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WHAT IS ENERGY, ANYWAY? (pp. 16-17)

We can usefully divide the universe into two categories: stuff, and the ability to make the stuff do something. You might call these “matter” and “energy.” Albert Einstein is famous in part because he showed that matter, or mass, and energy are really the same thing—wind up an old-style alarm clock and you have made the spring a tiny, tiny, tiny bit more massive, and the extra mass will be turned to energy to move the clock’s hands and make the ticktocks over the next day.8 Blow up an atomic bomb, and although you would have difficulty measuring the amount of mass lost, you will easily see the energetic effects of that loss. For most ordinary purposes, though, it is sufficient to treat mass and energy separately.

If you put the right chemicals together in the right pattern, you can make a diamond that looks pretty and scratches things really well, or a hammer that can break things. Use the hammer to break the diamond into tiny bits, toss the dust out the window, and the diamond is no longer useful to you. The stuff is still there—mass is conserved, as the physicists say—but you have to gather the mass in the right way to make it valuable.

Energy is much the same. If you store a lot of energy where you want it, you can use it to make the stuff do what you want. Put a lot of heat energy in a small place, and you can cook a turkey. Or you can let the heat drive the expansion of gases to drive a piston to drive a car to drive you across the country to visit grandma for a turkey dinner. When you are done, the energy is not gone, but it is spread out—you heated the room while cooking the turkey, and then the heat from the warmer room spread out into the outdoors and eventually was radiated to space. Once the heat energy is too spread out, you can’t use it. Just like the dust from your broken diamond, the energy exists but it isn’t valuable any more.

THE GREAT PENNSYLVANIA DESERT (pp. 24-30)

I live in Pennsylvania—Penn’s Woods. I am fortunate to teach at a great university, Penn State. After class, our students walk off campus into a town that is younger than the university. The university was founded in 1855 far from any city, up the hill from an iron furnace. That furnace still guards the main road out of town. Of the thousands of people who pass each day, I suspect few even notice the furnace and fewer realize that they are there because of the furnace.

Much of the infrastructure of the U.S. East Coast in the early 1800s was built of Juniata iron, which was mined, smelted, and forged in and near the valley of the Juniata River in central Pennsylvania. Beginning in the late 1700s, entrepreneurs converted the rusty soils of the region into pig iron, which was then forged into other useful items. Place names such as Pennsylvania Furnace, Lucy Furnace, Harmony Forge, and the older and more easterly Valley Forge of Revolutionary War fame testify to the influence of the iron industry. Iron-making grew in central Penn-sylvania because the region offered the iron-rich deposits, limestone, water power, and timber needed for iron manufacture in those days.

Later, use of coal allowed the iron industry to focus in a few places such as Pittsburgh, but the iron-making of the Juniata Valley was done in widely scattered furnaces fueled by charcoal. The making of the char-coal is a fascinating chapter in history, oddly romantic now but decidedly not romantic to the people who did it.

A single iron furnace needed about six hundred bushels of charcoal per day to operate.7 As many as one hundred men and boys worked, mainly in the autumn and winter, to cut the wood for this charcoal. Wood was cut into four-foot lengths, and anything thicker than about six inches had to be split to make the conversion to charcoal work bet-ter. The four-foot-long logs (just over one meter) were stacked four feet high in eight-foot-long cords; a good cutter could supply three of these cords in a single day.

After a winter of cutting, the colliers took over, doing the “coaling” to make charcoal during dry times in spring and summer. An experienced collier and assistants would set up a camp on a flat, dry spot near the cut wood, and live there for several weeks while tending the coals. Thirty or more cords of wood would be stacked carefully in a “pile” fifteen feet high and twice that wide. This pile was then covered with dirt and sod, but leaving strategically placed holes and a central vent. Then the pile was burned beneath the dirt for up to two weeks. The dirt cover slowed the supply of oxygen, while the holes let in just enough air so that the fire smoldered rather than going out. Such a smoldering fire heated the wood sufficiently to drive off or burn up its water, oxygen, and other volatile materials. The pile shrank as it lost these materials, so workers were forced to walk around on top and pack the soil cover back down, lest the holes get big enough to let in enough oxygen to burn up the valuable charcoal. These workers surely walked carefully, knowing they were one misstep from plunging into the glowing hot pit. Eventually, after enough of the original wood was lost, the holes in the soil cover were blocked completely, the fire slowly went out, and the charcoal—now almost all carbon—was separated, cooled, and hauled by mule cart to the furnace.

A lot of other activities were going on around the furnace as well, including mining the iron ore and the limestone, “flatting” the charcoal so that there were no big chunks to clog the furnace, charging the furnace, blasting air in to raise the temperature high enough to melt out the iron and allow the impurities to combine with the limestone flux, and eventually producing the valuable “pigs” of iron and a vaguely attractive blue or green glass slag. Anyone walking near one of the old furnaces today, or kayaking a river downstream of a furnace, is still likely to find pieces of the slag. If you’re a history buff, this is a fascinating corner of our heritage.

If you’re not a history buff, why should you care? With the forest yielding roughly 30 cords per acre, and the furnace needing 10,000 to 12,000 cords per year, one furnace required clearing 300 to 400 acres (approximately 150 hectares) per year. The pig iron was then taken to a forge, where conversion to useful wrought iron required almost as much charcoal as went into making the pig iron. Thus, the forged iron production from a furnace accounted for clear-cutting a square mile—640 acres, or 250 hectares—of forest every year. This did not include the wood people used to heat their houses or cook their meals. A well-insulated house in Pennsylvania with an efficient stove might be heated for the winter with three or four cords of wood, so ten houses would require another acre of wood (0.4 hectare) per year for heating; an inefficient open fireplace would consume wood ten times faster.8 Even without considering construction, the rate of tree use was immense.

The remarkable rate of deforestation was recognized even before iron-making was established in the Juniata region. Pennsylvania’s most famous multitasker, the great scientist/diplomat/ publisher/writer/etcetera-er Benjamin Franklin, invented a highly efficient stove, and then set out to make a little money by promoting his invention. He was quick to identify the waste involved in not using his stove.

Franklin discussed the fact that the Swedes, Danes, and Russians conserved wood by burning in stoves rather than

consum’d . . . as we do in great Quantities, by open Fires. By the Help of this saving Invention our Wood may grow as fast as we consume it, and our Posterity may warm themselves at a moderate Rate, without being oblig’d to fetch their Fuel over the Atlantick; as, if Pit-Coal should not be discovered (which is an Uncertainty) they must necessarily do.

We leave it to the Political Arithmetician to compute how much Money will be sav’d to a Country, by its spending two thirds less of Fuel; how much Labour saved in Cutting and Carriage of it; how much more Land may be clear’d for Cultivation; how great the Profit by the additional Quantity of Work done, in those Trades particularly that do not exercise the Body so much, but that the Workfolks are oblig’d to run frequently to the Fire to warm them-selves: And to physicians to say, how much healthier thick-built Towns and Cities will be, now half suffocated with sulphury Smoke, when so much less of that Smoke shall be made, and the Air breath’d by the Inhabitants be consequently so much purer.9

His words, translated into modern English, are being spoken and written routinely today. His concerns about efficiency, saving money, improving the balance of trade, avoiding air pollution, and worrying about the availability of fossil fuels sound remarkably like the concerns of our green-energy entrepreneurs, and his focus on making money for Benjamin Franklin has much in common with the modern mood. We will surely revisit these issues that concerned Dr. Franklin!

Despite his optimistic view, however, the wood did not grow as fast as it was consumed, because the people who were his “posterity” did not consume the wood at a moderate rate—iron-making, heating and cooking for a rapidly growing population, and logging for building material chewed through the forest. John Bartram, friend of Franklin and often called the father of American botany, in his 1743 travels through Pennsylvania and southern New York, noted,

We observed the tops of the trees to be so close to one another for many miles together that there is no seeing which way the clouds drive, nor which way the wind sets; and it seems almost as if the sun had never shone on the ground, since the creation.10

A bit over a century later, Joseph Rothrock, who served at my university (then called the Agricultural College of Pennsylvania) as professor of botany and of human anatomy and physiology before becoming Pennsylvania’s first Commissioner of Forestry, referred to our “forests” as the “Pennsylvania desert”—across vast tracts of our commonwealth, the trees were simply gone.11 With the trees went the vast majority of the “charismatic macrofauna”: the elk we have now were imported from the Rocky Mountains to replace the native stock that was lost, the fishers are imports from New Hampshire and New York, the last known Pennsylvania mountain lion was killed in 1856, the native wolves and bison are gone.12

Don’t for a minute believe that this is somehow a unique issue for Pennsylvanians. The Sung dynasty of China of a thousand years ago produced iron in prodigious quantities, with similar effects on the forest,13 and Europe was a bit ahead of the Americas in doing this as well. In the Sherlock Holmes story “The Adventure of Black Peter,” we read,

Alighting at the small wayside station, we drove for some miles through the remains of widespread woods, which were once part of that great forest which for so long held the Saxon invaders at bay—the impenetrable “weald,” for sixty years the bulwark of Britain. Vast sections of it have been cleared, for this is the seat of the first iron-works of the country, and the trees have been felled to smelt the ore. Now the richer fields of the North have absorbed the trade, and nothing save these ravaged groves and great scars in the earth show the work of the past.14

Pennsylvania, like many other places, now has lots of bears and tur-keys and deer and a wealth of other wildlife because of the efforts of a lot of people, good laws, and game management. But this was made possible by the simple fact that we quit cutting the trees faster than they grew back. Benjamin Franklin in 1744 was concerned about his posterity. The first U.S. Census in 1790 found 484,000 of his posterity, who were busily cutting the trees. Immense deforestation had occurred by the time my university was founded in 1855, when the state population stood at 2.6 million, and Joseph Rothrock was working for 6.3 million people in 1900 as Commissioner of Forestry to heal the Pennsylvania desert. Yet the U.S. census estimated in 2007 that 12.4 million people lived in the largely forested state. Much of the difference is that we found other ways to generate most of our energy and much of our building material.

PEAK WHALE OIL (pp. 30-36)

We were camped in Colorado’s Pike National Forest, west of Pikes Peak, and in the middle of what might politely be termed an “adventure.” The campground was well populated with cars and tents and campers and coolers containing calories, and the two hungry black bears were determined to get their share. At the campsite next to ours, an old cooler with some metal in its walls and a very sturdy latch resisted the bears’ efforts until the larger one finally batted the cooler away—the way it bent around the tree it hit was rather sobering testimony to the strength of a hungry bruin. A few coolers in other campsites yielded more easily, but a bear contemplating a long, cold winter isn’t happy with the food from just a few coolers.

Our group of a dozen more-or-less hardy souls had locked our food in the van, but the bears seemed convinced that they needed to inspect everything, including our tents, just to make sure. So while some of our group slept, the rest of us sat around a small fire and watched for the bears. When two or more eyes gleamed at the edge of the firelight, we tossed a half cup of white gas onto the fire. After a little calibration, we found the right volume to make a fireball big enough to scare the bears and small enough to avoid torching the trees overhead (or us, if we got it wrong). Thereafter, we succeeded in keeping the bears out of our camp, as they focused on cleaning out the campsites of people hiding in their solid vehicles.

We stoked our fire with Coleman fuel thrown from Dixie cups, some-what higher-tech weapons than were available to our ancestors of half a million years ago. But the issues are virtually unchanged—we, or the foods we collected, are of value to big hungry beasts, but our mastery of fire’s light and heat gives us a serious weapon in our effort to avoid supplying someone else’s dinner, one way or another.

Burning trees is great for scaring lions, tigers, and bears, and it pro-vides enough light for a little social interaction or food preparation in a dark winter, but the red and flickering light is hardly appropriate for a pioneer quilter trying to sew twelve even stitches per inch. So our ances-tors put a lot of effort into inventing and using better ways to see at night. By the 1800s in the United States, a homeowner could choose from many light sources. Candles were common, made from various animal fats (tallow), from beeswax, and even from bayberries on Cape Cod and surroundings. However, candlelight was fairly dim, candles were time-consuming to make, and the smell from tallow candles was often quite unpleasant or downright stinky.15

Camphene lamps provided good light from a relatively inexpensive mixture of alcohol and turpentine, but they had a tendency to blow up. For example, an 1853 New York Times article detailed the death of a thirteen-year-old Brooklyn girl after a camphene lamp she was carrying exploded. An 1856 front-page article in the Times described how alert policemen saved a house by rushing inside and tossing into the street a camphene lamp that had exploded, and the stove that the panicked residents had knocked over while running outside to escape the original explosion. In 1854, the Times reprinted a story from the Frankfurt, Kenucky, Commonwealth describing the horrible death of three daughters of a Methodist preacher in a camphene-lamp explosion.16

Various oils have long been burned in lamps, including oils extracted from plants, animals, and seeping petroleum. Olive oil is mentioned in the Hebrew Bible in Exodus and figures prominently thereafter; a long-burning drop of olive oil in the temple led to the celebration of Hanuk-kah. Olive oil also appears in the Quran. Olives and oil are so tightly wedded in history that our words “oil” and “olive” share a common origin—“oil” originally came from olives, and only later was the word broadened to include other things such as petroleum.

For northern Europeans, North Americans, and others far from the Mediterranean, however, olive oil was not the best solution because olives don’t grow well in Pennsylvania and colder places. For our more northerly ancestors, whale oil was often the favored illuminator. Whale oil was expensive, but the best whale oils gave a good, clear light with little smoke, little smell, and little danger of explosion.

People were willing to pay extra for whale oil, so other people went to work to get it. Whales were used to supply a host of products, from whalebone stays in corsets to combs, decorative scrimshaw teeth, meat, and more. (The February 22, 1922, issue of the New York Times reported the death of a young Zurich skier who had been stabbed in a fall by one of her whalebone corset stays, and noted that it was the second such accident in Switzerland that winter.)17 But the oil was the centerpiece for the whalers of the 1800s.

Real money and jobs were involved. According to a summary of relevant documents by the New Bedford Whaling Museum in Massachusetts, there were 10,000 seamen on ships in the New Bedford fleet at the peak in 1857.18 In addition, many industries operated onshore to supply the whalers and to process the products returned to shore.

A summary of key data from the 1878 book History of the American Whale Fishery reveals a remarkable history.19 From a very low level, whale-oil production increased past 2.5 million gallons per year around 1820, quintupled to about 12.5 million gallons per year at about 1850, and fell back to 2.5 million gallons per year by 1875. The initial rise in production was accompanied by a fall in price, from a high of about $15 per gallon (in modern dollars as reported in 2007) to a low of about half that, a slow rise, and then a jump to almost $25 per gallon as the first major drop in production occurred. The price then dropped back a bit, but it remained volatile and relatively high to the end of the record. And in the middle of the high-price/falling-production interval, the first modern oil well was drilled, in 1859 in Titusville, Pennsylvania, which is about one hundred miles north of Pittsburgh.

Some people see this history and cheer the working of the free market: as the price rose, alternatives were developed; therefore, the sys-tem works, and we have nothing to worry about in our future. Other people see the oceans being swept free of whales, a tragedy of the com-mons as a few people profited from the natural treasure of the seas and overhunted some whale species nearly to extinction, with the wealthy enjoying what should have been the common good while the poor were burned to death in explosions of the camphene lamps their poverty forced them to use. The reality is somewhat more nuanced than either of these particular morality plays, but both of them have more than a little truth.

The drop in Yankee whaling had multiple causes.20 The U.S. Civil War didn’t help. The South sank many whaling ships during the war. The North sank more, turning old whalers into the “Stone Fleet,” sailing them to Charleston harbor, and scuttling them in the main channels in an attempt to block Confederate shipping. Recovery of whaling following the war was damaged by some big disasters in the Arctic: thirty-three ships were crushed in the ice off Alaska in 1871, and 12 more were lost there in 1876. Insuring a vessel that stood a good chance of sinking on the Arctic grounds didn’t seem like a smart bet. (The whalers were in the Arctic rather than off Cape Cod because, just as in 2010 the oil-well drillers were in the deep waters of the Gulf of Mexico rather than up on shore, the easy-to-get resource had been exhausted.) Whale-oil prices in the late 1800s were below their peak, and the availability of superior fossil-fueled lighting products was increasing. The U.S. whaling fleet slowly faded away, as U.S. capitalists took their investments elsewhere.

Whaling did not die with the U.S. fleet, however. Other nations, especially Norway and also Japan, expanded their whaling. By adopting faster chase boats, cannons firing exploding harpoons, factory ships for whale processing, new target species such as blue whales that were too fast for the old U.S. technologies, and new markets for whale products including margarine and a resurgence in whalebone corsets, whaling continued. Eventually, major depletion of many whale species, and the threat of extinction of some, led to the 1946 International Convention for the Regulation of Whaling, to “provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry.”21 Under the International Whaling Commission, a moratorium was placed on commercial whaling in 1986. Recovery of some of the endangered stocks is underway.

Quite simply, humans burned whales for energy. The ocean didn’t produce whales fast enough to meet our demands. We found alternative energy sources that allowed us to leave some whales in the oceans. But those alternatives were and are primarily fossil fuels. At least in part, we have whales because we use fossil fuels, just as we have trees because we use fossil fuels. The publication Vanity Fair featured an illustration in 1861 showing the “Grand Ball given by the whales in honor of the discovery of the oil wells in Pennsylvania,” with whales in evening dress toasting, “The oil wells of our native land: May they never secede,” and noting, “Oils well that ends well.” The cartoonist for Vanity Fair showed the value of fossil fuels to whales.22

The growth in fossil fuels after we switched from whale oil has been phenomenal. The amount of whale oil produced in the United States during the heyday of whaling, the whole nineteenth century, would fit in about four loads of a really big supertanker. The tens of thousands of men, the hundreds of ships, the decades and centuries of sailing to the ends of the Earth to mine whales from the oceans, the thrills and art and tragedy and suffering, all of it produced an amount of oil in one century that would not supply modern U.S. imports for one day. No one who is paying attention could possibly conceive of going back to the old ways as the fossil fuels run out.23