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Brief History of Our Relationship with Energy

Since the very beginnings of civilization, humans used energy to power their daily activities. The history of humanity runs parallel with the history of its energy use: as our civilization and population grew, so did our energy usage. Ancient empires fell and gave rise to new ones, and the sources of energy used to power these empires continuously evolved; occasionally, revolutionary advances propelled humanity into a new era. Perhaps the most famous of these shifts was the **Industrial Revolution**, which took place in the second half of the eighteenth century and is associated with James Watt and the introduction of the coal-powered steam engine. However, Industrial Revolution was not the only significant energy transition in human history: many other revolutions preceded and followed it. History of energy is thus very much a history of **energy transitions**. In fact, we are presently finding ourselves in the middle of one such transition: as the environmental consequences of high usage of fossil fuels become more and more dramatic, we are seeking to transition away from them toward energy sources with lower carbon dioxide emissions.

Earth, our home, is 4.5 billion years old. Formed by the accretion of the solar nebula – a disc-shaped cloud of gas and dust left over from the formation of Sun – it slowly cooled and eventually became habitable for life. The process of Earth's formation gave rise to some sources of energy that we use today. Geothermal heat, which we will cover in Chapter 24, stems in part from the leftover heat trapped under the Earth's crust in the process of planetary formation. The uranium and thorium nuclear fuels, which we will return to in Chapter 11, are also as old as the Earth itself – they presumably originated in the explosion of a supernova that gave rise to the material that formed our solar system.

Humanoids like modern-day humans showed up very recently in this long planetary history: they first appeared a mere 2 million years ago in eastern Africa. If the entire 4.5-billion-year history of our planet was condensed into a 24-hour time span, humans would have emerged slightly after 11:59 p.m.! From there, they spread through the remainder of the African continent, and later – through the modern-day Arabian Peninsula – into Eurasia. America was reached last, via the then-frozen Bering land bridge to northeastern Asia, possibly as late as 20 000 BCE.

For a very long period of our history, our ancestors powered all their daily activities using only the energy provided by their muscles. This energy in turn came from digested food. The first major change in this energy consumption pattern – and consequently human civilization – came approx. 500 000 years ago, when our prehistoric ancestors learned to

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control fire. Wood-burning fires allowed them to cook meat and increase their caloric intake, to keep warm during cold spells and at night, and to ultimately manufacture simple tools. With the subsequent domestication of first crops – grains and peas – humans could move away from the hunter-gatherer lifestyle and form more permanent settlements, but also needed more energy to cultivate crops. Most of this energy was provided by the Sun, and some came from human muscles pulling the plows.

The next big jump in our energy consumption came with the **domestication of animals** to be used for work (Figure 1.1). Oxen were domesticated first around 9000 BCE in India and the Middle East. Donkeys (5000 BCE, Egypt), horses (4000 BCE, in Eurasian steppes), and camels (around 3000 BCE, in Somalia and southern Arabia) followed. All these animals were stronger than humans and their usage translated into faster, deeper plowing and higher yields per unit of area. In this early era, domesticated animals were not used as a source of meat nearly as much as they are today – they were too valuable to be simply eaten. Instead, they were needed for labor, milk, cow dung (which was used as fuel), and their hides. Increased use of farm animals allowed the production of more food, increasing human population. More humans required more crops to be grown, which led to further increases in the need for domesticated animals, which in turn needed to be fed too – soon creating a virtuous circle.

The next significant benchmark was the use of wind energy to power transportation, in the form of **sailing ships**. First sailing ships have been documented in Egypt and Phoenicia (present-day coastal Lebanon) around 4000 BCE. These were also the vessels

Figure 1.1 Early prehistoric depictions of ancestors of domesticated horses, found in a cave near Lascaux, France. Domestication of horses and other farm animals helped our ancestors cultivate fields and transport goods. Source: Patrick Janicek, licensed under the Creative Commons Attribution 2.0 Generic license.

capable of transporting many people and significant amounts of cargo, allowing trade and warfare across the Mediterranean. Sailing ships persisted as an important form of transportation until the nineteenth century and were quite efficient in their usage of wind energy – comparable and occasionally better than the modern-day wind turbines. It was this form of energy that allowed the creation of colonial empires and the transfer of goods from one side of the world to the other: the very first seeds of **globalization** (Figure 1.2). Wind also brought Europeans in contact with advanced kingdoms in parts of the world previously unknown to them: Aztecs, Mayas, and Incas in the Americas, or Kongo and Zimbabwe in Africa, to name just a few. Conflicts soon ensued, almost uniformly ending with European military conquests of these nations and ushering in the age of colonial expansion. Wind energy continued to be used on land as well, to power windmills and to pump water.

Pause here for a minute and reflect on the fact that the vast Roman, Mongol, and Spanish empires were built on just three sources of energy: wood, domesticated animals, and wind! All three of them were what we today call **renewable sources of energy**, even though most of the forests cut down in those days were not actively replenished. It was another empire – the British empire – that required a new source of energy. As population growth, industrialization, and maritime trade started significantly depleting British forests, coal became a useful and apparently inexhaustible alternative to wood. The steam engine, made practical in the 1770s by James Watt, accelerated the ascension of coal, a **fossil fuel**, into Britain's most significant energy source. Combustion of coal in the steam engine produced pressurized steam, which could be used to mechanically move pistons of

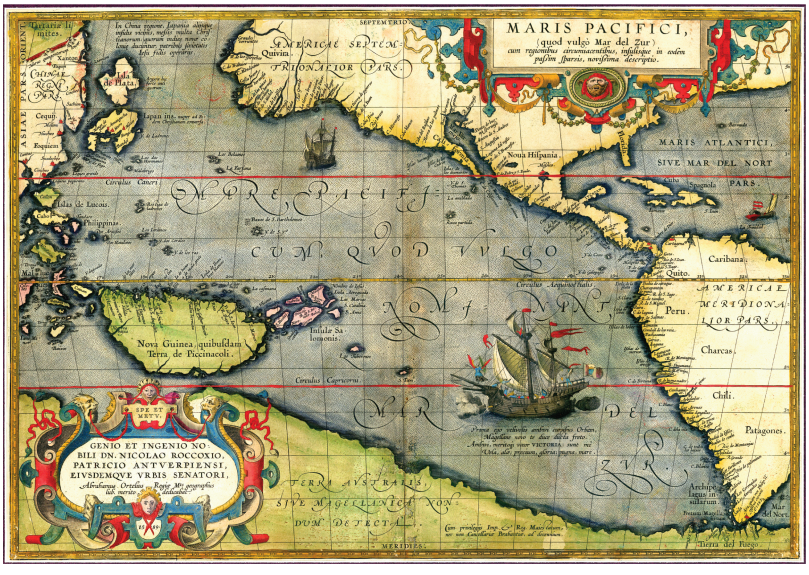

Figure 1.2 Portuguese explorer Ferdinand Magellan (c. 1480–1521) was the first to circumnavigate the globe in the years before his death. Wind-powered *Victoria*, featuring prominently in this map of the world, was the sole ship of his expedition to complete the journey, opening a new era of colonial expansion of Portugal and other western European powers. Source: Ortelius's map (1590), in public domain because of its age.

Figure 1.3 Coal-powered trains are one of the enduring images of industrialization. Today, however, they are increasingly a tourist attraction: even trains transporting coal to power plants run on – diesel. Source: Pixabay.

an engine. The development of railways followed shortly (Figure 1.3), leading to the creation of an internal transportation infrastructure that could move people and cargo on land. The abundance of coal in Britain allowed the country to become the first true industrial power in the world, spreading its economic and military influence across the globe. However, the mining, transportation, and combustion of coal brought with it the pollution, which was significantly worse than that coming from wood. The beginnings of the Industrial Revolution in Britain were associated with the first concerns about the environmental effects of high energy use.

The beginning of the twentieth century brought two significant advances into the world of energy. First, in the early 1900s, the inventions of Tesla, Westinghouse, and Edison allowed the production and commercial distribution of electricity, opening the way to a myriad of electric appliances we use today. Broad **electrification** became a quick way for countries to industrialize and modernize – a trend that was dramatic in the 1930s' Soviet Union and is currently ongoing in China, India, and many developing countries (Figure 1.4). The second technological leap occurred in 1908, when Henry Ford opened the first production assembly line that mass-produced the now-iconic Ford Model T. While cars existed before Ford, they were expensive, slow to manufacture, and often impractical. The creation of Model T led to a fast increase in the ownership of cars – *individual transportation engines* – and the creation of a complex road infrastructure that we know today. Use of personal automobiles also vastly increased the demand for oil and its light gasoline fraction. Before the advent of the automobile, oil was exploited mostly as a source of lighting fluids: a more reliable and cheaper fuel than the whale oil that dominated the lighting industry before it. The rapid growth in oil consumption accelerated with the creation of airplanes in 1903 and the increased switch to diesel fuel in railway transportation and shipping.

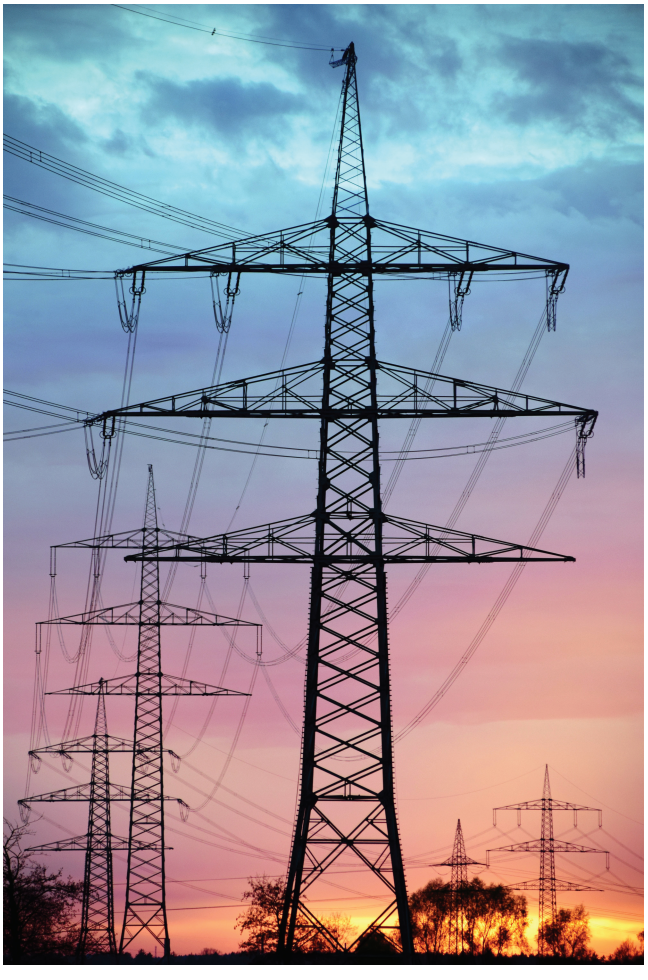

Figure 1.4 Our modern quality of life was largely enabled by the increased use of energy in the form of electricity. Mass electrification begun in the early twentieth century and is still ongoing in some countries. Source: Pixabay.

The middle of the twentieth century saw the development of **nuclear power** – an incredibly concentrated source of energy coming from the atomic nucleus. The first use of nuclear energy was destructive, in the form of the atomic bombs the United States dropped on the Japanese cities of Hiroshima and Nagasaki. However, since the 1950s, nuclear energy was used only peacefully: as a source of electricity that does not generate carbon dioxide and other pollutants. Nevertheless, nuclear energy continues to face strong environmental opposition because of its association with nuclear weapons and the generation of radioactive waste products that must be properly disposed and present a security concern. Additionally, the public worries about the capacity for very rare, but catastrophic accidents, such as the 1986 Chernobyl explosion in the USSR or the 2011 failure of reactors in Fukushima (Japan) because of a tsunami. In the twenty-first century, modern nuclear reactors are again

considered as a viable alternative to fossil-fuel-powered electricity generation plants, as they do not emit greenhouse gases.

In parallel with the expansion and diversification of our energy supply, the last 50 years have witnessed increased awareness among the governments and public about the potential pitfalls of using large amounts of energy, especially that derived from fossil fuels. Prolonged smog (Figure 1.5) episodes in the London of 1950s and 1970s' Los Angeles, as well as the rare but dramatic nuclear accidents have largely been responsible for the increased understanding and concern among the citizens about the consequences of their energy use. Modern environmentalist movements were born, and regulatory responses to pollution crises soon followed. This "age of awareness" brought with it the concepts of recycling, energy conservation, and increased research aimed at large-scale commercialization and installation of alternative energy sources: solar, wind, biomass, and geothermal. These sources of energy are not relying on our finite fossil fuel deposits and are thus called renewable fuels. In addition, they do not emit traditional pollutants responsible for poor air quality, nor carbon dioxide responsible for global warming. The concept of **sustainability** was born. As the human society continues to grow in complexity, population, and economic output, more and more attention is needed to ensure that such development considers and preserves the natural resources: fuels, but also our and our descendants' rights to clean air, water, and soil.

In the early years of the twenty-first century, world's energy landscape is once again undergoing profound changes. Centers of energy consumption and pollution are shifting from the developed to the developing countries, who are trying to avoid the costly mistakes made by the now-developed countries during their industrialization one or two centuries ago. Fuel mixture is changing too: once-dominant coal has been dethroned by the cleaner

Figure 1.5 Smog, shown here in Hong Kong, is one of the many undesirable effects of our massive energy use. Fossil fuels are especially problematic, but even renewable sources of energy can have questionable environmental consequences when deployed on a huge scale. Source: Andrea Piacquadio, via Pexels.

Figure 1.6 Our century is seeing an accelerating shift from using the fuels buried deep within Earth's interior to producing energy from sources that replenish themselves day after day – such as wind, solar, and biomass. Source: Yves Bernardi from Pixabay.

natural gas as the main fuel for electricity generation in the United States. Renewable energy sources (Figure 1.6) are coming down in price and increasing in their market share. And many of these changes are driven by the fear of accelerating climate change, caused by the unrestrained emissions of carbon dioxide into the atmosphere by fossil fuel combustion.

This book will delve deep into the incredibly diverse fields of energy and sustainability. In the first half of it, we will offer the reader a broad perspective of the ways we produce and consume energy today. We will talk about fossil fuels, nuclear energy, and hydroelectric power and will analyze energy consumption patterns in the fields of electricity generation, transport, industry, agriculture, as well as in the residential sector. The second part of the book will discuss the technologies that will become more relevant in the future energy production and consumption patterns. Between the two, we will build a case for the transition between the fuels of the present and the future.

Before all this, we need to learn how to describe, quantify, and measure energy, sustainability, and the related physical quantities.

1.1 Discussion Questions

1.1. Imagine how our energy consumption patterns would look today if there was no oil. What if there was no natural gas? Repeat this analysis, excluding, one by one, all the fuel sources we currently use.

1.2. Find the earliest examples of global efforts that aimed to tackle a problem associated with pollution. Which have succeeded and which have failed?

1.3. Find examples, both old and new, of popular books, songs, or works of art that touch upon energy issues. Are any of them intended for children, or are they only for adults?

1.4. Poll your friends and relatives with some simple energy-related questions. Where does electricity come from? How is it produced? How much carbon dioxide does their car generate? What is carbon dioxide and what does it do to you? Do their answers surprise you?

1.5. Research the closest power plant to the place where you live. Which fuel does it use and what is its generating capacity?

Further Reading

Books

Rhodes, R. (2018). *Energy: A Human History*. New York: Simon & Schuster.
Smil, V. (2018). *Energy and Civilization: A History*. Cambridge: MIT Press.

Websites

History of the Bering Land Bridge Theory. http://www.nps.gov/bela/learn/historyculture/the-bering-land-bridge-theory.htm.
Earliest Evidence for Humans in the Americas. http://www.bbc.com/news/science-environment-53486868.

Movies

David Attenborough: A Life on Our Planet, directed by Jonathan Hughes, Keith Scholey, Alastair Fothergill, and Jonnie Hughes, 2020.