Without smart demand management, the expansion of wind and nuclear will not work.

'Future Grid' Draft 1.1, September 12, 2009 — David J.C. MacKay

Wind fluctuates.

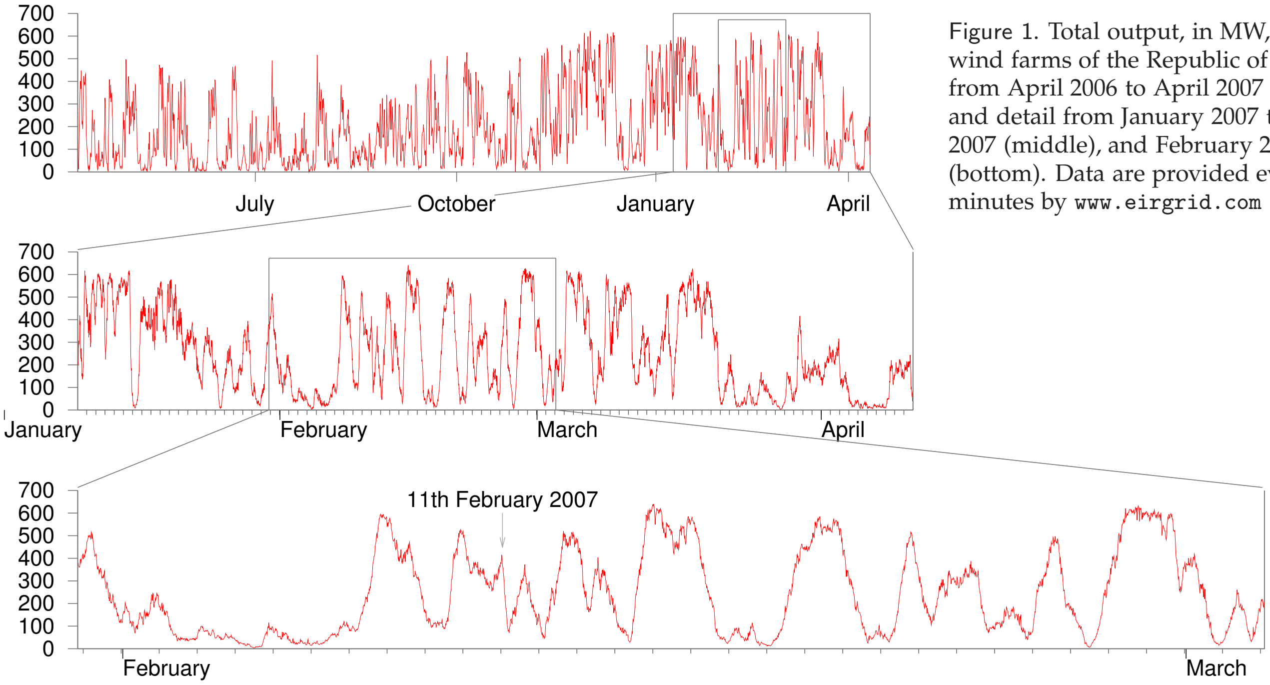

Figure 1. Total output, in MW, of all wind farms of the Republic of Ireland, from April 2006 to April 2007 (top), and detail from January 2007 to April 2007 (middle), and February 2007 (bottom). Data are provided every 15 minutes by `www.eirgrid.com` .

Demand fluctuates.

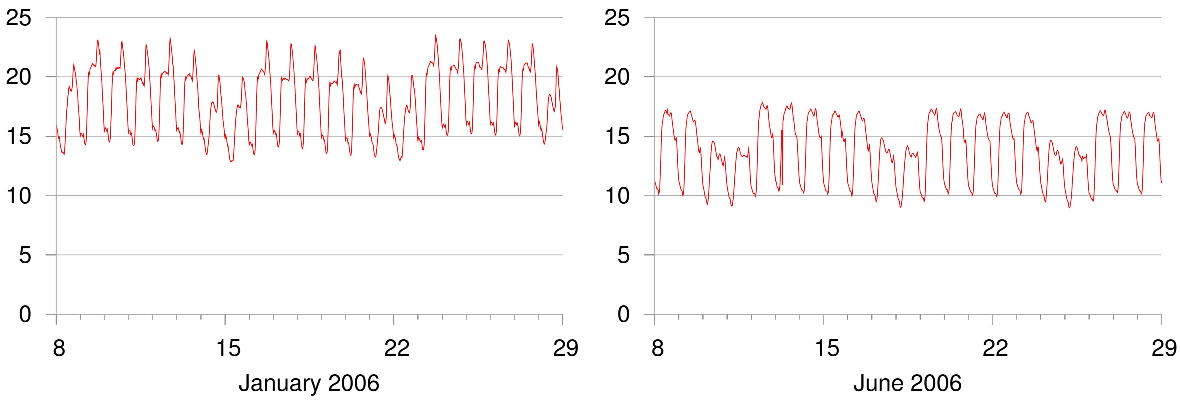

Figure 2. Electricity demand in Great Britain (in kWh/d per person) during two winter weeks and two summer weeks of 2006. The peaks in January are at 6pm each day. The five-day working week is evident in summer and winter.

Nuclear gives best value if it runs near capacity all the time.

Without fossil fuel power stations, the only dispatchable power sources will be hydroelectricity, and biomass power stations (including landfill-gas and other waste-to-energy).

Transport and heating need to be largely electrified.

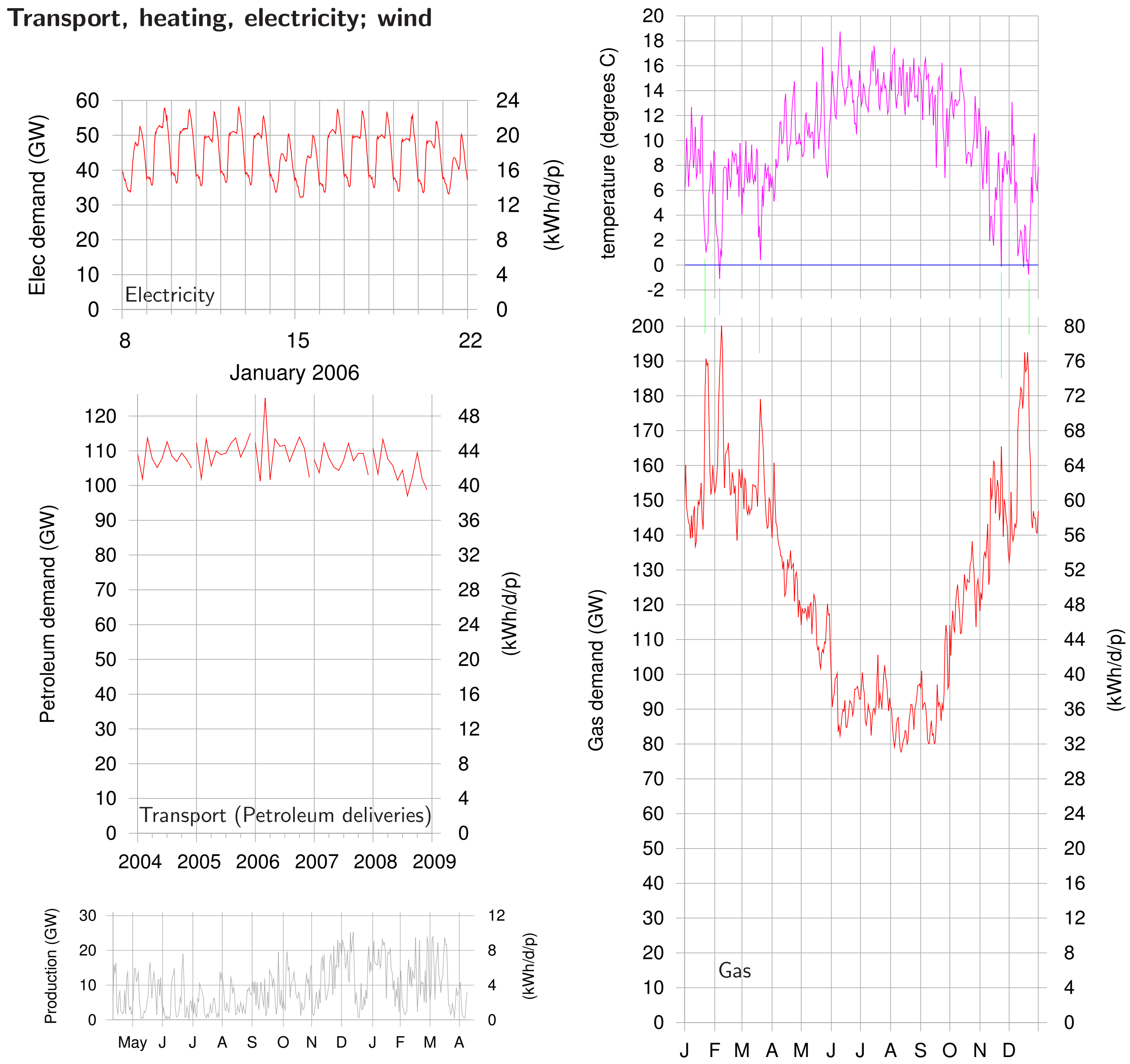

Figure 3. Electricity, gas, and transport demand; and *fictional* wind (assuming 33 GW of capacity), all on the same vertical scale.

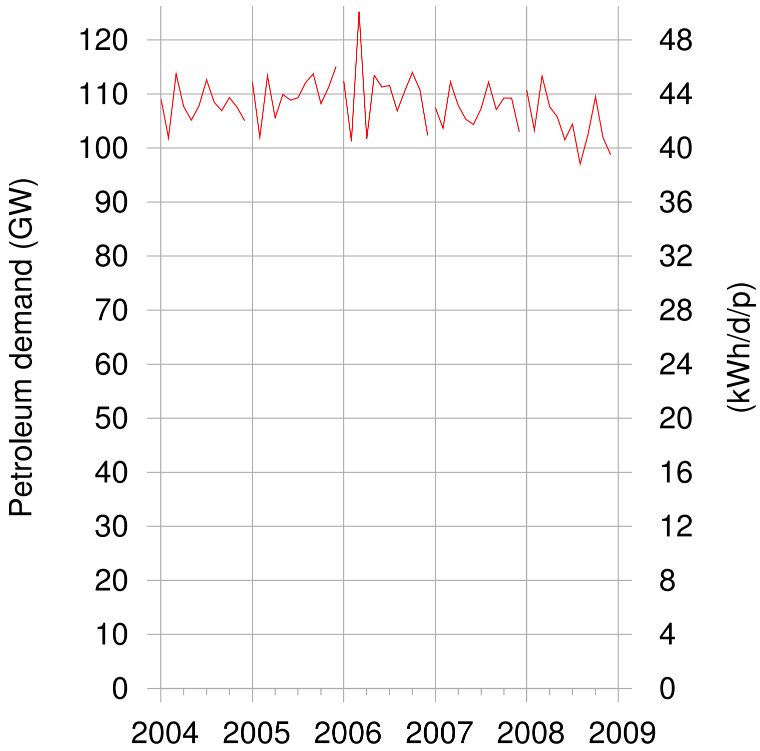

Figure 4. Transport demand, in GW, monthly, 1998–2008. Source: Petroleum Deliveries for Inland Consumption, DUKES, DECC.

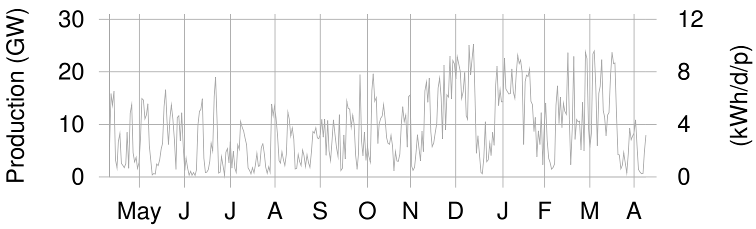

Figure 5. Total output of Irish wind farms scaled up by a factor of 33/0.745 to represent the output of 33 GW of UK wind capacity. (Ireland's wind "capacity" in 2007 is 745 MW, dispersed in about 60 wind farms.)

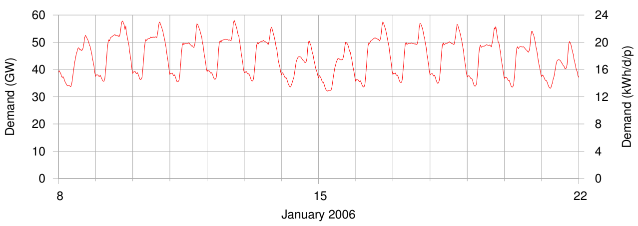

Figure 6. Electricity demand in Great Britain during two winter weeks of 2006. The left and right scales show the demand in national units (GW) and personal units (kWh/d per person) respectively. These are the same data as in figure 2.

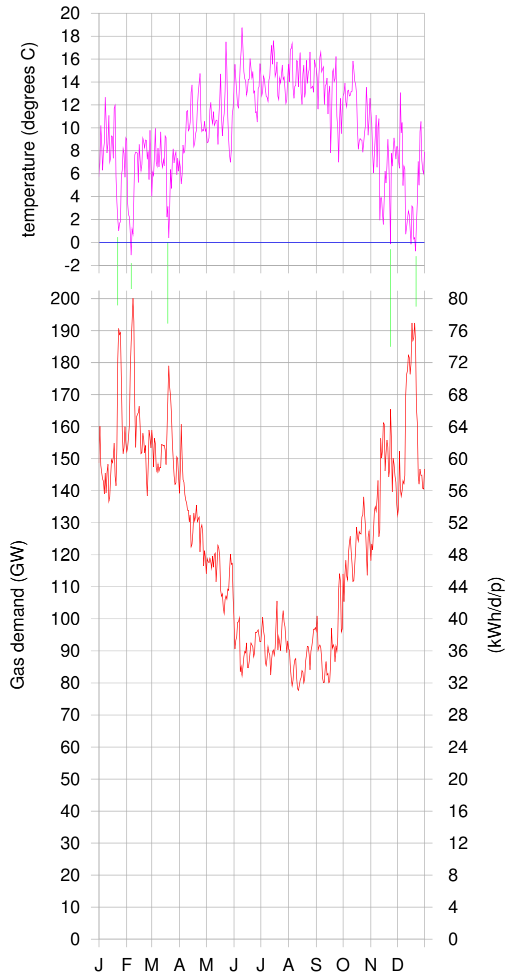

Figure 7. Gas demand (lower graph) and temperature (upper graph) in Britain during 2007.

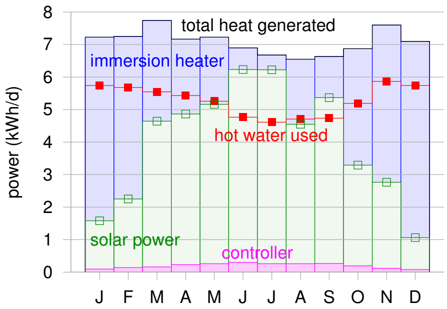

Figure 8. Solar power generated by a 3 m² hot-water panel (green), and supplementary heat required (blue) to make hot water in the test house of Viridian Solar. The average solar power from 3 m² was 3.8 kWh/d. The magenta line shows the electrical power required to run the solar system. The average power per unit area of these solar panels is 53 W/m².

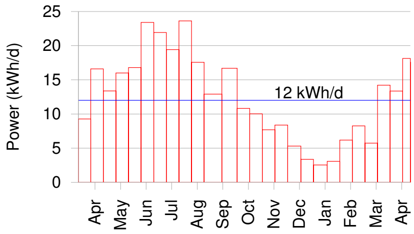

Figure 9. Solar photovoltaics: data from a 25-m² array in Cambridgeshire in 2006. The peak power delivered by this array is about 4 kW. The average, year-round, is 12 kWh per day. That's 20 W per square metre of panel.

Other energy sources

Other storage options

Seasonal heat stores

Virtual storage

Britain has a 2 GW interconnector to France. We could plausibly build 5 GW of interconnectors between Britain and Norway (with cables from both Scotland and England); perhaps 1 GW to Denmark; and perhaps a 1 GW interconnector to Iceland, assuming that Iceland would increase its hydroelectric capacity.

Figure 10. Laying a high-voltage DC link between Finland and Estonia. A pair of these cables transmit a power of 350 MW. Photo: ABB.

Figure 11. Marchlyn Mawr, the upper reservoir of the Dinorwig pumped storage facility. See Chapter 26 (pages 186–194) for further information.

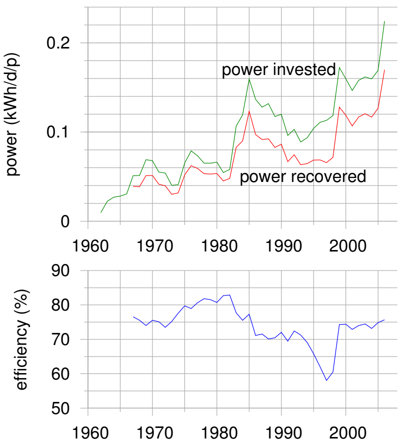

Figure 12. Efficiency of the four pumped storage systems of Britain.