Chapter 2
A Brief History of Energy Use in Human Societies

> *It is clear that there is some difference between ends: some ends are energeia, while others are products which are additional to the energeia.*
> Aristotle, Greek Philosopher, the first to describe the concept of energy.

Abstract Energy has always been among the most essential resources that endorses the progress, evolution and prosperity of human societies. This chapter aspires to provide a brief overview of historical evolution of energy use by human beings, from the discovery of fire and the agricultural revolution, to the industrial revolution and the domination of fossil fuels. By using historical evidence and brief diagrams, the narration provides a synoptic description of the unique and continuous quest of mankind for energy resources, unveiling the crucial role that energy still plays in modern economic systems as being the essential fuel of the economic process.

Keywords Energy history · Exosomatic metabolism · Organic economy · Fossil fuels economy · Industrial revolution

2.1 Introduction

Energy has always been among the most fundamental elements for the survival, reproduction and evolution of human society. The sun is the ultimate source of energy. Nonrenewable fossil fuels are formed by solar energy that has been captured over extremely long geological periods. What is more, renewable energy sources are directly (photovoltaic systems) and indirectly (wind, water, etc.) interrelated with the sun. Inevitably, almost all organisms rely, either directly or indirectly, on solar energy for their survival and maintenance. Life on earth would be impossible without the photosynthetic conversion of solar energy into plant biomass (Smil 1994). The sun provides approximately 1366 watts per square meter per second ($W/m^2/s$), hence, about 170,000 terawatts ($TW/m^2/s$) on the Earth's surface (Ruddiman 2001). In the food chain, solar energy flows are captured and converted through the complex process of photosynthesis. Part of this energy is

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used by organisms, while a great proportion is lost as heat and a small portion is passed down the food chain as one organism digests another.[1] Apart from the food chain, intelligent human systems utilize the solar energy embodied in fossil fuels and the renewable energy sources as the essential power, the "engine" of modern civilization. The present chapter gives a brief overview of the historical evolution of energy utilization by the human societies.

2.2 The Mastery of Fire and Agriculture: The Organic Energy Economy

The very first milestone of mankind's utilization of energy was the mastery of fire. The utilization of fire for cooking and heating, using biomass (mainly wood) as fuel, dates back at least 4–500,000 years (Bowman et al. 2009). In addition, fire created light and thus improved safety in human settlements, a fact that promoted the expansion of habitation (Goudsblom 1992; Fouquet 2011). The burning of wood and other forms of biomass eventually led to the discovery of ovens which, besides cooking, permitted the early forms of crafting. Ovens made it possible to produce pottery and to refine metals from ore.[2] Early humans lived a largely nomadic existence, closely in synchrony with the change of seasons and periodic plant growth.

The next milestone of mankind was the Agricultural Revolution (Heinberg 2011). The introduction of agriculture increased the amount of available food, permitting the first permanent human settlements, which caused a substantial increase of human population. Water and wind power were the next essential steps in the evolution of the human conquest of energy. The watermill was invented about 2500 years ago (Lucas 2006). Using both the water and the windmills, humans managed to master the water and air power necessary to meet their needs for crushing grain (wheat, etc.) in order to produce flour, crushing olives for olive oil production, tanning leather, smelting iron, sawing wood, and so on (Reynolds 1983). However, despite the improvements in energy use and the exploitation of several energy resources, the rapid growth of population in Europe about a thousand years ago—as a result of this progress—led to dramatic pressures on land for cultivation, and forests were being encroached upon to provide more land (Georgescu-Roegen 1984; Fouquet 2011).

This first era of mankind's quest for new energy resources, from the early discovery of fire to the agricultural (and farming) revolution, could be briefly described as the **Organic Energy Economy** (Fouquet 2011). This solar-based energy economy was intimately based on intensive land use and biomass

[1]Energy Literacy. Essential principles and fundamental concepts for energy education. U.S. Department of Energy. Available on-line at: http://www1.eere.energy.gov/education/pdfs/energy_literacy_2.0_low_res.pdf. (Accessed March 2015).

[2]Ibid.

consumption. This pre-industrial economy, dominated by the so-called "*somatic energy regime*" (McNeill 2000), was an era in which "*endosomatic metabolism*" and biomass consumption were the predominant elements of the "*agrarian metabolic regime*" (Krausmann 2011). Inevitably, the organic energy economy was limited to the consumption of energy at the rate that solar energy can be converted into useful goods and services. In this context, population growth and the limited land availability imposed crucial restrictions upon further economic growth and gradually forced a transition towards a new energy regime, the era of fossil fuels (Fouquet 2011; Krausmann 2011).

2.3 Transition to the Fossil Fuel Economy

The milestone that determined the transition from the organic economy to the fossil fuel economy, the invention that characterized the era called "The Industrial Revolution", was the steam engine. The unique process that the steam engine initiated was the conversion of chemical energy (heat) into mechanical energy (motion) (McNeill 2000). The biomass energy stocks accumulated in the earth's crust for hundreds of millions of years were now available to serve human needs for the first time in mankind's history, to such an extent that the dawn of the fossil fuel era was about to begin. While the early steam engine was mainly used for pumping water out of coal mines, it soon became—thanks to the efficiency improvements made by James Watt, a Scottish inventor and mechanical engineer—a valuable tool which increased human muscle and animal power for extracting more coal, drove the manufacturing industry, moved ships and trains, and laid the foundation for today's complex and energy intensive human (economic) systems (Fouquet 2011).

During the 18th century, many industries had already substituted wood-fuels with coal, while heating services made the transition from organic biomass to fossil fuels by the beginning of the 19th century.[3] Specifically, between 1650 and 1740, the real prices of wood-fuel increased substantially, which encouraged its progressive substitution with coal (Fouquet 2008, 2011). The timing of this substitution was absolutely essential, given the fact that during the second half of the 17th century the harvesting of forest trees had to be regulated, even restricted, in England and elsewhere in Europe (Georgescu-Roegen 1984). Wrigley (1988) suggests that, by 1800, had the British economy been dependent on wood-fuel, a surface area equivalent to the whole of Britain would have had to be coppiced every year in order to supply the energy demands of the economy. On the other hand, wind and water power provided only one-tenth of the total power of the British economy in 1800 (Fouquet 2006). By 1900, steam engines provided two-thirds of all power services; the expansion of the railway network provided more than 90 % of goods

[3]Three quarters of the energy requirements of British economy were used for heating services (households, buildings, industry) (Fouquet 2008).

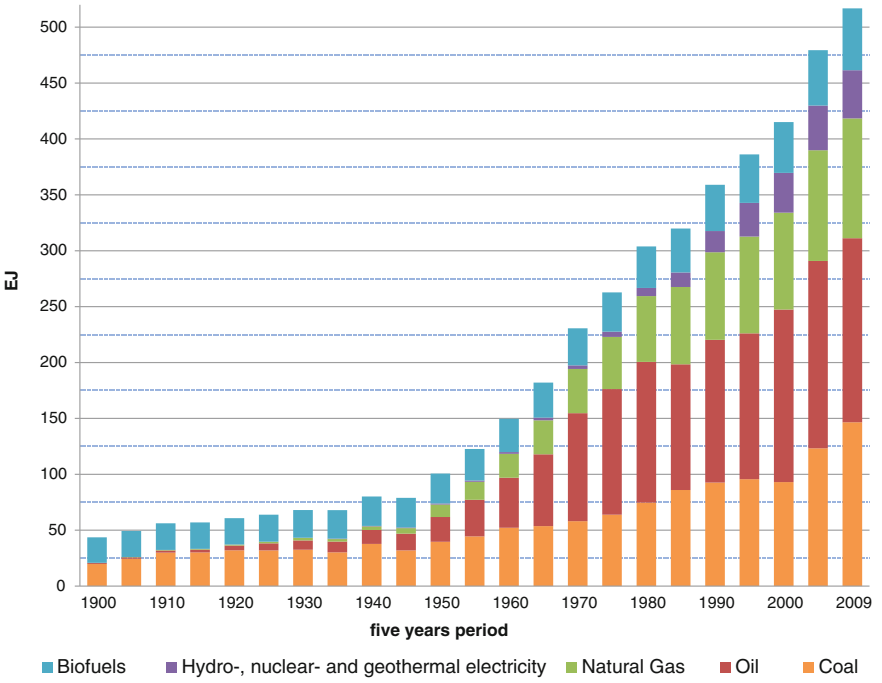

Fig. 2.1 The world's total primary energy supply for 1900–2009

transportation on land, while steam ships were carrying about 80 % of all freight cargos at sea (ibid).

Remarkably, the growing demand for coal in the 19th century raised concerns about coal scarcity and its consequences for the production process (Jevons 1865). However, new technological improvements managed to maintain a constant coal supply, and simultaneously kept prices low (Fouquet 2006). Furthermore, the introduction of new energy resources, such as petroleum and petroleum by-products, enhanced the fossil energy mix. The major invention that really promoted the use of refined oil was the internal combustion engine. While the process of refining crude oil[4] provided the foundation for the oil age, it was following the invention and development of internal combustion engines in Germany, after 1880, that the use of oil took off (McNeill 2000). Peak oil production was reached in the US in late 1960s, and the heightened concerns about security in maintaining a constant energy supply induced by the oil shocks of 1973 and 1979, led to a rapid increase in natural gas use. Clearly, after the 1970s natural gas consumption

[4]Discovered by James Young in the 1850s, while Edwin Drake, in 1859, managed to successfully drill for oil through deep rock.

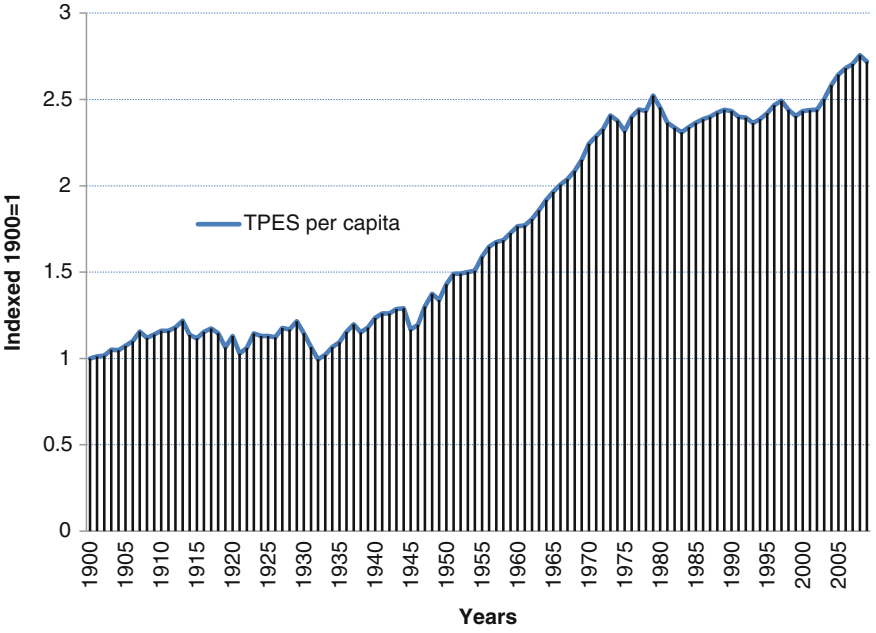

Fig. 2.2 The world's per captia total primary energy supply 1900–2009

increases dramatically (Fig. 2.1). Coal consumption overcomes biofuel consumption from the very first years of the 20th century, while oil consumption takes the lion's share from coal in the early 1960s. The use of natural gas increases dramatically after WWII, while hydro, nuclear and geothermal electricity use increases constantly from the early 1970s. Finally, and remarkably so, bio-fuel consumption steadily increases throughout 1900–2000, with a further acceleration of incremental trends occurring in the early 2000s (Figs. 2.1 and 6.1a).

Figure 2.2 displays the trajectory of the world's per capita Total Primary Energy Supply (TPES), for 1900–2009. An extraordinary and unparalleled rise in per capita energy use occurred after WWII. This trend shows signs of stabilization from 1980–2000; however, from 2000–2009, a further acceleration is seen again.

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