books

Reshaping the energy landscape

Beyond Smoke and Mirrors

Climate Change and Energy in the 21st Century

Burton Richter
Cambridge U. Press, New York, 2010. $29.99 paper (248 pp.).
ISBN 978-0-521-74781-3

Sustainable Energy—Without the Hot Air

David J. C. MacKay
UIT Cambridge, Cambridge, UK, 2009. $49.95 paper (384 pp.).
ISBN 978-0-954-45293-3

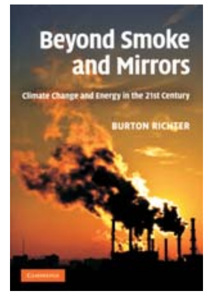
Challenged by Carbon

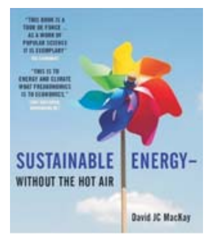
The Oil Industry and Climate Change

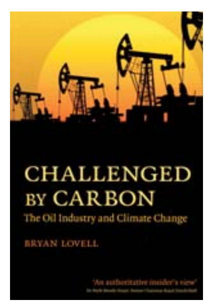
Bryan Lovell
Cambridge U. Press, New York, 2009. $29.99 paper (230 pp.).
ISBN 978-0-521-14559-6

Reviewed by David Keith

How do we grow the global supply of energy, make it more accessible to the poor, and at the same time cut carbon emissions to near zero? And how can physics contribute? During the past quarter century, physics has had its strongest industrial impact at the intersection of solid-state physics and information technology. Following Moore's law, computation has made fast progress. Many IT firms spend more than 10% of their gross income on R&D and can move innovations from the laboratory to the marketplace in just a few years. And even though planar transistors are approaching quantum limits, those limits are still quite a way out, and we are just beginning to exploit the third dimension. As Richard Feynman noted, "there's *plenty* of room at the bottom."







The energy industry is a different story. It moves much more slowly, spends about 1–2% on R&D, and moves more than 8 gigatons of carbon per year in fuels that cost less than $1 per kilogram. Also, unlike computation, many energy-conversion technologies, from gas turbines to solar cells, are within a factor of two of their thermodynamic limits. Physics can and must help resolve our energy challenges, but in order to contribute, physicists must understand the technical and economic constraints that make energy so fundamentally different from computation.

As a physicist who has long worked on energy technology and policy, I am often approached by young physicists who want to work on energy. Many of them are naturally drawn to the most exciting applied physics that has some connection to energy: exotic fuel cells, high-temperature superconductivity, or high-efficiency solar photovoltaics. But what's really needed is for physicists to develop a systematic understanding of the energy system as a whole, or they won't have the intuition to distinguish useful solutions from merely clever physics that has little chance of large-scale application.

Three books, two by physicists, Nobel laureate Burton Richter and the UK's Energy and Climate Change chief scientific adviser David MacKay, and one by geologist Bryan Lovell, provide a marvelous introduction to our options for reshaping the energy system to gradually eliminate carbon emissions in order to manage the risks of climate change. Richter's *Beyond Smoke and Mirrors: Climate Change and Energy in the 21st Century* is a wonderfully balanced overview. It opens with a fine summary of the science linking carbon to climate (see article by Raymond Pierrehumbert on page 33), provides a concise primer on the economics of long-term climate policy, and concludes with a short, sensible, and well-argued set of opinions and policy recommendations. The bulk of the book describes the energy system sector by sector and examines the opportunities for decarbonization.

MacKay's *Sustainable Energy—Without the Hot Air* takes a different tack. Rather than being handed a synoptic overview, the reader is drawn into a data-driven joyride through the energy domain. MacKay's book is packed with data-rich graphics supported by footnotes with calculations and URL links to primary data—the whole book is available free online, but I recommend the paperback.

Lovell's *Challenged by Carbon: The Oil Industry and Climate Change* leads the reader on a personal journey through climate, carbon, and politics. Of the three books, Lovell's takes the deepest look at climate science; a highlight is its treatment of the science and implications of the Paleocene–Eocene Thermal Maximum (PETM), a warming event that was caused 55 million years ago by the rapid release of a quantity of carbon comparable to the amount humanity is now releasing by consumption of fossil fuels.

Among the possible triggers for the PETM was an uplift of the North Sea that may have released methane from hydrates as it created the sandstone formations from which oil is drawn. Lovell skillfully exploits that irony, weaving it into his career experiences as an academic and topnotch petroleum geologist involved in oil discovery, the scien-

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tific understanding of the PETM, and climate-policy debates at the highest levels of the global oil industry.

None of these books does a great job assessing the cost of cutting carbon. MacKay's book is packed with data on everything from renewable energies to nuclear power to energy storage, efficiency, and transportation. But it doesn't cover cost. Richter's book does an excellent job of presenting the economics of cutting carbon in layman's terms, but is uneven in its treatment of the costs of specific technologies. His treatment of nuclear power is balanced in nearly every respect but cost. Richter cites a few academic studies that equate the cost of nuclear to coal, but sadly, that is not a likely near-term outcome. Olkiluoto-3, for example, now under construction in Finland, is one of the very few power reactors being built in a Western economy. It is behind schedule and over budget, with capital costs already over $4500/kW, whereas Richter cites generic costs below $2000/kW.

I share Richter's view on the importance of nuclear power and his optimism that we should, in principle, be able to build nuclear plants at a reasonable cost. Many first-generation US power reactors built in the 1970s cost less than $2000/kW in current dollars, cheap enough to make decarbonization look easy. But costs have increased so much that we cannot now repeat what we did then; that fact is a painful example of the stark contrast between progress in energy and that in information technologies.

These books do not cast as much light as one might wish on questions that lie at the intersection of technology and society: For example, can we build cost-effective nuclear power while maintaining public trust? Like Richter and MacKay, I believe that goal is both achievable and urgent, but it will take more than technology. We will have to resolve the nexus of failures in the first generation of nuclear power plants, failures for which regulators, utilities, reactor vendors, and environmental groups all bear some responsibility.

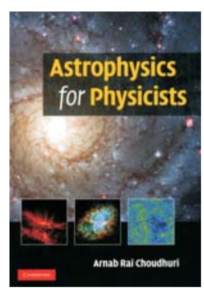
The three books are complementary in addressing the difficulty of cutting carbon with renewables and efficiency alone. They also discuss the corresponding need to examine two technologies—nuclear power, and coal power in combination with CO_2 capture and storage—that are distrusted by the public and entail long-lived risks, yet share the promise of affordably delivering the required low-carbon power at affordable cost. MacKay delivers on an assessment of the difficulty of decarbonizing with efficiency and renewables alone, Lovell takes a deeper look at CO_2 capture and storage technology, and Richter is best on nuclear power.

In summary, if you are skeptical about climate science and value a nuanced personal view, read *Challenged by Carbon*. If you love data, read *Sustainable Energy—Without the Hot Air*. And if you want a consistent overview of the energy and carbon challenge, read *Beyond Smoke and Mirrors*. Taken together, these three books provide an accurate, balanced, and complementary overview that will help you navigate the energy rapids without tipping.

Astrophysics for Physicists

Arnab Rai Choudhuri
Cambridge U. Press, New York, 2010. $60.00 (471 pp.). ISBN 978-0-521-81553-6

Essentially all branches of basic physics find applications in astrophysics. Therefore, the first major challenge for any author attempting to craft an astrophysics textbook is to lay out the basic physics before moving on to the subject at hand. Even an ideal undergraduate text, though, would serve only temporarily as a comprehensive text in a field that is evolving so rapidly. For example, the must-cover topic of general relativity, though now a classical subject, is seeing its applications expand at an increasing rate.



With *Astrophysics for Physicists*, Indian Institute of Science physics professor Arnab Rai Choudhuri introduces the topic at the advanced undergraduate level. The book is designed for a one-semester course covering stellar astrophysics and relativistic astrophysics with cosmology; those two topics are often taught over two semesters in two separate courses using two separate textbooks. Such courses often use Dale Ostlie and Bradley Carroll's *An Introduction to Modern Stellar Astrophysics* (Benjamin Cummings, 1995), Peter Hoyng's *Relativistic Astrophysics and Cosmology: A Primer* (Springer, 2006), or Barbara Ryden's *Introduction to Cosmology* (Benjamin Cummings, 2003), reviewed in PHYSICS TODAY (October 2004, page 77).

Astrophysics for Physicists can be divided into three sections. The first discusses the tools of astronomy and covers such topics as coordinate systems, celestial mechanics, telescopes, and the basic properties of light. The second discusses the nature of stars, beginning with the determination of stellar parameters from their observable properties (positions, spectra, luminosities, and so forth) and proceeding to the physical principles that govern stellar atmospheres and interiors. The book also explains the formation, evolution, and death of stars. The third section covers the most interesting and important applications of Einstein's general relativity in present-day astrophysics and cosmology: black holes, neutron stars, gravitational waves, and the cosmic microwave background.

Any text for a one-semester course will necessarily be limited in its coverage; its content would naturally reflect the interest and expertise of the author. As one would anticipate from the author's background in solar magnetohydrodynamics, *Astrophysics for Physicists* contains good passages on fluids, plasmas, magnetic fields, and general relativity, and it provides strong mathematically based discussions of many of the important areas of astrophysics. It stresses theory, but also discusses several experimental and observational topics, such as gamma-ray bursts, interferometer detectors of gravitational waves, and the angular power spectrum of the cosmic microwave background.

The book tends to be more extensive and technical in stellar astrophysics, plasma, magnetic effects, and general relativity. Rapidly developing areas including cosmology, relativistic jets, black hole thermodynamics, and relativistic compact objects such as quasars are given less thorough treatments. Though the text does cover the developing area of pulsars, some equally worthy topics are mentioned only briefly. An example is the book's one-page (page 123) discussion of extrasolar planets. Not only is that one of the hot topics in astrophysics, it also could have provided an opportunity to explore relevant basic physics. To Choudhuri's credit, the book is overall fairly up to date in most areas.

It is also unfortunate that the book's first section must dwell so much on the arcane units of astronomical observations, many of which were created to quantify observations when the observers had no idea of the underlying physics. Much old astronomical terminology continues to persist for