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# Review of *Sustainable Energy -- Without the Hot Air* by David MacKay (2009)

**Abstract**
David MacKay. *Sustainable Energy: Without the hot air.* (Cambridge, England: UIT Cambridge Ltd., 2009). 384 pp. ISBN 978-0954452933 (also available as a free e-book).

Physicist David MacKay transforms what has historically been a debate fraught with skepticism and hysteria into an informed conversation. He does this by providing clear, accurate quantitative information on energy production and consumption in a form that allows comparison and invites thoughtful analysis. By recalibrating power into kilowatt-hours per day per person, he makes the numbers meaningful on an individual level. He then meticulously estimates the productive capacity of various renewable energy sources, explores alternative energy solutions, and ends with an array of concrete plans to get the planet off fossil fuels for good.

**Keywords**
sustainable energy, kilowatt-hours per day per person, numeracy

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**Cover Page Footnote**
Kira Hamman teaches mathematics at Pennsylvania State University, Mont Alto. A logician by training, she nevertheless thinks about the physical world a lot and would like to see it survive. She figures both sustainable energy and numeracy are important parts of making sure that it does.

This book review is available in Numeracy: http://scholarcommons.usf.edu/numeracy/vol9/iss2/art9

As readers of *Numeracy* presumably know, the robust international quantitative literacy movement includes people from a wide range of backgrounds: mathematicians, yes, but also scientists and social scientists, educators, journalists, and private citizens. Its success depends in no small part on this diversity. Each constituency brings a unique perspective to the conversation, and the absence of any one of those perspectives would diminish the scope and efficacy of the effort. Yet even in a movement as broad and varied as this one, occasionally someone stands apart. Sir David MacKay was such a person.

MacKay's book, which is available free online,[1] is a bold and brilliant illustration of the transformative power of numeracy. The book takes on no smaller a question than the survival of the planet, made manifest in the tension between humanity's consumption of fossil fuels and its ability to produce energy sustainably. Frustrated by the dearth of numbers in the sustainable energy debate, and by the fact that when numbers do get thrown around they are chosen "to sound big, to make an impression, and to score points in arguments, rather than to aid thoughtful discussion," MacKay sets out to provide numbers that have context and meaning. He then uses those numbers to frame a rational and accessible conversation about what is, after all, a deeply fraught issue. The result is a master class in the capacity of quantitative information to inform and elevate debate.

Part I of the book is aptly titled *Numbers, not adjectives.* Railing against the rampant use of words like *huge* to describe things that are fundamentally quantitative, MacKay points out that the question is not whether something is *huge* (the amount of energy a country might sustainably produce, for example), but how it compares to something else that is also *huge* (the amount of energy that country actually consumes). For most countries the latter is a known quantity, although it is often presented in a form that suffers from the flaws described in the previous paragraph. The former, however, requires thoughtful estimation, and that MacKay offers in spades. Indeed, most of Part I is taken up with estimating the productive capacity of renewables and comparing it to actual consumption using MacKay's "balance sheet." Sections on consumption (in red) discuss the usual suspects – cars, planes, heating and cooling – as well as less obvious things like food, farming, and "stuff." These sections alternate with sections (in, you guessed it, green) estimating production from all conceivable renewable sources: wind, solar, hydroelectricity, offshore wind, wave, tide, and geothermal. Some of these things many readers will not even have heard of, but here they are explained calmly and rationally, and their potential is analyzed in terms that an average person might reasonably be expected to understand.

And there we have the first major breakthrough of the book: MacKay's commitment to presenting numerical data in a format that is actually

[1] https://www.withouthotair.com/, Web site for *Sustainable Energy – without the hot air* (accessed June 12, 2016)

understandable to actual people. He uses the kilowatt-hour (kWh) as the primary unit of energy throughout because, he explains, it is the unit most households see on their electric bills. He measures power (the rate of production or consumption of energy) in kWh per day, for the same reason, and then personalizes the quantities even further by usually expressing power in kWh per day *per person*. Thus we go from vague hyperbole ("The UK has the best wind resources in Europe") to concrete numbers (making some generous but reasonable assumptions, the UK could produce 20 kWh/d/p from windmills). Beyond that, MacKay gives the production numbers meaning by stacking them up against consumption amounts. (UK usage averages 125 kWh/d/p. Wind alone, it would seem, is not the answer.)

In this part of the book MacKay also tackles meaninglessly huge numbers and meaninglessly small gestures. Do politicians who express $CO_2$ emissions in gigatons do so with the expectation that their audiences will grasp those quantities? Of course not; they do so because "gigatons" sounds big and impressive. The same politicians extol the virtues of such things as unplugging one's phone charger when not in use, often while reciting the mantra "every little bit helps." In fact, unplugging a phone charger saves 0.01 kWh per day, an amount of energy that would power a car for approximately one second. MacKay rephrases the mantra: *if everyone does a little, we'll achieve only a little.*

By the end of Part I, the red consumption column stands at 195 kWh per day per person and the green production column stands at 180 kWh/d/p. These numbers are necessarily based on a variety of assumptions: that people do not want their coastlines entirely covered in windmills, for example, and that the average person uses all the energy he or she wants. In fact, that second assumption is not true, and as we have mentioned the actual number for the UK is about 125 kWh/d/p. (It is worth noting here that the number for the United States is roughly double that of the UK: about 250 kWh/d/p.) MacKay's number is in some sense aspirational; it represents consumption if everyone had what they needed, such as reliable heating in the winter. This assumption is important because one way to balance the sustainable energy equation is to reduce consumption. MacKay is pointing out that in fact the reverse is likely to happen, and energy consumption will go up as standards of living increase.

In the last section of Part I, MacKay goes through the "chorus of opposition that greets any major renewable energy proposal." Wind farms are "ugly and noisy," solar panels "spoil the visual amenity of the street," waste incineration brings "health risks, traffic congestion, dust and noise," and so on. He estimates that, given the social reality, the most the UK could actually produce from renewables is along the lines of 18 kWh/d/p – not even enough to keep the heat on.


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How, then, to proceed? In Part II, *Making a difference*, MacKay uses the data he amassed in Part I to frame some possible answers to this question. There are, of course, two ways to close the gap between the red demand column and the green supply column: decrease consumption or increase production. MacKay starts with the first, and outlines how we might create more energy-efficient versions of two of the most significant energy consumers, transportation and heating. Answers: electric cars, heat pumps, and roof-mounted solar water heaters. Oh, and turn your thermostat down!

Moving on to the question of production, MacKay discusses "clean coal" and concludes that it is at best a stop-gap measure. He is cautiously optimistic about nuclear power, but acknowledges that it has serious PR issues. Perhaps his most compelling idea is a renewable energy version of our current system: buying from places that have more than you do. Europe's sustainable energy problems are rooted in the fact that it has a high population density and a low density of possible renewables. Countries such as Libya and Saudi Arabia, on the other hand, have low population density and large area for possible renewables (in particular, those countries have the space and the geography to host large solar farms). Redistributing renewable energy from places that have a lot to places that don't have enough seems a promising idea, although it will certainly not appeal to those whose interest in sustainable energy stems from a desire for energy independence.

Here we come to the book's second breakthrough moment: MacKay takes everything he's done up to this point and assembles five possible energy plans for Britain, each plan offering a different way to get the green column to stack up to the red column. This is an audacious move in any number of ways, not the least of which is that any concrete plan of action for sustainable energy is guaranteed to generate ridicule and hysteria in equal measure. MacKay is undaunted. All the plans are composed primarily of ways to increase sustainable production to meet current, or even projected, demand, with conservative expectations for reduction in consumption due to increased efficiency and new technology. All are impressively thorough, and although MacKay freely admits that "there is something unpalatable about every one of them," he argues that the alternatives—lowering demand either by reducing energy use per capita or by reducing the population itself—are likely to be far less palatable to most people.

The last two parts of the book are taken up with technical details and data. MacKay, a physicist, is no slouch at either, and the contents of these sections offer grist for even the most demanding of mills. Thermal mass, potential and kinetic energy, the physics of cars, planes, and wind power—it's all here. We get the raw data behind the first two parts, as well as sections on applying the concepts in the book to places in the world other than the UK. By the time

MacKay gets to the exhaustive lists (yes, plural) of references, the reader can be forgiven for finding them unnecessary.

The book is masterful. Comprehensive yet approachable, it is a serious treatment of a serious topic that avoids taking itself too seriously. It would be easy for such a work to become preachy, but MacKay's respect for the reader prevents this; he wants to teach us, not tell us. His voice, almost playful at times, rings clearly throughout, and both the book and the reader benefit from it.

Sir David MacKay died earlier this year, at age 48, of cancer. I did not know him. I wish that I had. His book is dedicated "to those who will not have the benefit of two billion years' accumulated energy reserves," and his concern for such people—our students, our children—is palpable. But he knew that even palpable concern would not be enough to change the world. "In a climate where people don't understand the numbers, newspapers, campaigners, companies, and politicians can get away with murder," MacKay says. To change the world we need numeracy: understanding of the numbers. MacKay's book is a giant step in the right direction.


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