mere fraction of the way to the center. It is like a cracked eggshell, fragmented into about eight large plates and many smaller ones. Along with the burning star that is our sun, the Earth is primarily energized by its own interior, a hot core left over from the planet's creation more than 4 billion years ago. The fury of that heat becomes apparent when volcanoes erupt, vomiting up the innards of the planet. That heat drives the plates into constant slow motion—as much as ten centimeters a year.[1]

Throughout Earth's 4.5-billion-year history, these moving plates press against each other, forming mountains; tear apart, leaving huge depressions; slip under and slide past each other. Their rocky surfaces bear the scars of their journeys. Ice scrapes on rocks in the middle of the burning Sahara Desert and tropical rainforest plants buried in the middle of North America allow geological detectives to unravel the mobile plates' ancient pathways.[2]

A watery shroud swathes the cracked crust of our gigantic ball of heat, sloughing off the outer layers and sending them into motion. The water enveloping the planet in clouds, oceans, lakes, rivers, groundwater, and glaciers constantly circulates, melts, rains, freezes, and evaporates. The frenzy of water's activity along the surface of the earth shapes its face, eroding mountains, cutting grand canyons, slowly slipping ever downward through the tiny spaces between the crumbs of soil into the rocks below.[3] When the weather turns cold, the water inside the rock freezes, expanding and shattering the rock. All of these processes slowly but surely break the mountains down.[4]

The products of that weathering and erosion, sediments, slip down the land, settling in puddles, washing into streams, and finally slipping into the sea. Rivers swirling with sands and sediments rush toward the ocean. As they approach the sea, the rivers' flow slows, and the suspended sediments start to sink. On the floor of the sea, the layers of sediment slowly build up. The bottom ones get buried under progressively more and more weight and eventually turn hard and compressed. They become rock.

The ocean teems with tiny crustaceans, worms, and algae, microscopic life on which the entire food chain hangs. The seas are cloudy with them. But among the three kinds of sea creatures—the ones fixed on the bottom, like corals; the ones swimming around, like fish; and the tiny creatures that simply float with the currents and tides; the tiniest are by far the most prolific, producing up to 80 percent of the total organic matter in the ocean.[5]

Those hordes of miniscule marine creatures are called plankton. The term "plankton" refers less to a specific kind of organism than just a strategy: those creatures that are too small or weak to swim well and who thus choose to float along the currents and tides, hoping for the best. Phytoplankton, microscopic one-celled photosynthesizing organisms, are the engines of the sea. They form the basis of the food chain under the water by feeding on sun and carbon dioxide, and then raining down to sustain the creatures below, swallowed in bits by other plankton or in great mouthfuls by those that swim.

The goal in life for plankton is not to sink. They must stay within the layer of the water that gives them enough light and warmth, and this struggle tends to keep them quite minute. In order to avoid predators, they hide by making themselves transparent or schooling together in great clouds or by simply becoming smaller and smaller. Particles of food suspended in the surrounding water nourish them.[6]

Especially prolific are the diatoms, half-plant half-animal creatures that reproduce by division, and which can lurk for years, undead, waiting for the right opportunity to come alive again. The longest ones measure eighty micrometers. After they die, their glasslike shells sink to the bottom, joining the discarded fish bones and teeth littering the seabed, infused along the coasts with incoming sediments from rivers.[7] The tiny shells of these and other single-celled creatures fall to the bottom and mix with the mud to turn into what geologists call carbonate "ooze."[8]

Plankton remains and other sediments can blanket the sea floor with about .1 millimeter of organic rubble a year. Over 10 million years, that adds up to an entire kilometer. Indeed, the accumulated remains of coccoliths, tiny shelly spheres about ten micrometers in diameter,[9] formed most of the towering white cliffs that loom over both sides of the English Channel.[10]

Most of the organic material that starts sinking to the bottom never reaches the seafloor. It gets eaten by fish or demolished by burrowing bacteria. But in fits and bursts at specific times and locations, organic sediments are preserved unrecycled and are buried untouched. If conditions are precisely right for those silty layers to accumulate, they may, in time, turn into oil.

The slime in question, this preancestor to oil, is packed with carbon.

Carbon is the building block of life, the stuff plants turn into food and that we breathe out as carbon dioxide. It is the black sooty stuff that makes up coal and graphite along with the hardest material on earth, glittering diamonds, as well as countless other substances when partnered with other elements. An entire branch of scientific inquiry, organic chemistry, is devoted to studying carbon.

Billions of years ago, carbon-containing meteorites and other small, solid celestial bodies bombarded the earth, steadily increasing the amount of carbon on the newborn planet.[11] There are about 49,000 metric gigatons[12] of carbon on Earth today,[13] making it the fourth most plentiful element in the universe after hydrogen, helium, and oxygen.[14]

Carbon circulates around our planet, sinking into the earth, spewing out in volcanoes and wafting up into the atmosphere. Seven hundred and fifty gigatons of carbon hang in the atmosphere, accounting for less than 1 percent of the world's carbon. At those lofty heights, carbon envelops the planet in a warming shell, letting heat in but not out.[15]

The vast majority of the world's carbon—more than 30,000 gigatons—resides in the world's oceans. (About 10,000 gigatons are locked in methane hydrates, a crystallized form of methane that forms under cold deep seas.)[16] The ocean and the airs above it conduct a gentle, give-and-take conversation with carbon, whispering the element back and forth depending on which side's concentration is greater.[17] Carbon dioxide dissolves in seas and ocean currents carry the carbon-laden waters down into the dark depths. Phytoplankton also turn the carbon from the air into food, storing it in their watery tissues. Other hungry creatures take with their bite of phytoplankton all of its stores of carbon, passing the carbon along the food chain.[18]

A similar process occurs on land as plants transform carbon into food and living tissue by photosynthesis. Animals eat the carbon-rich plants, growing their bodies and exhaling the byproducts, carbon dioxide, into the air—where plants can once again breathe it in. In total, forests and the rest of terrestrial life hungrily eat, breathe, and exhale another 3 percent of the world's carbon.

When fused with hydrogen, carbon repels water, which is why oil won't mix with water. Oil, along with natural gas and coal, is a hydrocarbon, so named because it consists of hydrogen and carbon. The simplest oil molecules are long chains of carbon atoms with hydrogen atoms hitched along the sides and ends of the molecules. A single carbon atom with a few hydrogens attached to it is methane, a light gas. A chain of three carbons is propane; four carbons is butane. A chain of eight carbons is octane. As the chains and rings of carbon get longer and longer, they stick to each other better. The hydrocarbon gets thicker. Thirty-carbon chains are waxy; refiners string even longer chains together to make plastics.[19]

For creatures like plankton that are composed mostly of water and live in water, a barrier of water-repelling material is crucial. It is what separates them from the sea that surrounds them, the thin barrier between the animate water inside and the inanimate water outside. Not surprisingly, a key component of planktonic cell membranes is made of chains of hydrocarbon molecules. If you zoomed in on the cell membranes of marine algae you'd see it: a chain of fifteen or seventeen carbon atoms strung together, holding the incoming waters at bay.[20]

Hydrocarbon-rich plankton corpses pile up in the sediments at the bottom of the sea. As more and more rich organic sediments collect on top, each layer is buried deeper under the subsiding seabed. When the sediments have sunk several kilometers underground, their compaction expels much of the water. Because much of the organic material comes from plankton, and minus water, plankton contains water-repelling hydrocarbons, the layers become rich in hydrocarbon. Over millions of years, the sunken, hydrocarbon-enriched layers harden, turning into thin sheets of dark chocolate brown or black rock.[21] If you took a chunk of it and put it under a microscope, you might see bits of shell, pollen, and even whole microorganisms fossilized there in the hardened rock.[22]

Once buried deeply, at least seventy-five hundred feet down, these sedimentary layers will turn into a hydrocarbon-impregnated shale or mudstone. Under increasing pressures as they get closer to the center of the earth, the organic-rich layers are gently heated at temperatures of around 180 degrees Fahrenheit, as warm as a hot cup of tea. Cooked over millions of years, the hydrocarbons in the rock mature. The heat splits the large molecules into progressively smaller ones and the hydrocarbons in the rock become lighter, less viscous, and much more volatile. The water-repelling cell membranes of single-celled marine creatures get squished and simmered into oil, which now infuses the shale, or "source rock" as petroleum geologists call it, in drops and blobs.[23]

If the rocky layer continues to descend into the earth's crust, going deeper than eighteen thousand feet, the pressure becomes too great, the layers too sunken, and the heat too intense. The oil "cracks" into the smallest and lightest molecules of all—methane, or natural gas.[24]

Just over a fifth of the world's carbon has been entombed this way, resting in the earth's crust.[25] Before people started to unearth oil, geologists from the U.S. Geological Survey figured around 2 trillion barrels[26] of carbon-rich oil were secreted underground. By unleashing oil from its silent tomb and burning it, we send the carbon locked in oil's hydrocarbons back into the atmosphere. During the last ice age, the carbon blanket in the atmosphere was only half as thick as it is today. Now, as more carbon wafts up to weave itself into that blanket, it thickens, keeping the planet warmer and warmer.[27]

If the world's oil all resided underground in deeply buried layers of shale, that carbon-rich, plankton-blessed rock, people would have never known about it. Part of the story of oil is how it moves and gets trapped in places where humans can get at it.

Oily shale and mudstone source rocks are full of oil, it is true, but it is practically impossible to get the oil out of that sludgy rock, as it is too dense. Of course, people have tried. There's a massive amount of oily shale in Colorado, deposited by a gigantic lake that covered parts of Utah, Colorado, and Wyoming more than 60 million years ago. Today, the lively lake is gone, but its oily sediments remain unburied, what one petroleum geologist dubbed an "unborn oilfield."

Chunks of Colorado's rich shale burn almost like coal, as railroad workers discovered when they used the rocks to encircle their campfire. There are tons of oil in that shale; if people could get it out, the amount would be roughly equal to all the world's conventional oil.[28]

In the 1980s, Exxon, desperate for a new source of oil, spent over $1 billion trying to get oil out of Colorado shale, ultimately abandoning the project when the price tag zoomed to $8 billion for a measly fifty thousand barrels of oil a day.[29] To deliver the unborn oil, the company would have to mine the rock, crush it, and then heat it, producing more waste than would fit into the hole they dug to mine the rock to begin with.[30] The procedure is also highly polluting, releasing three to six times more greenhouse gases into the atmosphere than conventional oil production, according to Greenpeace, which has campaigned against shale oil development.[31]

Instead, people look for the places where geological forces have moved the oil out of the shale into a rock more suitable for drilling. That happens when the shale layers get squeezed, as the constantly moving plates start pushing and pulling on the rock. Millions of years of such pressure on the rocks squeezes the oil out, buoyed by its own relative lightness. A migrating stream of oil can travel long distances, sometimes more than a hundred miles.[32] Where does it go? Crushed under tremendous pressure, under thousands of feet of shifting layers of rock, the oil searches for the easiest route out, through the tiny fractures and pore spaces in the rocks that suffocate it. It is a tortuous path, twisting and turning amid the miniscule gaps, aiming for the sun.[33]

The rock layers are heavy, but not all of them are very dense. Say the migrating oil encountered a rock made from a buried beach of white fine sand that had fused together into a porous sandstone. Even under great pressure, up to a quarter of the volume of that fine-sand-beach-turned-rock will be empty space. The even-sized sand grains stack upon each other like a pile of ping-pong balls, leaving plenty of room between them. Or say the traveling oil met up with limestone that had been lifted back up to the sea and exposed to fresh water again. The acidic water would have dissolved passageways for itself as it trickled through the rock, leaving behind a network of tiny connected veins. Or it could run into a buried reef, with its countless tubes and passageways created by living creatures, likewise riddled with connecting holes.[34] Such a porous rock will start to soak up the oil like a sponge. The oil-saturated sandstone or limestone becomes what is known as a "reservoir rock."[35]

The oil-soaked sandstone, this oily sponge, must also have a lid on it. Otherwise, the oil will keep on trickling out, dispersing itself over vast areas and becoming so spread out it will be impossible to collect. Something impermeable must sit on top of the sandstone, forming a kind of seal for the migrating oil. The very structure of the rocks may change in a way that could trap the seeping oils. An impermeable rock layer, perhaps more shale through which water and oil won't flow, might be shifted into place above a stream of migrating oil, curling over it like an overturned soup bowl. Over millions of years, those curved layers (called "anticlines" by geologists) can capture the oil in the porous rock layer below. Natural gas from deeper layers may drift upwards and also become trapped above the oil, along with water migrating amidst the rock.[36]

Sometimes, if there are multiple layers of shale, sandstone, and salt, over and over again, the salt will tend to float upwards, because it is lighter than the other layers above it. The bulging salt layers will push up the sedimentary layers above them, forming a kind of dome. When the shale's oil is squeezed into the sandstone, the dome will bar its further movement. Anticlines formed by salt domes are excellent traps for oil.[37]

However, years of erosion can occasionally wear down the rocks that entomb such oil-filled traps, bringing an entire oilfield to the surface. It happened in Alberta, Canada. All of the light oil and gas quickly dispersed into the air, leaving behind only a tarry, oily sludge—the infamous Alberta tar sands, a dead oilfield to shale's unborn one.[38]

A worthwhile oil reserve, then, must have thick layers of oil-rich source rock, porous reservoir rock, and an impermeable "cap" rock, all in the right position to form a trap, and pressurized and heated to just the right conditions. It is an elaborate sequence of events that takes place over millions of years, enlisting the carcasses of billions of creatures, the rising and falling of seas, and the shifting of tons of rock. All told, earth has given birth to 2 trillion barrels of oil, a labor that appears as improbable as it is quite awesome in scale.

Kenneth Deffeyes is a retired professor of geology from Princeton University, a cheery rotund man who grew up in the oil patch. His fondness for the oil he's spent his life scrutinizing, for Shell, Princeton, and the various oil companies for whom he's consulted, compels him to roll down his car window when he drives by a refinery, in order to take a deep breath. The story of oil's unlikely ancestry appears to fill him with glee. "If any one of these conditions is missing, tough luck. If one of them is only partially developed, you get a small oilfield," he says. "The chances of rolling a seven with the dice six times in a row is rather small!"

"So it does look like accidents on the highway, where you get a lot of little fender benders and a few of these giant pileups with forty cars in it," he goes on. "Well, the Middle East is a giant freeway with a forty-car pileup. It is a place where everything was just right."[39]

Around 180 million years ago, a warm shallow sea washed just above the equator, splitting the single continent that had previously covered the earth into two major subcontinents, Laurasia and Gondwanaland. Ancient reef-building organisms slowly built their wondrous reefs in this sea. It's been named the Tethys, as in the mythical daughter of the Greek god of heaven and the goddess of earth who bore three thousand ocean nymphs and all the river gods.[40] The Tethys sent its warm, equatorial ocean currents and its diversity of shelly and fishy Jurassic and Cretaceous life flowing all the way around the globe.[41] Dolphin-like reptiles and sea-going crocodiles cruised its waters, with forty-foot plesiosaurs as kings of its underworld.

Up on the land, dinosaurs stomped amidst the spiky, pineapple-like cycads. Our ancestors among them, the early mammals, were just tiny vermin, "the cockroaches of their day," as paleontologist Michael Benton put it, although we would claim the Tethys' products of that time as our own, much later.[42]

For more than 100 million years, the Tethys sea floor collected rich layers of sediments, as abandoned shells, plankton, and other organic sediments descended gently on the seabed. Then the seas lapping up on the shore receded, leaving behind a salty crust on top of the organic layers. Sands rushed in and buried the salts. This happened over and over again, leaving thick sequences of source rocks, reservoir rocks, and evaporites. Slowly, the layers began to sink, which compressed them into that essence of ancient life, oil.[43] Those sunken sea-bottoms of the Tethys now contain about two-thirds of the world's oil.[44]

Much of it got trapped in the Middle East. Around 15 million years ago, the sea-floor under the Tethys was consumed into the earth, its sediments scraping up onto the surface. The continents of Arabia and Asia that once lined its shores collided. The impact smashed the land, throwing up the soaring, snow-capped Zagros mountains, which lie in today's southwestern Iran. The southwest side of the mountains was left with a huge depression, the Mesopotamian basin, one of the largest sedimentary basins in the world, where the organic-rich sediments of the now-vanished Tethys came to rest. Meanwhile, the stress of the massive continental smash rippled, folded, and faulted the rock, squeezing the oil out of its deeply buried layers. The oil started to migrate. The long-gone beaches and reefs of the Tethys, buried and turned to sandstone and limestone, sucked up the migrating oils. In some places the salty layers sealed them in salt domes; in others, the stresses folded the sediments, forming huge anticlines that trapped the oil.[45]

With trillions of barrels of crude oil migrating through the twisted crevices in the rocks underfoot, it isn't surprising that some of it managed to find its way to the surface. Some of it would simply vanish, evaporated into thin air. Some would linger, collecting in muddy pools, trickling down cliff faces, or burbling up under rivers, creeks, and seas.[46] Bacteria would feed on the rich hydrocarbons, swirling in black puddles. In tropical seas, bacteria would crowd hungrily around the warm seeps of oil clouding the water, forming mounds later colonized by reef-building creatures.[47]

Newly evolved humans walked out of their ancestral Africa, using the land bridge formed by the crash between Africa and Asia that had swallowed the Tethys, and settled in the fertile valley between the Tigris and Euphrates Rivers. It wasn't long before they found the remains of that ancient rich sea. Its oils were slowly oozing out onto the fertile soils basking in the sun.[48]

The first thing they noticed was the otherworldly sound. Natural gas percolated through the fissures under the ground, sending up a ghostly echo. It sounded to the people above, craning their ears to the earth, like the voices of the gods of the underworld. They found oily pools and gathered some of the strange liquid, divining the future from the shapes that the liquid would make when thrown into water. Soon the stuff was put to more practical use, gummed onto boats and houses to create watertight seals. The seeps were so plentiful that the Mesopotamians were able to dig up over fifty thousand kilograms of solid petroleum sludge. They found some light liquid oil as well, but deemed it useless. Pliny declared it too combustible and therefore "quite unfit for use."[49]

The Persians filled pots and other vessels with a stinky volatile mix of sulfur and crude oil, which they'd set afire and then hurl at their enemies. The ancient Greeks greased their arrows and lances with petroleum to make flaming torches. By the seventh century AD, the Byzantine Empire had perfected a liquid combustible made primarily of boiled petroleum called "Greek Fire," which set hearts trembling throughout the region for centuries.[50] They used the combustible mixture to fend off waves of attacks from Muslims, Western Europeans, and Russians. Soldiers cavorted with long tubes full of crude, which they would light and throw into their enemies' faces. Muslim states used incendiary warfare—weapons made fiery with oil—to fend off Christian invaders.[51]

Tethys' hydrocarbons inspired godliness as well as aggression. In Baku, the ancient Persian city that is now the capital of Azerbaijan, some of the oil escaped with gusts of natural gas and burned continuously. The Persians worshipped those miraculous everlasting fires. The prophet Zoroaster, born in Azerbaijan or Iran more than two thousand years ago, created a new religion based on fire worship, which flourished as the official religion of Persia for over four hundred years. His followers, the Zoroastrians, tended perpetual fires in their temples. When Muslim Arabs conquered Persia in the seventh century, extinguishing the eternal flames, the Zoroastrians fled to India. Today, 270,000 Zoroastrians in India and Iran pray to the sacred fire five times a day, a modern testament to an ancient wonder, pure combustion spurting out of the belly of the earth.[52]

Oil has become so enmeshed in our lives that, like the air we breathe and the ground underfoot, many of us barely notice much about it, aside from a slightly pungent odor at the pump during the weekly five-minute ritual of refueling the car. But oil, as part of our planet, its legacy of life, and its capacity for change, is not something we can so easily separate from our own organic earthbound selves, pouring it into our machines at arm's length, noses held.

The way oil is created, its ancient pedigree, its tortuous journey to the places in the earth where we can find it, its elaborate chemistry—all of this makes it precious. Yet, it has rarely been treated as such. Once we encountered oil, we wallowed in it, consuming crude about one hundred thousand times faster than it could possibly accumulate again.[53]

CHAPTER ONE

The Eclipse of Coal

By the mid-1500s, England's forests were dwindling. People needed to feed their fires and they turned to a strange, fiery black rock that they clawed out of the ground. They didn't know it at the time, but the rich rocks they found were the ancient condensed remains of ferns and other plants that had rotted in swamps eons before: coal. Burning it wasn't a great option. The black coals reminded them of the black swellings of bubonic plague. The smoke made them sick. Extracting coal was time-consuming, dangerous, and inconvenient. The mines held poisonous and explosive gases, and were apt to unexpectedly fill with water. But it was better than the alternative: freezing to death among the denuded hills of England.

And so, coal was dug out of the ground to feed Britain's fires, coating the cities with a thick layer of grime and filling the skies with low-hanging dark clouds. By the 1700s, the coal that ran in shallow veins close to the earth's surface was gone. They'd have to dig deeper to get more, risking even worse flooding and explosions.[1]

Continuing to rely on such a difficult, costly fuel source would be risky, possibly even foolhardy. The amount of energy needed to pump the water out of those deep holes that burrowed beneath the water table might be equal to, or even greater than, the amount of energy that the lumps of coal that came out of the ground could pay back.[2] Yet coal was already a business worth fighting for. Mine-owners calculated that they could still profit from bigger and deeper mines, even if they had to foot the bill for more workers and more machines, as long as they could recoup their investments by selling even more coal.

In other words, the more depleted the coal became, the more trouble it would be to get more out and, at the same time, the more coal they'd have to sell to make it all worthwhile. Yet the topsy-turvy formula worked. By consolidating, hiring more workers, and attracting greater investment, coal mining soon became one of the biggest, most capital-intensive industries in Britain.

In 1712 the steam engine was invented and quickly employed to drain the water out of ever-deeper coal mines. The steam engine, "the most wonderful invention which human ingenuity had yet produced," wrote historians, bestowed "the art of converting fuel into useful power for the benefit and convenience of humanity."[3] The additional coal made accessible by the steam engine was used, in part, to fuel the steam engines and the fires that smelted the iron to make the engines. It was a self-sustaining cycle that allowed both coal production and iron production to intensify, driving the price of both down. Soon, the industrial revolution—that frenzied partnership among iron, steel, and coal—was banging along. Britain, with its huge coal reserves, and its formidable Navy kept honed by accompanying the coal convoys down the English coast, sat at the very top of it.

Coal bestowed power in the eighteenth and nineteenth centuries, but it came at a price. Coal's black smoke was so thick that it could be seen hovering over English cities from miles away, in some cases blocking the sun's rays entirely. Londoners, squinting by their sooty windows, switched on their lamps to read the morning papers. Children toiled in the coal-fired factories, and even worse, in the dank, toxic coal mines themselves. "For watching the doors the smallest children are usually employed," noted economist Friedrich Engels, "who thus pass twelve hours daily, in the dark, alone, sitting usually in damp passages without even having work enough to save them from the stupefying, brutalizing tedium of doing nothing." Children dragged themselves homewards after their long shifts in the mines so tired that many were found, hours later, asleep on the road.[4] Deprived of sunlight, subject to poisoned air and explosions, they died in droves. Most of the poor in mid-nineteenth-century Manchester didn't survive to see their eighteenth birthdays. Those who did aged prematurely. Some of the tragedies that befell coal workers were hidden, for a time, by coal-mine owners who conspired with local newspapers to censor coverage of mine explosions.

Nevertheless, London was affectionately dubbed "The Big Smoke," a smog-shrouded city that Lord Byron romantically described as "a wilderness of steeples peeping on tiptoe through their sea-coal canopy."[5] Painters such as James Abbott McNeill Whistler, Joseph Mallord William Turner, and Claude Monet captured the city's foggy phantasmagoria, and Charles Dickens wrote of coal's "soft, black drizzle." Jack the Ripper stalked his prey under cover of coal's thick brown haze.[6]

Across the Atlantic, a different story was unfolding. People found tons of black coal, but they also found something else, a liquid fuel that would slowly gain in popularity until it overtook coal altogether.

By the 1850s, people in northwestern Pennsylvania had noticed the black grease floating on top of their creeks and springs. Skimming it off the top, or soaking their rags in the oily waters, they used the liquid for the first thing that would come to mind in those rough days: to try to ward off the bewildering array of illnesses that plagued them. At the time, cholera, yellow fever, influenza, and smallpox epidemics ravaged the North American populace. Some entrepreneurial types started selling the oil under the name "Seneca Oil," as a cure for worms, deafness, toothaches, and dropsy.

When set alight, oil's long chains of carbon split apart, releasing the energy stored in their powerful bonds. Afterwards, oil's hydrogens and carbons pair off with the oxygen in the air, forming carbon dioxide and water.[7] The amount of energy stored in a gallon of oil is equal to the amount in almost five kilograms of the best coal, or more than ten kilograms of wood or more than fifty well-fed human slaves toiling the day away.[8] Oil contained so much energy that it could be used with abandon and still release much more energy than was required to get it out of the ground.

The men in Pennsylvania had a better idea than time-consuming hand-digging for this miraculous new liquid. They would drill an oil well, just as they had drilled wells for water and salt. First they'd find the oil seeps in creeks and hills and then they'd stab the earth nearby to get more out. In the famous story, in 1859 Edwin L. Drake, a former railroad conductor, drilled a hole on a farm where seeping oil was collected; at sixty-nine feet, the hole started, incredibly, to fill with dark fluid.

Explorers of all ilks criss-crossed the globe, hunting for the telltale leaks that might produce riches when tapped. On the other side of the ocean, Russians drilled the seeps whose eternal fires had so entranced the Persians. They shipped the oil from Baku in tankers—the first was called the *Zoroaster*—across the Caspian Sea. Around Baku, the smoke from the two hundred refineries that distilled the oil was so dense that the area was known as "Black Town." Russia's dirty oil started filling lamps across Asia, along with oil extracted from dripping rocks in Indonesia by Royal Dutch Shell. Entrepreneurs with dollar signs dancing in their eyes braved the hostile lands and people of Persia to drill along oil seeps there.[9]

By 1862, drilling near known oil seeps in Pennsylvania was bringing up 3 million barrels annually. They called it oil "production," a funny term given that they weren't "producing" anything, but taking something the earth had made countless years before humans had evolved. It took just thirty years for sixteen thousand farmers, entrepreneurs, and speculators to drain Pennsylvania's oil, by piercing the earth in as many places as they could and siphoning the oil out as fast as was then technically possible. When the oil wells abruptly ran dry, it was like a plague had fallen upon the nearby towns that had mushroomed around the wells. Having no idea how much oil there was underground or where it came from, they hadn't seen the end coming.

Unlike coal, which could essentially be thrown into a fire pit as soon as it came out of the ground, crude oil required energy-intensive processing in order to be truly useful. The oil that bubbled out of the ground was a messy mix of thousands of different kinds of hydrocarbons, the mushed remains of the cell walls of ancient algae, in various states of pressurized decay. There'd be some long chains of carbon, with seventy or more carbons linked together, as well as light gas, tiny little hydrocarbons with just four carbons linked together, and everything in between besides. The mix would vary from crude to crude, depending, in part, on how deeply buried the oil had been.

The different hydrocarbons in crude oil all burned at different temperatures, which was a problem when trying to harness the energy of their explosive combustion. The various fractions would have to be distilled into their various pure components, so that machines could be tailormade to specific types of hydrocarbons. To do it, refiners would essentially boil the crude.

As the crude gets hotter, different fractions reach their varying boiling points and turn into gas. At room temperature, the methane immediately evaporates. At more than 100 degrees Fahrenheit, the 8-carbon-chains—octane or gasoline—turn to gas and drift off. At around 500 degrees, the 16-carbon-chains, the diesel, evaporate. At over 1,000 degrees, even the tarry 80-carbon-chains, the coke, start to stew. In modern refineries, each constituent is lovingly captured, as its vapors rise in giant steel towers, cooling as they float higher and higher.[10]

But in the nineteenth century, there was only one fraction that was deemed useful. That fraction was kerosene, which was used to illuminate the nineteenth-century night, marking a considerable improvement over scarce sperm whale oil and the flammable turpentine people poured into their smoky lamps.[11] American refiners distilled as much kerosene as they could; like Pliny, they considered gasoline worse than useless because it was so volatile.[12]

John D. Rockefeller, a stern, pious entrepreneur from New York, built his fortune on the market for kerosene. Rockefeller considered his task in almost spiritual terms, delivering light to a world of darkness. "Give the poor man his cheap light, gentlemen," he told his colleagues.[13] But in reality it was big business, and hugely lucrative. Rockefeller made it so with his merciless quest to expand his oil empire and dominate markets. He deployed secret front companies to underprice competitors, forcing them out of business. He controlled the means of transporting the precious fluid, extracting deep discounts from the railroads for train transport of his oil. The company countered the inevitable public outcry with clever deceits. "We should . . . parry every question with answers which while perfectly truthful are evasive of bottom facts," proclaimed one executive.[14]

Then, in the early hours of October 21, 1879, a sleepless Thomas Edison watched blearily as an electric current zapped through a glass globe in his New Jersey laboratory. Emitting a dim reddish glow, the world's first incandescent light bulb had been invented, and the electric power industry crackled to life.[15]

Society's desire for kerosene rapidly dissipated in the face of the new light. Yet Rockefeller and the other oil barons were swimming in oil. With the Pennsylvania fields wasted, the nascent American oil industry had moved on to Ohio and Indiana in the mid-1880s, where oil had also been dribbling out of the ground. A new market had to be found, and fast.[16]

The railroads forged in the heat of the Industrial Revolution, ferrying coal, steel, and people, coupled with horse-drawn carriages, defined transportation in the nineteenth century. Both required sizable inputs of energy to power their motion. Rail transport required tons of steel and sweat to build the trains and the rails, and then coal and humans to power and maneuver them along the tracks. Animal-powered carriages required less energy input, just room and board for the creatures and materials to build the carriages, but were likewise less powerful and more limited in terms of range and utility. The ratio of the amount of energy put into the system versus the amount of energy released was, in other words, stubbornly constant.

In 1860, a small contraption that could radically increase the ratio of energy input to output had been invented: the bicycle. This compact simple machine could make human motion almost four times more powerful, catapulting an hour's exertion from a three-mile slog into a twelve-mile sojourn. It required little maintenance and its humble materials could repay their energy investment handily. Unlike the train, which relied on mountains of coal, and the carriages, exploiting animal metabolism, the bicycle was small-scale, human-powered, and efficient. (This is true even by today's standards. Modern trains require 210 kilocalories of energy to move a single person a mile forward. A bicycle can do it with just 20 kilocalories, the amount of fuel in a bite of banana.)[17]

The bicycle had quickly taken the world by storm. "Thousands of riders acquired a taste for speedy mechanical road transport," wrote car historians Jean-Pierre Bardou and Jean-Jacques Chanaron. It was a completely new way to move, because unlike the trains, which only traveled at certain times, and to and from certain places, bicycles could take their riders virtually anywhere and were "entirely under their own control."[18]

Perhaps it was inevitable, with trains steaming about and bicyclists sweating over their handlebars, that the two forms of transport would eventually merge. In 1886, four years after the invention of the light bulb had pulled the kerosene market out from under the wobbling oil barons, German engineer Karl Benz attached a motor to a tricycle. Inspired, two American bicycle mechanics designed their own motorized vehicle in 1893, a gasoline-burning automobile.

The new inventions didn't exactly overwhelm train-horse-and-bike society. Three years later, the bike mechanics hadn't sold even a dozen of the autos.[19] The *New York Times* was not impressed. In the January 3, 1899, edition, they wrote:

> There is something uncanny about these newfangled vehicles. They are unutterably ugly and never a one of them has been provided with a good or even an endurable name. The French, who are usually orthodox in their etymology, if in nothing else, have evolved "automobile," which being half Greek and half Latin is so near indecent that we print it with hesitation.[20]

Besides being ugly and indecent, cars weren't very efficient at transporting people. Even today's cars require three times more energy than trains and thirty times more energy than bicycles to transport people a given distance.

But cars could be fast, and what's more, unlike the coal-powered trains, cars needed oil to speed along. Coal might compete with oil on some applications (after all, coal was much more abundant) but for this one, oil definitively trumped coal.[21] Coal was bulky and its energy was given off too slowly for machines that would need to be turned on and off quickly.

By 1900, Americans had built four thousand of the new gasoline vehicles, holding automobile races and other events to entice the public.[22] The fluid needed to propel the new machines continued to turn up in new and unsuspected regions. In 1901, an amazed public learned that essentially by chance, the premonition of a one-armed mechanic, oil had been struck under a salt dome in Texas, gushing out of the ground under its own pressure in a column twice as high as the derrick. Geologists and explorers renewed their hunt, this time looking for salt domes over which to position their drill-bits.[23]

With oil flowing so profusely, it wasn't long before American car production surpassed Europe's—the birthplace of the bicycle and the motorized trike—churning out forty-four thousand cars in 1907.[24] In 1909, automaker Henry Ford announced he would "build a motor car for the great multitude,"[25] and it was only a year later, with Ford's affordable Model T's zipping off the assembly lines, that gasoline sales surpassed those of kerosene.

These new vehicles would go on to conquer the pedestrian, the bicyclist, and the railways themselves, paving over their rights-of-way with smooth asphalt for their immense engines, creating a thirsty new market for the oil industry in the process. Bicycle paths, like those linking Pasadena to Los Angeles, were abandoned half-built, as investors fled from the two-wheeled future they had earlier envisioned.[26]

The oil empire that Rockefeller founded, based on secrecy, consolidation, and market dominance, had found its *raison d'etre.* Although Rockefeller's Standard Oil monopoly was beheaded in 1909, fed on a fatty diet of gasoline sales, Standard's subsidiaries would slowly regenerate into the gigantic uber-companies from which they sprang.[27]

Britain had taken the plunge and converted its warships from coal to oil in 1912, even though the country itself had coal reserves but no known sources for oil.[28] It was like switching to an all-fruit diet while sailing the Arctic seas; they knew they'd have to take the stuff from someone else's country, and they already knew where: Iran. The British government had bought into a new British company, Anglo-Persian Oil, today known as the more familiar BP. The company had struck oil in Iran and the crown took it upon itself to protect BP's access to Persia's abundant hydrocarbons.[29]

Across the Atlantic, motorized warfare was off to an inauspicious start. In 1916, General John Pershing enlisted two thousand of the newfangled vehicles to travel two hundred miles into Mexico to hunt down revolutionary leader Pancho Villa. But so undeveloped were the roads and untested were the new machines that "at the end of the campaign," writes highway historian Lee Mertz, "all two thousand vehicles lay strewn along the line of march in various states of breakdown."[30]

The following year's military exploits proved no better for the reputation of the automobile. The Americans were preparing to send 2 million soldiers, with their horses and fodder, across the ocean to join in the First World War. But how to get them there? All of those men and animals, spread out over the continent, would have to be amassed on the U.S. east coast in order to board ships across the Atlantic to Europe. That appeared impossible. Desperate, the military decided to try trucks again, despite the troubles during the campaign against Pancho Villa.

The nascent auto industry produced thousands of trucks to carry the soldiers and their equipment to ports on the east coast. Once again, the decrepit roads stymied the effort. Where they existed, the roads were impassable. The dirt paths were swamped in mud and obscured by piles of snow. The new trucks, those pinnacles of oil-industry and car-making technology, couldn't get through. The trucks ended up being loaded onto trains, which carried them to the next section of passable road, while crews worked around the clock to clear snowdrifts.[31]

Still, the Allied forces didn't lose faith in the internal combustion engine and its magic fuel, a faith that turned out to be worth the trouble. Britain and the United States unleashed the fury of their agile, petroleum-burning machines—about 163,000 oil-burning vehicles and 70,000 airplanes—vanquishing Germany's bulky coal-fired ones. Black gold was crowned king. Ten days after Germany surrendered, in November 1918, British statesman Lord George Nathaniel Curzon declared the Allied forces' triumph as petroleum's. "The Allied cause had floated to victory upon a wave of oil," he said.[32]

Back at home, demand for light clear gasoline continued to grow. In 1930, essentially by luck, oil explorers discovered the bountiful oilfields of East Texas. Texan oil flowed from a geological formation, at the time unexpected to hold crude: an "angular unconformity." As jubilant oil hunters fanned out searching for more, General Motors, Standard Oil and Firestone banded together to take over the nation's streetcar companies. Between the world wars, only about one in ten Americans owned a car, as most urban residents traveled by electric streetcar, which whisked commuters along their steel tracks leaving just the bumpy margins of the roads for automobiles.[33] As Texas's oil spilled forth, the companies boldly attempted to force consumers to opt for gasoline-burning cars instead, curtailing electric trolley services and replacing them with unpopular diesel-burning buses.[34]

Meanwhile, chemists were beginning to unlock the mysteries of a small but popular set of natural and semisynthetic materials called "plastics," from the Greek word "plastikos," meaning "able to be molded."[35] These elastic substances derived from all kinds of unlikely sources—amber, horn, wax, bitumen, shellac (from the secretion of the lac beetle), and gutta percha—and their unusual properties made them uniquely useful. Gutta percha, a dark-brown material from the Malaysian palaquium tree, was used for sheathing the first submarine telegraph cable. Shiny hard buttons could be made from casein, a paste of milk curds mixed with formaldehyde. Flexible but firm tires could be made from rubber trees, grown in plantations in Southeast Asia, and mixed with sulfur to form "vulcanized rubber." Celluloid, cellulose from cotton mixed with vegetable oil into a dough that could be molded into shapes or pressed into thin sheets, was used to capture early photographs and to form into billiard balls, replacing earlier ones made of elephant tusk ivory.[36]

At first, chemists thought these jelly-like compounds were actually a multitude of small molecules somehow held together. But then the truth came out: these elastic materials consisted of single molecules of unheard-of lengths. Some could have hundreds of thousands of atoms strung together in long flexible chains.[37]

With this insight, chemists set about building similar molecules, cracking, reforming, linking, and de-linking carbon chains, much as refiners did. The best compounds they came up with indeed were extremely malleable. Some could even be melted, molded, hardened into shape, and then melted and molded again. They could be stretched out in thin sheer sheets, cut into slivery threads and woven into fabrics, or shaped into poles and platforms to build furniture. The new synthetic plastics didn't *have* to be made out of oil—coal, alcohol, or natural gas could all be changed into the necessary building blocks—but with the gush of byproducts from refineries, oil was the cheapest and easiest option.[38]

In 1940, *Popular Mechanics* magazine predicted that "the American of tomorrow" would be "clothed in plastics from head to foot . . . will live in a plastics house, drive a plastics auto and fly in a plastics airplane."[39] The Second World War would help make it so.

By 1941, Japan had taken control of the rubber plantations of Southeast Asia, cutting off the supply of natural rubber to the United States. For American soldiers and pilots fighting in Europe, this meant that a flat tire had become a death sentence. The U.S. government pumped over $3 billion into the fledgling petrochemicals industry, demanding a ramped-up supply of synthetic rubber, along with whatever other goodies the industry could devise. With a river of byproducts streaming out of the oil refineries—themselves working in overdrive to provide fuels for the war effort—the petrochemists outfitted soldiers not just with synthetic rubber tires, but with nylon parachutes, synthetic rubber life rafts, plexiglas airplane windows, and plastic raincoats. Other crude byproducts, such as naphtha and methane, were blasted into nitrogen ammonia for explosives.[40]

Out on the battlefield, oil's essential role in powering the machines of war was undisputed. Military leaders took aim at the veins and capillaries of the enemy's oil supply. Allied submarines targeted Japanese oil tankers, crippling the oil lifeline to that oil-poor country. Allied torpedoes sent over 2 million tons worth of Japanese warships and oil tankers to the bottom of the South Pacific. The sunken oil might threaten delicate coral reefs and fishing grounds many decades later, but it wouldn't power the Japanese war machine.[41] "Toward the end," commented one Japanese captain, "we were fairly certain a tanker would be sunk shortly after departing from port." By the first quarter of 1945, not a single drop of imported oil reached Japanese shores, and the Japanese started building their naval ships to burn labor-intensive coal instead.[42]

When the war was over, the U.S. government sold its chemicals plants back to the oil and petrochemicals industry for a fraction of their cost. Exxon nabbed a $2 million petrochemicals plant for a mere $325,000. Monsanto acquired one that cost over $19 million for $10 million. DuPont got a $38 million facility for $13 million. Off to a running start, refineries and petrochemicals companies "were now ready to supply copious amounts of petrochemicals," writes historian Peter H. Spitz, serving "pent-up consumer demand for products that could be made from these materials."[43]

The United States, with seemingly plentiful oil in Texas, Oklahoma, California, and elsewhere, had little need, at first, to plunder foreign lands for its black gold. But many fields were rapidly exhausted as the Second World War exerted its heavy demands on the industry. The technology that would allow the industry to sniff out deeper, more hidden oil reservoirs had yet to be developed. By the end of 1943, Secretary of the Interior Harold Ickes was sure the United States stood on the brink of an oil famine. "If there should be a World War III it would have to be fought with someone else's petroleum, because the United States wouldn't have it," he wrote, warning that "America's crown, symbolizing supremacy as the oil empire of the world, is sliding down over one eye."

Ickes insisted that "we should have available oil in different parts of the world," and "the time to get going is now." No matter how generous domestic oil reserves may have been, controlling the giant foreign oilfields that other countries would have to rely on could only elevate the United States' strategic power. After all, with more and more sectors of the economy reliant on oil, military prowess dependent on its riches, and popular support contingent upon a growing economy, securing access to oil was crucial to maintaining power. In 1944, then-President Roosevelt staked America's claim to the Middle East's oil. Arrangements were duly made with the British. "Roosevelt showed the [British] ambassador a rough sketch he had made of the Middle East. Persian oil, he told the ambassador, is yours. We share the oil of Iraq and Kuwait. As for Saudi Arabian oil, it's ours," as historian Daniel Yergin described the exchange.[44]

Elites in Western countries had been helping themselves to slaves, silk, spices, and other goods from less powerful regions of the world for centuries, from the Niger Delta to the Indian subcontinent. Oil would be no different.

In 1946, a Justice Department investigation found General Motors, Standard, Firestone and other oil, auto, and rubber companies guilty of attempting to control public transportation. But the miniscule fines levied against the auto and oil industries were nothing compared to the grand upheaval they had effected. By the 1950s, the electric trolley system of public transportation had been effectively dismantled. The abandoned trolleys rusted in Los Angeles' vacant lots, where homeless scavengers turned them into impromptu shelters. Commuters would have to either take the bus or buy a car.[45]

While the oil industry was swept up with increased demand, basking in its ability to create ever more products and dominate a wide variety of markets, the coal industry was mired in conflict. Exploited coal miners had been rising up in anguish. Between 1929 and 1954, the U.S. coal mining industry lost 5 million worker-days to strikes every single year. And for every interruption in the coal supply, fed-up factory managers would invest in the switch to reliable oil.[46]

The black environs of London, the coal capital of the world, had become murderous. Although the moths could perhaps adapt—the peppered moth famously turned black so it could blend in with London's dark, lichen-stripped trees[47]—the people, increasingly, could not. On December 4, 1952, the wind sweeping through London died down and a warm humid layer of air descended on the city. The 1,000 tons of smoke particles, 2,000 tons of carbon dioxide, 140 tons of hydrochloric acid, and 370 tons of sulfur dioxide that Londoners' coal fires had pumped into the air that day were trapped over the city. Five still, windless days followed, and the stagnant 30-kilometer cloud of smog smothering the city turned amber, then green, then brown, and finally black. The sulfur dioxide reacted with sooty water droplets in the air to form a soup as acidic as battery acid, which scraped Londoners' throats, unleashing a torrent of mucous and inflammation. Many didn't make it to the overflowing hospitals, but collapsed in the street, blinded by the black fog. Fifty corpses littered a single city park, and the undertakers started to run out of caskets. When the smog finally lifted a week later, over 4,000 had perished.[48]

Before the war, coal accounted for about half of U.S. energy use; by 1955, it was responsible for less than a third. By 1956, even the city of London banned coal fires.[49]

It took less than a century for oil to eclipse coal, following the arc of oil-rich America's eclipse of coal-rich Britain. It wasn't just that oil was so powerful and versatile it could be used for everything from lighting lamps and powering vehicles to making clothes. It was also that the riches that could be earned by its extraction triggered intense competition between profit-seeking companies. The more precious oil became, because of geological depletion or because access to its reserves was cut off, the farther the industry's operations would reach, and the hungrier these big companies would be for sales to sustain themselves. And so, oil companies penetrated one market after another, in some cases endeavoring to manufacture new markets, helped all along by the nations whom their black gold showered with war-making prowess.

Coal continued to be burned, of course: over a billion tons of it in 2001 America alone, mostly for electricity. But it would no longer be smoking away in front of people's faces. Instead of hundreds of thousands of little fires, the industry would burn a handful of gigantic bonfires, transforming coal's dirty energy into likable electrons before piping it into people's homes. During the coal era, the typical American family would shovel about three hundred pounds of coal into their stoves every week. Now the stuff they would pump into their machines would be fluid.[50]