

Sustainable Energy – without the hot air

David JC MacKay

This remarkable book sets out, with enormous clarity and objectivity, the various alternative low-carbon pathways that are open to us.

Sir David King FRS

Chief Scientific Adviser to the UK Government, 2000–08

For anyone with influence on energy policy, whether in government, business or a campaign group, this book should be compulsory reading.

Tony Juniper

Former Executive Director, Friends of the Earth

At last a book that comprehensively reveals the true facts about sustainable energy in a form that is both highly readable and entertaining.

Robert Sansom

Director of Strategy and Sustainable Development, EDF Energy

We have an addiction to fossil fuels, and it's not sustainable. How can we replace fossil fuels? How can we ensure security of energy supply? How can we solve climate change?

We're often told that "huge" amounts of renewable power are available – wind, wave, tide, and so forth. But our current power consumption is also huge! To understand our sustainable energy crisis, we need to know how the one "huge" compares with the other. We need numbers, not adjectives.

This book shows how to estimate the numbers, and what those numbers depend on. Taking the United Kingdom as an example, it asks first "could Britain live on renewable energy resources along?" and second "how can a country like Britain make a realistic post-fossil-fuel energy plan that adds up?" It answers these questions in detail, bringing home the size of the changes that society must undergo of sustainable living is to be achieved. It's not going to be easy to make an energy plan that adds up – but it is possible.

David MacKay is a Professor in the Department of Physics at the University of Cambridge.

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You can see the full contents and read the book free online at www.withouthotair.com

A total delight to read. Extraordinarily clear and engaging.

Chris Goodall

author of *Ten Technologies to Save the Planet*

... a really valuable contribution ... uses a potent mixture of arithmetic and common sense to dispel some myths and slay some sacred cows.

Lord Oxburgh KBE FRS

Former Chairman, Royal Dutch Shell

Engagingly written, packed with useful information, and refreshingly factual.

Peter Ainsworth MP

Shadow Secretary of State for Environment, Food, and Rural Affairs

a delight to read ... this fascinating book is a mine of quantitative information.

Dr Derek Pooley CBE

Former Chief Scientist at the Department of Energy,
Chief Executive of the UK Atomic Energy Authority,
and Member of the European Union Advisory Group on Energy

Started reading your book yesterday. Took the day off work today so that I could continue reading it. It is a fabulous, witty, no-nonsense, valuable piece of work, and I am busy sending it to everyone I know.

Matthew Sullivan

Carbon Advice Group Plc

David MacKay's book sets the standard for all future debate on energy policy and climate change.

David Howarth MP

Shadow Solicitor General, Liberal Democrats



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4 Wind

The UK has the best wind resources in Europe.
Sustainable Development Commission
Wind farms will devastate the countryside pointlessly.
James Lovelock



How much wind power could we plausibly generate?
We can make an estimate of the potential of on-shore (land-based) wind in the United Kingdom by multiplying the average power per unit land-area of a wind farm by the area per person in the UK:
$$\text{power per person} = \text{wind power per unit area} \times \text{area per person.}$$

Chapter B (p263) explains how to estimate the power per unit area of a wind farm in the UK. If the typical windspeed is 6 m/s (13 miles per hour, or 22 km/h), the power per unit area of wind farm is about 2 W/m².

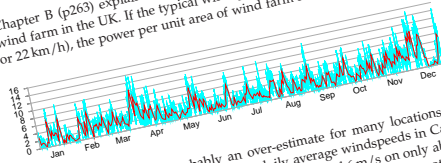


Figure 4.1. Cambridge mean wind speed in metres per second, daily (red line), and half-hourly (blue line) during 2006. See also figure 4.6.

This figure of 6 m/s is probably an over-estimate for many locations in Britain. For example, figure 4.1 shows daily average windspeeds in Cambridge during 2006. The daily average speed reached 6 m/s on only about 30 days of the year – see figure 4.6 for a histogram. But some spots do have windspeeds above 6 m/s – for example, the summit of Cairngorm in Scotland (figure 4.2).

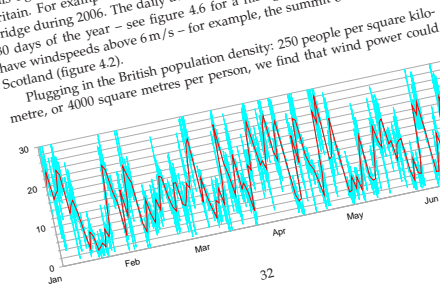


Figure 4.2. Cairngorm mean wind speed in metres per second, during six months of 2006.

Plugging in the British population density: 250 people per square kilometre, or 4000 square metres per person, we find that wind power could be delivered by a square 100 km by 100 km. An area of roughly 15 W/m². So, allowing for a safety margin, the power delivered would be 1500 GW. So the correct statement is that the desert, completely filled with solar concentrators, would produce enough power to supply every person in the world, and to supply the UK's current primary energy consumption. To supply every person in the world, the Sahara is not the only desert, so maybe it's more relevant to focus on smaller regions, and ask what area is needed in the North Sahara to supply everyone in Europe, "what area is needed in the North Sahara to supply everyone in Europe and North Africa with an average European's power consumption?" Taking the population of Europe and North Africa to be 1 billion, the area required drops to 340000 km², which corresponds to a square 600 km by 600 km. This area is equal to one and a half times the area of the United Kingdom, or to 16 Waleses.

The DESERTEC plan

An organization called DESERTEC [www.desertec.org] is promoting a plan to use concentrating solar power in sunny Mediterranean countries, and to deliver the power to cloudier northern parts. HVDC technology has been in use since 1954 to transmit power both through overhead lines and through

over 2 tons per person of stuff every year, of which about 1.3 tons per person are processed and manufactured stuff like vehicles, machinery, white goods, and electrical and electronic equipment. That's about 4 kg per day per person of processed stuff. Such goods are mainly made of materials whose production required at least 10 kWh of energy per kg of stuff. I estimate that this pile of cars, fridges, microwaves, computers, photocopiers and televisions has an embodied energy of at least 40 kWh per day per person.

To summarize all these forms of embodied energy, I put on the consumption stack 48 kWh per person for the making of stuff (made up of at least 10 kWh per kg of stuff-transport, I will put on for the making of stuff daily newspaper, 2 for road-transport; and another 12 kWh per person by sea, by road, and by

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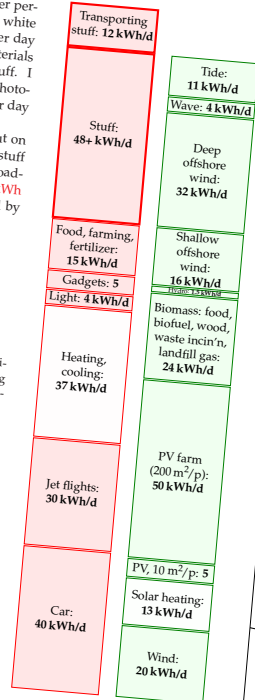


Figure 15.11. Making our stuff costs at least 48 kWh/d. Delivering the stuff costs 12 kWh/d.

able is so-mirrors or he in sev-tries, and rling en-ll deliver /m².



Figure 25.3. Stirling dish engine. These beautiful concentrators deliver a power per unit land area of 14 W/m². Photo courtesy of Stirling Energy Systems. www.stirlingenergy.com



Figure 25.4. Andasol – a "100 MW" solar power station under construction in Spain. Excess thermal energy produced during the day will be stored in liquid salt tanks for up to seven hours, allowing a continuous and stable supply of electric power to the grid. The power station is predicted to produce 350 GWh per year (40 MW). The parabolic troughs occupy 400 hectares, so the power per unit land area will be 10 W/m². Upper photo: ABB. Lower photo: IEA SolarPACES.

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