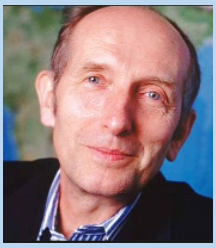
Energy Transitions

Vaclav Smil

Distinguished Professor Emeritus, University of Manitoba, Canada



Energy transitions are not sudden revolutionary advances that follow periods of prolonged stagnation, but rather continuously unfolding processes that gradually change the composition of sources used to generate heat, motion and light. Such transitions also replace dominant prime movers by new converters and introduce better, and invariably more efficient, final uses of energy. Historically, changing sources of primary energy supply generated the most attention, as coal combustion displaced traditional biofuels and was, in turn, augmented by the rising use of hydrocarbons and primary (hydro and nuclear) electricity. And while the recent focus has been on the unfolding transition from fossil fuels to renewable sources of energy (modern biofuels, wind, solar), the most consequential global shift during the coming 20-40 years will be the rise of natural gas to become the world's single most important fuel.

Inventions and diffusion of new prime movers drove most energy transitions: just think what steam engines did for coal and what internal combustion engines (ICEs) have done for hydrocarbons. The overall level of primary energy supply and its composition can be substantially modified by still considerable opportunities for more efficient use of energy: transitions toward universally adopted optimal conversion efficiencies could be as important as harnessing of new energy resources. The pace of unfolding changes will be determined not only by those fundamental factors that have been critical in the past but also by several new considerations arising from unprecedented features of modern energy systems.

The most important historical lesson is that new resources require extended periods of development. The verdict is clear: only small economies endowed with suitable resources can undergo very rapid resource transitions. For example, in the Netherlands natural gas supplied 50% of total primary energy just 12 years after the discovery of the giant Groningen field in 1959. The scale of large economies makes everything more inertial, and global resource transitions unfold across generations. Even though the country is endowed with abundant hydrocarbon resources, it took the United States 25 years to raise the share of oil consumption from 5% to 25%, and for natural gas it took 33 years. After crude oil reached 5% of global primary energy supply, it took another 40 years to rise to 25%, and the comparable period was even longer, 55 years, for natural gas.

There is no shortage of national, even global, targets for renewable energy deployment (such as 30% of all electricity from wind by 2030, 50% of all energy from non-fossil sources by 2050), but these are, at best, aspirational goals and not realistic aims. Between 2000 and 2010, global output of renewable energies grew by 2% but that of fossil fuels by 2.65%. **During the first decade of the twenty-first century the world has been running into fossil fuels, not away from them, a reality that will not change rapidly.** And while the contributions of wind and solar PV more than tripled during that decade, the world is now more dependent, in both absolute and relative terms, on fossil-fuelled generation than it was in 2000.

Reliable and inexpensive performance will often favour long-established uses. The first diesel engines powered an ocean-going vessel in 1911, but 30 years later when the US Navy needed a large number of transport ships in WW II, it chose to equip them with much-tested oil-fired steam engines rather than with diesels. Similarly, after nearly 130 years of development, gasoline-fuelled ICEs will not rapidly yield their huge market share to electric cars powered by new batteries, and there are no real alternatives to diesels in marine transport and to gas turbines in flight.

Public acceptance and environmental considerations have become critical components in the conquest of new markets. New energy sources and techniques now face unprecedented public scrutiny and must comply with many environmental laws and restrictive regulations. In many countries significant shares of the population were uneasy about nuclear electricity generation even before major accidents undermined public confidence in this rewarding but risky process. Widespread hydraulic fracturing to produce oil and gas and mass-scale underground carbon sequestration are two recent innovations facing such public perception challenges.

High power-density demand will be even more important. Urbanization and industrialization have created unprecedented needs for incessant flows of highly concentrated energies. Since 2008 more than half of the world's population has been living in cities where buildings, factories and transportation and communication networks require high power density of energy supply (particularly of electricity and liquid fuels). In the absence of mass-scale energy storage (on a multi-gigawatt scale, orders of magnitude above our current capabilities) meeting such demand with the intermittent, low power-density flows of renewable energies is a difficult task. A non-fossil future is highly desirable and eventually inevitable, but a civilization built on fossil fuels cannot make that transition easily or speedily.