Energy: the natural agent of change

Men draw from nature the necessary resources to meet their own needs, which they define according to their current aspirations — which are not always reasonable, but that is a different story. To that end, they need two things: energy and information, the most basic production factors for economic activity.

Energy is the natural agent of change. Simply put, it is everything that can be converted into heat, the "lowest" form of energy. In theory and in practice, energy is inseparable from time. Until the Industrial Revolution, men mainly relied on muscle power: their own and that of the animals they domesticated. Naturally, animal power comes from the energy absorbed mainly as food and transformed by the metabolism process. Men gradually learned to use other natural forces (turning potential energy from gravity into kinetic energy, for example), first by multiplying the effects with phenomena such as the lever, then by using chemical energy in certain situations (heating with wood and, later, coal, biomass, etc.). Scientific advances based on those practical experiences allowed the "mechanical arts" to reach a high level of perfection as early as the Age of Enlightenment.

But the invention of the steam engine is what set the great technological revolution in motion, constantly rekindled by other, no less considerable discoveries, often associated with new forms of energy, including a wider range of fossil fuels (oil and natural gas), electricity, nuclear power, etc. Like financial assets, energy takes many imperfectly interchangeable forms. Entropy (i.e. the phenomenon by which all isolated systems evolve towards chaos) — a record of time passing — translates that imperfection, which makes heat the lowest form of energy. For example, animal power results from chemical processes set in motion by feeding them; and electricity can now be generated from the potential energy of water, wind, fossil fuels, atoms and sunlight. Power is hard to store, but swift progress is being made. Breakthroughs in battery technology have brought the reign of the electric car within reach, although arguably not nearly as soon as people may think.

The sun is the ultimate source of every form of energy available on Earth, but the physical processes at work radically diverge depending on how long their cycles are. Fossil fuels are solar energy stored on the scale of geological time. At the opposite end of the spectrum, 21st century solar panels instantly convert sunlight into electricity. Wind turbines, the descendants of windmills, generate power from the mechanical action of atmospheric movements, whose origins date back to the star we are revolving around.

The development of energy technology has kept pace with advances in physics. For example, it has been known since Einstein that, theoretically, energy and matter can be completely transformed into each other: the energy–matter tandem is a single reality. However, that assertion bears interpretation. According to the theory of special relativity ($E=mc^2$), the mass of a chocolate bar is equal to eight times more than the energy released by the explosion of an equal amount of TNT. But this surprising fact has no practical application. Chocolate is not an explosive and cannot be used in a nuclear power station! As for solar power, its economic exploitation is based on photovoltaic cells, whose physics obey the laws of quantum mechanics. Nuclear and solar power would have been unthinkable within the framework provided by classical physics prior to the 20th century.

At the basis of the Anthropocene Era, then, lies the prospect of a sort of human domestication of the sun. On a human time scale, our star seems like an endless source of energy. Yet, many unresolved challenges continue to impede the access and use of this energy. Hydroelectric power comes up against geographical limitations. Despite the progress of extraction technologies, fossil energy is not renewable on the human time scale and, worse still, its emission of carbon dioxide is disrupting the planet. Nuclear power is cleaner to begin with, but raises unresolved safety and security issues. Perhaps it will be impossible to eliminate or store radioactive waste. Lastly, wind turbines can mar the landscape and cause sound pollution.

Direct solar power looks more promising due to the applicability of Moore's law. Formulated in 1965 by the co-founder of the integrated circuit manufacturer Intel, Moore's law states that the number of transistors in a dense integrated circuit doubles approximately every two years. That also seems to apply to solar panels, which would help to make them less expensive and solve their main problem, namely the amount of ground space they occupy. Other technologies that seem to have a bright outlook, although not in the immediate future, include hydrogen-powered cars. Moreover, we should not lose sight of nuclear energy. In the long-term, the dream of nuclear fusion has still not yet vanished.

In his 2014 book *The Zero Marginal Cost Society*, futurologist Jeremy Rifkin heralded the imminent arrival of an age when limitless clean energy will be available at quasi zero marginal cost. The terminology used is important. The marginal cost of any given item is that of an additional unit of that item. As a general rule, production capacity is limited. Below peak capacity, the marginal cost can become very low, if not almost nil. Hereafter, new facilities and fixed costs are necessary. Rifkin's announcement sounds less groundbreaking when that key distinction is made. His idea of "imminent" is two decades. Power companies generally do not share his optimism, or at least disagree with the timeframe. What's more, technological research has a Darwinian aspect.

The most successful projects are not always the most expected ones. One thing is clear: the revolution continues, and it must be seized on the fly.