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BOOK REVIEW

V. Smil, Energy in Nature and Society: General Energetics of Complex Systems

The MIT Press, 2008, 480 pp., £48.95 hardback, £20.95 paperback, ISBN: 978-0-262-69356-1

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Energy is a central concept in physics. Thus I was particularly drawn to this new book by an author who, in the last 30 years, has written 20 books, half of which have the word "energy" or "energetics" in their titles. Vaclav Smil, a Distinguished Professor at the University of Manitoba in Canada, has written on energy in the environmental context broadly, and specifically on agriculture, the biosphere and biomass, and in the developing world and China.

Here, with erudite quotations Professor Smil provides an excellent, balanced overview of both the sources and the uses—by the human species—of different forms of energy on our planet. The fundamental aim of this book is "to produce a comprehensive, systematic, revealing (and hence interdisciplinary and quantitative) treatment of all major aspects of energy in nature and society". This most ambitious aim is definitely achieved by the analyses and syntheses presented.

The first two chapters adopt a historical and physics approach to the concept of energetics, contrasting quantities such as power, or energy flow (in W or J/s), power density or rate of energy flow per unit area (in W/m^2), and specific energy or energy intensity (in J/kg). The conversions between different forms of energy—chemical, electrical, electromagnetic, gravitational, kinetic, nuclear and thermal—are explained. This discussion is highly relevant in the light of today's discussions on biofuels. Energy fluxes are explored, ranging from that due to solar radiation (peaking at a wavelength of $\sim$500 nm) to terrestrial radiation (peaking at 10 μm), meridional heat transport in the ocean, tornadoes, geothermal processes, volcanoes and earthquakes.

That "sets the stage for reviewing both the bioenergetic fundamentals and the specific and ecosystemic peculiarities of the plant and animal kingdoms". Chapter 3 is on photosynthesis, the bioenergetics of primary production in bacteria or green plants. Phototrophs are organisms which obtain energy from sunlight for the synthesis of organic compounds. They require oxygen in the atmosphere to remove carbon dioxide from the atmosphere, i.e. in order to assimilate (or "fix") carbon. The complicated enzymatic chemical reactions of "net primary productivity" are explained. Trees store $\sim$20 MJ/kg

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(p. 366). Heterotrophs, the subject of Chapter 4, are carbon oxidisers which absorb carbon into relatively simple molecules. Animals produce water and carbon dioxide—this is aerobic respiration. “The daily metabolism rate of a school child is 15,000 times the power intensity of the Sun” (p. 91). The metabolic rate of a bird is more than an order of magnitude greater than that of a vertebrate of the same mass. And running requires about three times more energy than flying, weight for weight.

Chapter 5 discusses human energetics. “The gross energy of proteins is 23 MJ/kg” (p. 121). “The adult brain (2% of the body mass) claims about 16% of the basal metabolic rate (BMR)” (p. 123). The BMR of a person in their sixties is half that of someone in their twenties (p. 125). “The average height of 11-year-old Japanese boys increased by nearly 0.2 m during the course of the twentieth century” (p. 126). Humans are tachymetabolic (able to produce heat at the cellular level even in the absence of any muscular activity)” (p. 131). “Brief notes on the energetics of foraging societies (capable of sustaining up to only one person/km^2) are followed by more extensive analyses of traditional (solar) farming and preindustrial complexification based largely on animate power and biomass fuels (Chaps. 6 and 7)” (p. 21, at the end of Chapter 1). Smil notes, on p. 310, that the maximum density of residents in a modern city is $\sim$50,000 people/km^2.

The energetics of modern civilisation is discussed next. Fossil fuels are the topic of Chapter 8; global resources, engines and turbines, as well as electricity generation, are reviewed. The use of energy by today’s civilised societies is considered in Chapter 9; fossil fuel production and trade are contrasted with biofuels, hydroelectricity, nuclear fission and solar power systems. Half of the world’s population uses almost 90% of the world’s total primary energy supply—the other half consumes the remaining 10% (p. 259). Chapter 10 considers the cost of energy (energy return on invested energy) in the different phases of energy provision, then uses examples in terms of steel, ammonia (for fertilisers) and concrete production, and then of crop production for both humans and animals. “Food packaging is fairly energy-intensive, especially with the use of plastics and aluminium and the inclusion of waste disposal costs” (p. 306).

Chapters 11 and 12 survey the environmental implications and socio-economic complexities, respectively, that accompany this high-energy way of life. Houses typically consume between 20 and 100 W/m^2 (p. 314); flat plate solar collectors in very sunny locations can provide this amount of energy. Figure 11.4 (p. 316) is an illuminating graph of power (in W) versus area (in m^2)—the power density—for items ranging from a CD player through a house, a refinery, a city, a thunderstorm and a monsoon, i.e. over 15 orders of magnitude for each axis. “By the year 2000 the cumulative effect of global emissions of greenhouse gases had already burdened the atmosphere with an additional 2.4 W/m^2” (p. 316). The rate of heat release into the atmosphere of a car is $\sim$10 kW/m^2, a value comparable with that produced by the cooling tower of a power plant (electricity generating station) (p. 318). The emission of nitrogen oxides into the atmosphere is considered on p. 325, as are the effects of anthropogenic aerosols on the weather and climate (p. 326). Anthropogenic interference with carbon, nitrogen and sulphur biogeochemical cycles is examined on pp. 327–333. Regarding economic aspects, Smil’s discussion ranges from energy/GDP links, energy and “green” values, energy and the quality of life, energy and wars, to energy and the future. “Humans harvest $\sim$1.3 Gt of carbon as food” (p. 359), and almost twice as much goes into car making and fuels. “All we can do with some semblance of rationality is to map our tasks for the next generations” (p. 359). Imperatives are resource conservation, wind-generated power systems and roof-based solar energy systems. We “need to begin, with vigour and determination, the inevitable transition to the post-fossil fuel world” (p. 363).

Chapter 13, entitled "Grand patterns", pulls together many of the huge number of topics and issues covered in this remarkable book—solar energy, its reservoirs on Earth, human activities, civilisations, uses of energy, costs of transport, and sequestration of carbon dioxide. Professor Smil concludes that we must use the only resource freely available, i.e. solar radiation, much more and that we must have much, much better solar energy converters. "I strongly believe that the key to managing future global energy needs is to break with the current expectation of unrestrained energy use in affluent societies" (p. 384). We should soon return to the energy usage of the 1960s. "Our best hope is that we will find the determination to make choices that would confirm the Linnean description of our species—sapiens" (p. 388).

Useful appendices giving numerical values of relevant quantities follow, as do two pages of acronyms, 59 pages of references, a two page name index and an 18 page subject index.

The amazing breadth of this book is, I trust, evident from the enormously wide range of quotes from it given in this review. It is a very remarkable book, which is both multi-disciplinary and interdisciplinary, both factual and discursive, and with impressively clear diagrams. Anyone and everyone who is concerned about climate change and the future of our planet will find plenty of food for thought here. I commend this book wholeheartedly to our readership.