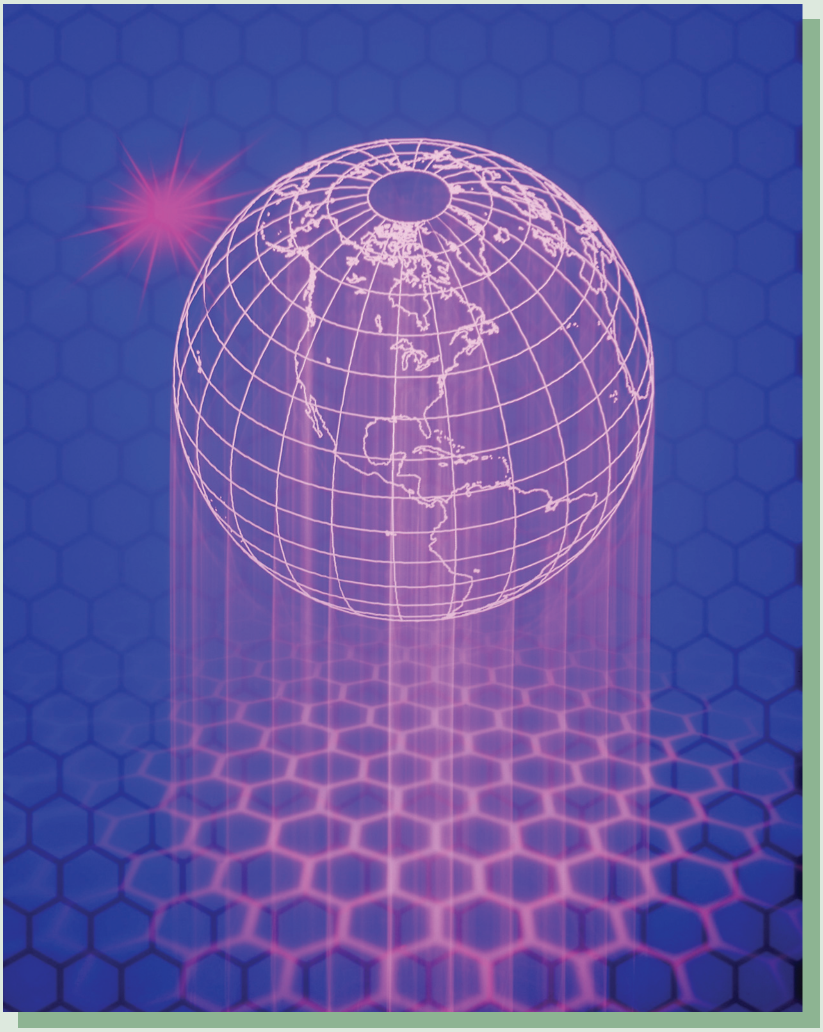
THE BASICS



CHAPTER

1

INTRODUCTION

In 1798, British philosopher, economist, and clergyman Thomas Robert Malthus predicted that human population would outpace food production. Population, he said, expands geometrically (e.g., 1, 2, 4, 8, 16,. . .), while agricultural production grows only arithmetically (e.g., 1, 2, 3, 4, 5,. . .). Ultimately, only disease and starvation could keep the human population in check.[2] Small wonder that economics became known as “the dismal science.”

But the predicted disasters never came. Instead, food and natural resources became more plentiful. Technology so increased human productivity that, in the West at least, food and resources take an ever-smaller portion of family income.

Some argue, however, that Malthus’s predictions were not wrong, just premature. The Earth’s food and energy supplies will eventually run out, they say, unless humanity is first overcome by pollution. In the 1970s, it appeared to many that these dire warnings were finally coming true. Gasoline shortages caused long and frustrating lines at service stations, and tight natural gas supplies disrupted home and business life. The environment was suffering from decades of neglect. Many lakes and rivers were dead or dying, and choking smog was common in major American cities.

Yet, the energy crisis ended by the early 1980s, and within ten years the oil shortage was replaced by an oil glut. Fish returned to rivers and lakes long thought dead. By 2000, the air in Los Angeles no longer burned visitors’ lungs. In Europe and North America, population growth either stopped or declined.

In 2001, however, California experienced rolling blackouts due to a shortage of electric power. At the same time, a potentially dangerous environmental

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[2] Robert Malthus, *An Essay on the Principle of Population as It Affects the Future Improvement of Society* (New York: Random House, 1798, 1960), pp. 9, 13, 17.

threat was in the news—global warming caused by greenhouse gases released by the burning of carbon-based fuels.

Has Malthus finally been vindicated? Are we really running out of energy resources this time? Why did the energy crisis of the 1970s happen, and why did it end? Why did an energy crisis recur in 2001, and why just in California?

Energy is the stuff of life. With it, we can accomplish practically anything; without it, we can do nothing. What happens if we run out? Should we use less now to make the fuel we have last longer? Where can we find more? And even if we find more fuel, what will happen to our climate if we burn it?

Like most other useful things, energy can be misused. Improperly handled, it may be enormously destructive. Whether energy is used for good or ill depends entirely on the knowledge and wisdom of those wielding it. It is vital, therefore, that everyone understands as much about the subject as possible. When it comes to energy, knowledge really *is* power.

WHAT IS ENERGY?

The best definition comes from the science of *physics*. Energy is the capacity to do work. Work is defined as force multiplied by the distance through which it acts.[3] In the United States, work is expressed in units of *foot-pounds*, while in Europe, work is expressed in terms of *newton-meters* (or *joules*). A joule is the amount of work done by a force of one *newton*[4] acting through a distance of one *meter.*

Power is the rate at which work is done, and is calculated by dividing work by the time taken to do the work. The faster the work is done, therefore, the more power is expended. In the United States, power is expressed in units of *foot-pounds per second* and in Europe as *joules per second* (or *watts*). Most Americans are familiar with the term *horsepower,* which is defined as 550 foot-pounds per second.

It is useful to think of energy in terms of work because the whole reason we want to control energy is for the work it can do for us. In fact, the word *energy* comes from the Greek words *en* meaning *in* or *at*, and *ergon* meaning *work*.

Energy is measured in the same units as is work—that is, foot-pounds or joules. However, in the United States, the most common unit of measure is the *British Thermal Unit*, or BTU. A BTU is defined as the amount of energy needed to raise the temperature of one pound of water by one degree Fahrenheit.

One BTU is equal to 778 foot-pounds and to 1,055 joules (see *Appendix E—Units* for more conversion factors).

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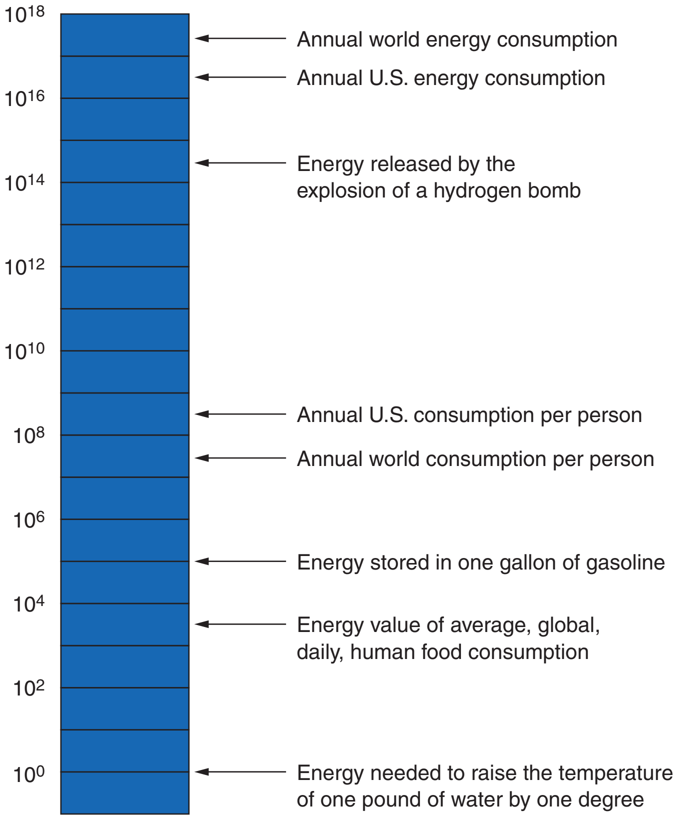
[3] Pushing on an immovable rock may seem like hard work, but to the physicist, no work is done until the rock actually moves.

[4] A *newton* is defined as the force needed to accelerate a one kilogram mass at the rate of one meter per second per second.

The following chart shows the orders of magnitude of energy use as measured in BTUs:[5]



Key:
$10^0 = 1$
$10^1 = 10$
$10^2 = 100$
$10^3 = 1000$
…
$10^{18} = 1{,}000{,}000{,}000{,}000{,}000{,}000$

Notice that this chart does not use a linear scale. That is, each mark along the scale does not represent the same amount. Instead, each mark increases in value by a multiple (or *factor*) of 10. This is called a *logarithmic scale* and is useful for representing very large numbers.

To show the range between 1 BTU and 10^{18} BTU on a linear scale graph, we would need a piece of paper much longer than the distance between the earth and the sun!

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[5] Adapted from Pennsylvania State University's Earth and Mineral Sciences website: www.ems.psu.edu/~radovic/fundamentals2.html

Huge amounts of energy are often measured in *quads*.[6] A quad is one quadrillion BTUs (that is 1,000,000,000,000,000; or 10^{15} BTUs). In 2001, the world used about 400 quads of energy, and the United States used almost a quarter of that amount.[7]

There are other useful ways in which to measure energy. The *kilocalorie* (or one thousand calories) is used to gauge the amount of energy contained in food. Typically, however, the word "Calorie" (with a capital "C") is commonly used instead of kilocalorie (abbreviated "kcal") when referring to food.

One thousand Calories (or one million "small c" calories), the amount of energy you might consume in a large meal, is equal to about 3,968 BTUs. One loaf of whole-wheat bread contains 1,440 Cal., or 5,714 BTUs, while one gallon of gasoline contains 126,000 BTUs. A person would have to eat 22 loaves of bread in order to be able to perform the same amount of work as a car engine running on a single gallon of gasoline.[8]

Another common energy unit is the *kilowatt-hour* used to measure electricity. One-kilowatt-hour is equivalent to 3,413 BTUs. Note that *kilowatts* measure capacity or flow, while *kilowatt-hours* measure quantity; a one-kilowatt electrical generator running for one hour produces one kilowatt-hour of electricity. It takes about one kilowatt of generating capacity to provide electricity to an average American home. The table on the following page shows the level of electrical energy consumption for uses ranging from residential to industrial.

Energy exists in two basic forms:

1. Potential—Energy at rest, waiting to be used
2. Kinetic—Energy in motion

A boulder sitting on the edge of a cliff is said to have *potential energy* by virtue of its position in the Earth's gravitational field. The boulder's potential energy is converted into *kinetic energy* when it is pushed over the edge, and gravity causes it to fall.

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[6] This is especially true when comparing different fuels that may, separately, be measured in tons, barrels, or thousands of cubic feet.

[7] Although it appears from the chart that the U.S. accounts for nearly all of the world's energy consumption, remember that the scale is logarithmic, and for each unit up the scale, the value is increased by a factor of ten.

[8] Actually, an internal combustion engine converts energy into work more efficiently than does the human body. Taking the relative efficiencies into account, a person would have to eat almost 31 loaves to be able to perform the same amount of work that an engine can using one gallon of gasoline.

SCALES OF SELECTED ELECTRICITY USE, UNITED STATES

Use	Approximate Scale (kilowatts)
Portable radio	.0001
Cellular phone	.001
Portable computer	.01
Desktop computer	.1
Home (average)	1-1.5
Commercial customer (average)	10
Supermarket	100
Medium-sized office building	1,000
Medium-to-large factory	1,000-10,000
Largest buildings (peak use)	100,000
Largest industries (peak use)	1,000,000-10,000,000

Adapted from Seth Dunn; *Micropower: The Next Electrical Era*; Worldwatch Paper 151; (Washington: Worldwatch Institute, 2000), p. 32, Table 4.

Other objects that have potential energy are a gallon of gasoline (chemical energy), a stretched rubber band, a compressed spring, and a charged electrical battery. Things having kinetic energy include a moving car (matter in motion), a discharging battery (electrons in motion), sound (air molecules in motion), and a hot stove (atoms in motion).

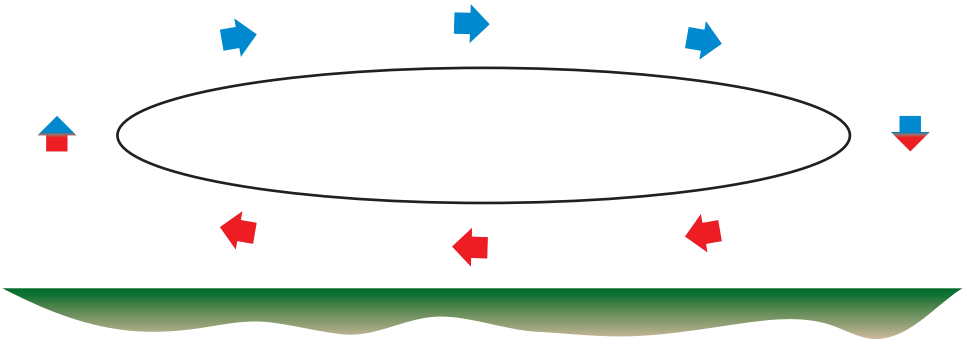
WHERE DOES ENERGY COME FROM?

Most scientists think that it all started with something they call "The Big Bang." According to this theory, all the matter and space that now make up our universe were once compressed into a tiny, though incredibly dense, speck. Somewhere between ten and twenty billion years ago, the speck exploded—the Big Bang. With this tremendous explosion, the universe started an expansion that continues even now. Radiation filled expanding space as did hydrogen and helium gas.

Because the explosion was not perfectly uniform, the gases were not evenly spread out. Around a billion years after the Big Bang, some of the denser areas of gas started to condense into huge clouds. Gravity—the attractive force between matter—caused these clouds to collapse into vast spinning galaxies. Within these galaxies, smaller concentrations of atoms formed. As the density of these concentrations rose, heat was generated inside them. Temperatures increased until thermonuclear reactions were triggered, and stars were born.

Through a process known as *fusion*, stars combine the light elements, hydrogen and helium, into heavier elements such as oxygen, carbon, and iron. These elements are released into the universe when, in Carl Sagan's words, stars end "their lives in brilliant supernova explosions."[9] All of the elements that make up our planet and our own bodies were created in this way. We are, quite literally, made of stardust.

Our own star, the sun, is the source of most of the Earth's energy. The sun's energy comes to us as heat and light, which, in turn, give rise to other forms of energy. For example, the sun's uneven heating of the Earth's atmosphere is one cause of wind.[10] Heated air expands and rises and is replaced by cooler air in a process called *circulation*. Circulation produces wind as is illustrated below:



The ground absorbs the sun's heat, and warms the air above it. The warm air then rises and the cycle begins.

The sun's heat also causes water to evaporate. Water vapor condenses to form clouds and eventually falls back down to the Earth's surface as rain. Rain falling on high elevations and flowing downhill has kinetic energy that can be used to turn water wheels and turbines.

Sunlight provides the energy that plants need to live. Plants use a process called *photosynthesis* to turn sunlight, water, and carbon dioxide into food and oxygen. Nearly all animals live off of plants, either by eating them directly, or by eating other animals that eat them. So the sun indirectly provides the energy that powers our own bodies.

Sunlight also helped create the fuel that heats our homes and powers our machines. Wood and other plant material provided people with ready fuel for

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[9] This quotation, along with the description of the Big Bang, comes from Carl Sagan, *Cosmos* (New York: Random House, 1980), pp. 246–47.

[10] The rotation of the Earth around its axis is another.

hundreds of thousands of years. In addition, all or most of the carbon-based fuels buried in the Earth's crust are probably a result of the sun's light. According to this theory, petroleum and natural gas were formed over millions of years in the oceans that cover most of the Earth. When the tiny plants living in the prehistoric oceans (and the tiny animals that lived off of them) died, their remains drifted down to the muddy ocean floor. There, bacteria caused them to decay. Tiny particles of sand and mud, called sediment, covered the plant and animal matter. As the sediment piled up, the remains were placed under enormous pressure that, in turn, generated heat. Most scientists believe that this combination of bacterial action, heat, and pressure transformed the plant and animal remains into crude oil and natural gas.

Coal was formed in a similar fashion when thick layers of dead plants piled up in swamps and rotted, turning into a substance called *peat* (which is itself used as a fuel in many parts of the world). When layers of sediment covered the peat, the resulting pressure transformed it into coal.

Because peat, coal, tar, bitumen, petroleum, and natural gas are believed to come from long dead plants and animals, they are often called *fossil fuels*.

A few scientists believe that at least some oil and gas may have been formed through nonbiological means. The chief American proponent of this theory is Thomas Gold, the astrophysicist who correctly predicted the existence of pulsars.[11]

At first, most scientists dismissed the idea out of hand, but new evidence has convinced some that nonbiological hydrocarbons do exist.

The theory may explain a number of mysteries, including the existence of hydrocarbons at extreme depths, in nonsedimentary rock, and on other planets.[12] It might also explain why some petroleum reservoirs seem to be refilling. Estimated Middle Eastern reserves, for example, have more than doubled in the last 20 years despite five decades of intense production and few additional discoveries.

If Gold's theory is true, then oil and gas could exist in the Earth's crust in vast amounts and could serve as a primary energy source for millennia.

Nonsolar sources of the Earth's energy include:

- *Tidal energy* caused by the sun's and the moon's gravitational pull.
- *Geothermal energy* produced by radioactive decay deep within the Earth and transmitted to the surface by the hot, molten layer of rock beneath the Earth's crust.
- *Fission*, the *atomic energy* released by the splitting of the nuclei (or cores) of uranium or plutonium atoms.

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[11] Pulsars are rotating neutron stars that emit beams of light and radio waves. These waves are detected as pulses as they sweep over the Earth.

[12] Thomas Gold, *The Deep Hot Biosphere* (New York: Copernicus, 1999).

Corbis

- *Fusion*, the atomic energy released when atoms combine, as occurs in the sun's core.
- *Chemical energy* from *exothermic reactions*. For example, heat is released when potassium and water come into contact.
- *Cosmic radiation* (also called *background radiation*) left over from the Big Bang and from distant stars. The amount of this type of energy that reaches Earth is very small.

A BRIEF HISTORY OF ENERGY

According to Greek mythology, the Titans were giant, immortal beings. Two of the Titans, Prometheus (whose name literally means *forethought*) and his brother Epimetheus (*afterthought*), were tasked with giving different powers to the animals to help them survive. Snakes received venomous fangs, bears enormous strength, and deer great speed. But when man's turn came, no gifts were left. Moved by the helplessness of primitive people, Prometheus stole fire from the gods and gave it to the humans. Zeus, king of the gods, was so angered that he chained the Titan to a mountain, where he remained for thousands of years until Hercules freed him.

Underlying this story is the realization that, unlike animals, man is not well-equipped to adapt to nature. To survive, we must adapt nature to ourselves.[13]

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[13] While humans are, perhaps, the only creatures that consciously *adapt* nature to fit their needs, virtually all living things inadvertently *alter* the environment by virtue of what they eat and emit, and by what eats them. It's a good thing for us that they do. If plants had not changed the atmosphere by producing oxygen, animal life as we know it would be impossible.

> *“Reasonable men adapt themselves to their environment; unreasonable men try to adapt their environment to themselves. Thus, all progress is the result of the efforts of unreasonable men.”*
>
> ***George Bernard Shaw, Irish playwright and writer***

With the story of Prometheus, the Greeks expressed the immense importance of fire in their lives. Indeed, the ancients saw fire as the spark of life and listed it among the four basic elements (earth, fire, water, and air) that they thought made up the universe.

Before fire, people’s only source of power came from their own muscles. Fire brought warmth and light to cold, dark nights. It gave protection against animals far swifter and stronger than any man. The earliest evidence of fire’s use was discovered in China, and dates back about 500,000 years.

Hundreds of thousands of years would pass before the next big leap—the domestication of animals. Evidence from China and southwestern Asia suggests that dogs were tamed there about 12,000 years ago. Sheep, goats, and pigs were domesticated around 8,000 B.C.; cattle in 6,000 B.C.; and horses, donkeys, and water buffalo in 4,000 B.C.[14]

By harnessing the power of the larger animals, people became far more productive. Oxen could plow land deeper and more quickly than a man or woman pushing a stick. Suddenly, more land could be cultivated than ever before and more crops grown on each acre.

With a more adequate and secure food supply, people began settling in one place. This enabled them to create and accumulate new, better, and larger tools (nomadic peoples were limited to what they could carry on their own or their animals’ backs). As a result, advances in energy technology began to appear more quickly. Even so, with the possible exceptions of the sail, the windmill, the waterwheel, and gunpowder, the technology used by the average person did not change much for thousands of years. Romans living at the time of Christ would have easily understood the science of the 16th Century.

It was not until the late 17th Century, with the invention of the steam engine, that technology took off. After that, as the timeline in *Appendix* A shows, the history of energy (and, with it, people’s lives) started changing at a furious pace.

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[14] Jared Diamond, *Guns, Germs, and Steel: The Fates of Human Societies* (New York: W. W. Norton, 1997), p. 167.

ANIMATE ENERGY

Humans and animals were the first controllable sources of work. A horse or ox could do the work of several people, but (by a grim logic) in places where water and arable land were scarce, slaves were preferred because they converted food into work more efficiently than did draft animals.[15] *Source:* U.S. Department of Agriculture.

PATTERNS IN HISTORY

Appendix A reveals a number of important patterns. The first is that the history of energy is really the history of our material development. People build machines to harness energy and magnify their ability to do useful work. This magnification has so increased human productivity that, in the West at least, children no longer must work in order to eat,[16] the elderly can look forward to a secure retirement, and women have been placed on an equal footing with men.[17] As Julian Simon wrote, energy truly is the *master resource*.[18]

Over time, people advanced to more efficient machines and to more efficient, concentrated, portable, and convenient forms of energy—from human muscles, to burning wood, to animal power, to wind and water power. Then, from these sources, humanity moved to whale oil and coal; next to petroleum, natural gas, and nuclear energy. Each advance left people better off and further from the hand-to-mouth existence that had been their lot for hundreds of thousands of years.

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[15] J. R. McNeill, *Something New Under the Sun: An Environmental History of the Twentieth Century World* (New York: W. W. Norton, 2000), pp. 11–12.

[16] Child labor did not begin with the Industrial Revolution. In the centuries before the machine age, one person using a stick for a plow simply could not produce enough food to support a family. Consequently, everyone in the family had to work or face starvation. By increasing the productive power of an individual, the Industrial Revolution created the conditions under which child labor could be outlawed.

[17] Technology makes brains more important than brawn.

[18] Julian Simon, *The Ultimate Resource* (Princeton, NJ: Princeton University Press, 1981), p. 91.

The timeline in *Appendix* A also illustrates the fact that far more discoveries and inventions have occurred in the past two hundred years than in all of the hundreds of thousands of years that went before. Much of this is because as one discovery or invention leads to another, innovation piles upon innovation ever more rapidly.

Yet the great outpouring of creativity during the last two hundred years also coincided with the growth of personal and economic liberty in the world. This should not be surprising because individuals who are free to act and to enjoy the fruits of their actions have a strong incentive to invent things to increase their productivity and wealth. Slaves have no such incentive; creativity dies without freedom.

Most of the advances made in the last two hundred years were made in western countries. It is no coincidence that these countries were also the freest nations in the world during those two centuries. The right of individuals to own and trade property at mutually agreeable prices is essential for the efficient allocation of resources necessary for technological progress and economic growth.

> “*It is not surprising that new products almost always come from the free world and that communist countries, which contain one third of the world’s population, account for only 3 percent of technological innovations.*”[19]
>
> ***Mark Skousen*, 1991**

The last and most important insight arising from the timeline is that people are very inventive. The appendix highlights only a few of the more important discoveries and inventions related to energy; a complete list would fill volumes. Throughout history, people have been faced with difficult problems, and throughout history, they have found solutions. Often, these solutions left them much better off than they were before the problems appeared. Strength is forged in adversity.

While a timeline can be useful for putting history into perspective and for revealing historical patterns, it can also be misleading. Timelines make history appear as if it were a logical progression, with one advancement leading inevitably to another—“The March of Progress.” Yet history is not predetermined; ideas drive history, and not history ideas. Reality is messy, and progress, when it occurs at all, moves in fits and starts. Often great discoveries are ignored, and sometimes inventions are made, forgotten, and then invented again. In 60 A.D.,

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[19] Mark Skousen, *Economics on Trial: Lies, Myths, and Realities* (New York: Irwin, 1991), p. 228.

Hero, a scientist living in Egypt, described the first known steam engine. But no practical use was made of this knowledge until steam engines were reinvented in the late 17th Century.

> “*To know and not to do is the same as not to know.*”
>
> ***Chinese proverb***

But the most misleading thing about the timeline is that it suggests that an invention or discovery just appeared on a certain date in history as if by magic. For example, we learn that the Wright brothers flew the first powered airplane on December 17, 1903. But this bare fact conveys nothing of the years of toil, failure, and ridicule that the brothers endured. Nor does it tell us of the thousands of dreamers and inventors who went before; who—through their knowledge, creativity, sweat, and sometimes even their deaths—helped make that first flight possible. In the words of Sir Isaac Newton, “If I have seen further, it is by standing upon the shoulders of giants.”[20]

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[20] Letter to Robert Hooke, February 5, 1675 or 1676.