Visualizing Sustainable Energy for Hungary

David J.C. MacKay Draft 1 – November 7, 2013

Among all the **energy-supply** technologies, the four with the biggest potential today are solar power, wind power, bio-energy, and nuclear power. Deep geothermal heat and power may also have large potential, though it has yet to be demonstrated at scale in Europe. Figure 1 visualizes, for illustration, the sizes of solar, wind, bio-energy, deep geothermal, and nuclear facilities that would each supply **12 kWh per day per person**. (I am not recommending this particular energy mix; I picked equal amounts from each source so as to make it easy to see the exchange rates, and easy to visualize alternative mixes.)

Balaton	=	$592\,\mathrm{km}^2$
Budapest	=	$525\,\mathrm{km}^2$
Hungary's area	=	$93\,033\,\mathrm{km}^2$
Population	=	9.97 Million
Today's energy demand	$\simeq$	83 kWh/d/p
Today's electricity consumption	$\simeq$	10 kWh/d/p
12 kWh/d/p $\times$ 9.97 Million p	$\simeq$	5 GW

- To deliver 12 kWh per day per person from wind (for everyone in Hungary) would require wind farms with a total area of $2500\,\mathrm{km}^2$ – 4.2 Balatons – roughly a seventy-fold increase in Hungary's wind power over 2011 levels. [Assumption: Windfarms deliver roughly $2.0\,\mathrm{W/m}^2$. April 2011 capacity was 329 MW. The wind capacity required to deliver 5 GW on average would be about 22.7 GW, assuming an average load factor of 22%.]
- To get 12 kWh per day per person from nuclear power would require 5 nuclear power stations with an average output of one gigawatt – a roughly 2.5-fold increase over today's levels in Hungary. [The four power stations at Paks have a capacity of 2 GW.] On the map, these facilities are not shown to scale. They would occupy an area of about $5\,\mathrm{km}^2$.
- To get 12 kWh per day per person from bio-energy would take roughly $10\,000\,\mathrm{km}^2$ – 11% of Hungary's land area (17 Balatons), assuming energy crops have a net power per unit area of $0.5\,\mathrm{W/m}^2$. This chemical energy could replace some of today's oil and natural-gas consumption.
- To supply 12 kWh per day per person from deep geothermal sources would require, say, 500 wells each delivering 10 MW. (Get photo to visualize.) (This is nearly three times as much as the deep geothermal potential that was described as achievable in GKM 2008.) (Need to clarify whether they were delivering heat only, not electricity – I expect so.) These wells have been visualized by 500 points on the map.
- To supply 12 kWh per day per person on average from solar power (for everyone in Hungary) requires solar parks with total area of $900\,\mathrm{km}^2$ (that's 1% of the area of Hungary, or a little over 1.5 Balatons). [Assumption: solar parks in a location where the insolation is on average $3\text{–}3.5\,\mathrm{kWh/d/m}^2$ ($125\text{–}146\,\mathrm{W/m}^2$) deliver on average $5.5\,\mathrm{W/m}^2$.]
- To supply 12 kWh per day per person on average from solar power in someone else's desert requires roughly $370\,\mathrm{km}^2$ of concentrating

solar power stations (roughly two thirds of a Balaton). [This visualization assumes that concentrating solar power stations can deliver an average power per unit area of about 15 W/m^2, and that the losses in transmission are 10%.]

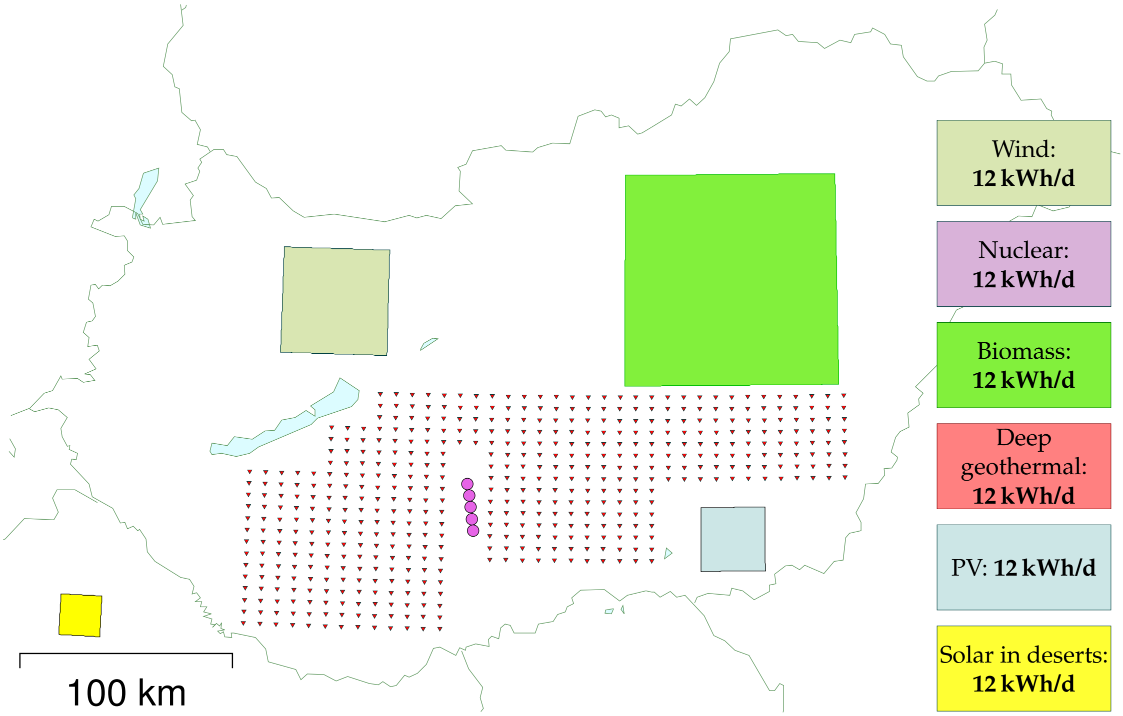


Figure 1. Visualizing sustainable energy options, on the supply side, for Hungary. Grey-green square: **wind farms**. Purple dots: **nuclear power stations** (not to scale). Light-green square: **bio-energy plantations**. (Some of these could occupy the same land as the wind farms.) Blue square in the southeast: **solar photovoltaic parks**. Yellow square in the southwest: **concentrating solar power facilities in someone else's desert**, to scale. Red dots (not to scale): **deep geothermal** facilities, each delivering 10 MW.

Of course there are other technologies I haven't mentioned in this short note, which can also contribute to a plan that adds up. Home-mounted **solar hot water panels**, for example, can easily deliver at least half of the hot-water demand of a typical family in almost all climates; **seasonal heat storage systems** might allow excess heat to be harvested in the summer and stored until the winter; and **clean coal** and **clean gas with carbon capture and storage** are crucial technologies to reduce the risks associated with fossil-fuel burning. And finally, I must emphasize that the focus on the supply side in this note does not imply that I have forgotten about demand reduction through **more efficient technologies** or **lifestyle changes that reduce energy consumption**, for example switching from car-driving to public transport, cycling, and walking; flying less; and buying less stuff.

Sustainable Energy – without the hot air

David J.C. 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

MacKay's book shows how, when it comes to energy, you too can do the simple arithmetic and learn the simple scientific facts needed to work out what energy you need and where it might come from.

Prof David Mumford
Professor of Applied Mathematics, Brown University
Member of the US National Academy of Sciences

Common sense, technology literacy, and a little calculation go a long way in helping the reader sort sense from nonsense in the challenges of developing alternatives to fossil fuels. MacKay has provided a high priority book on a high priority problem.

Professor William W. Hogan
Raymond Plank Professor of Global Energy Policy
John F. Kennedy School of Government, Harvard University

This is a complete resource for assessing the many options for choosing between different energy options and for using energy more efficiently. Teachers, students, and any intelligent citizen will find here all the tools needed to think intelligently about sustainability. This is the most important book about applying science to public problems that I have read this year.

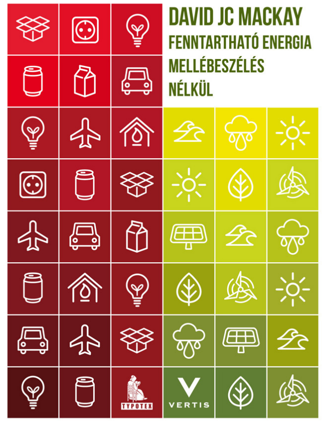
Prof Jerry Gollub
Professor of Physics, Haverford College and University of Pennsylvania
Member of the US National Academy of Sciences

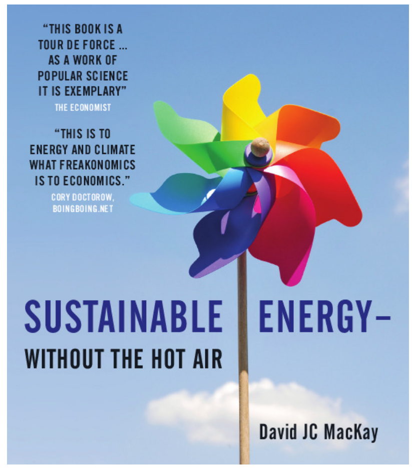
MacKay's book is the most practical, solidly analytical, and enjoyable book on energy that I have seen. This heroic work gets the energy story straight, assessing the constraints imposed by physical reality that we must work within.

Prof Tom Murphy
Associate Professor of Physics, UC San Diego

This book is a tour de force . . . As a work of popular science it is exemplary.

The Economist





"Sustainable Energy – without the hot air" was published in hardback and paperback by UIT Cambridge on 2nd December 2008 in the UK, and on 1st May 2009 in North America. The book is also available for free online at `www.withouthotair.com`.

A könyv fordítását Dr. Both Elöd készítette, a magyar kiadást a Vertis Környezetvédelmi Pénzügyi Zrt. gondozza. ISBN: 978-963-2795-75-1 EAN: 9789632795751

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