Sustainable Energy—Without the Hot Air. David J.C. MacKay. 372 pp. UIT Cambridge Ltd., Cambridge, UK, 2009. Price: $33.00 (paper) ISBN 978-0-9544529-3-3. (David Hafemeister, Reviewer.)

Sustainable Energy—Without the Hot Air is an excellent text on energy matters. I would choose it as text for a general education energy course. In this review I will nit-pick what it doesn't do, but I would adopt it because its competitors, in my view, are too wordy or not numeric enough. Energy is a serious topic that is affected by the many branches of the physics tree. Make no mistake about energy's importance. Would the United States have invaded Iraq in 1991 (the first time) to save the sanctity of a small nation—Kuwait—without the presence of oil in the Middle East? I believe not, so energy is actually a national security issue. Does the high use of fossil fuels endanger the environment? Yes it does, in many ways. Can we do better? Of course, we can. And MacKay, a physics professor at the University of Cambridge, offers this book for *free* (good for him) to those who will go to ⟨www.withouthotair.com⟩ or at a reasonable price for a printed version from online booksellers.

Renewables vs Enhanced-End-Use Efficiency: U.S. refrigerators used 1850 kWh/yr at the time of the oil embargo of 1973–1974 and now consume 25% of this, about 450 kWh/yr, saving some 50 GWe (gigawatt electric) of electrical U.S. power with improved refrigerators and freezers. Automobile fuel economy doubled from 13.5 miles per gallon (mpg) in 1973 to the 1975 Corporate Average Fuel Economy (CAFE) value of 27.5 mpg, which has been increased to 35.5 mpg in 2016. But more needs to be done. Building standards reduced energy consumption by 50%, with more savings to come in the future. Renewable energy is extremely important, but it is enhanced-end-use efficiency that will make the larger contribution in the near term. To legislate energy standards, the cost of conserved energy must be reasonably close to market prices. Adoption of higher energy standards is a political issue that the U.S. Congress addresses more strongly when beleaguered—as, for example, by an oil embargo. It is for this reason that the American Physical Society's Forum on Physics and Society published AIP Conference Proceedings, *Physics of Sustainable Energy: Using Energy Efficiently and Producing It Renewably*, with technical chapters by 30 U.S. experts.[1] MacKay's *Sustainable Energy* discusses renewables more thoroughly than enhanced-end-use efficiency technologies. I would reverse that priority in a second edition. It is a pleasure to talk of sun, wind, and biomass, and perhaps less exciting to talk of better appliances, lighting, buildings and automobiles, but faster results will come from enhanced-end-use efficiency improvements. The 2009 American Physical Society report *Energy Future: Think Efficiency* is a good place to start.[2]

Will renewable energy produce all U.K.'s Energy? MacKay does a good job scoping out the possible alternative energy supplies for the United Kingdom. With nice graphics he displays upper-bound alternative energy production rates on page 107. He concludes that contributions of the alternatives have been overestimated: "Figure 18.1 is bleak news. Yes, technically Britain has 'huge' renewables. But realistically, I don't think Britain can live on its own renewables–at least not the way we currently live." And on p. 222, "We are not on track to a zero-carbon future." And on p. 250, "I am worried we won't get off fossil fuels when we need to." The good news for their former colony is that the U.S. is in a better position to make this transition than the U.K. The U.K. average solar flux at 110 W/m^2 is less than one-half that of the U.S. Southwest. In the plentiful sunny regions of the U.S., photovoltaic (PV) systems produce electricity on houses at 30 cents/kWh (less in utility complexes), but with time-of-day pricing, this electricity can be sold at that rate in the summer months for air conditioning, but that is for only part of the year and not after sunset. The 1 kW PV on my roof is not economical, costing two to three times the local price, but I enjoy it every day. It is important to realize that the price of traditional electricity is rising while photovoltaic costs drop; at some point the curves will cross. Solar power will reduce peak power in California, but it is a long way from supplying nighttime power. Wind power is competitive in many regions, but it is a fluctuating supply. U.S. farmers are happy to rent the space over their crops in the windy Midwest. The transition to renewables should be easier for the U.S. than for the U.K. for two reasons: (1) The U.S. has been blessed with cheap energy in the past, thereby becoming less efficient but providing great opportunities to save energy, and (2) the U.S. has more favorable and larger areas to produce alternate energy. In his next edition, MacKay should describe the *smart grid* that is needed to balance wind at night with sunshine of the day, along with spot pricing of electricity that uses market forces to lessen demand during peak power times.

Economics for the masses: Economics will be the key to the adoption of alternative energy technologies. *Sustainable Energy* begins this process with an examination of the science aspects and then putting the costs in perspective (Chap. 28). The tabular results are interesting (p. 216), but they need an economics primer to deepen understanding of opportunity costs and present value accounting. A useful way to do this is to determine the annual cost of capital and divide by the annual energy saved, to obtain the cost of conserved (or produced) energy in money/kWh, money/gallon, or money/life–saved. MacKay uses approximate numbers to compare issues to separate important issues from less important ones that are distracting. He needs to beef up the economics in his next edition. An interesting place to begin is the scenario-dependent analysis of the purchase of an electric car, which depends on the cost and life of the lithium battery, as well on as on personal driving patterns.[3]

General Education Courses: Many energy texts for general education courses are not fulfilling from a physicist's point of view. They can be too thick with facts and pictures, but they often lack quantification and simple equations. Students get nervous if numbers or equations are too plentiful. There is a big difference between the students on my campus in Physical Science 320 and Physics 320. I am aware of the blowback from Physical Science 320 students when issues such as uranium enrichment, pollution plumes, or climate change are described with too much physics gusto. Many students who do well in math courses do not do as well when this math is applied to real objects. Since we usually have a student's attention on the topic of energy for only one term, there is a trade-off between breadth of material and depth of material covered. I would choose *Sustainable Energy* as a text over its competitors because MacKay has moved the energy discussion in the direction where energy alternatives can be considered quantitatively. Only a few universities offer upper division physics energy courses, as the pure side of physics is more in demand with the students and more acceptable to the faculty—a situation that needs change.

[1] D. Hafemeister, B. G. Levi, M. Levine, and P. Schwartz (ed.), *Physics of Sustainable Energy: Using Energy Efficiently and Producing it Renewably*, AIP Conference Proceedings 1044 (Melville, NY, 2008), 447 pp.

[2] B. Richter *et al.*, *Energy Future: Think Efficiency* (report of the American Physical Society, College Park, MD, 2008), p. 108 (www.aps.org/energyefficiencyreport/).

[3] D. Hafemeister, "Review of the 2008 APS energy study, Energy Future: Think efficiency," Physics and Society, 2009, Vol. 38, pp. 16–20.