Shale Gas In Perspective

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Draft 0.2 – Wed 14/8/13

1 *Shale Gas In Perspective*

How would the footprint of a shale gas operation compare with the footprint of other ways of delivering a similar quantity of energy? There are many dimensions to a "footprint" – the aspects considered in this note are **land area**, **vertical height**, and **vehicle movements**. Other aspects that one might also consider include environmental impacts such as noise, water, tremors, and carbon emissions, but those aren't addressed in this note.

Figure 1.1. Wytch Farm, on the perimeter of Poole Harbour in Dorset, is the largest onshore oil and gas field in the UK, and is also Western Europe's largest onshore field. The field was discovered in 1978, production ramped up in 1989 and peaked in 1996. Up to and including 2011, it had produced 81 bcf of gas and 59 Mt of oil. Wytch Farm is located in an Area of Outstanding Natural Beauty. The photograph shows the 34-metre-high extended-reach drilling rig, from which boreholes longer than 10 km have been drilled.

A shale gas operation

An illustrative shale gas operation is described by Taylor and Lewis (2013). A single 10-well pad of 10 laterals could produce 0.895 bcm (31.6 bcf; 9.5 TWh) of gas over 25 years, and would involve roughly 2900 truck movements (most of them in the first two years), assuming water is delivered by a mains connection, not by truck. For comparison, UK natural gas demand today is roughly 85 bcm (3000 bcf; 900 TWh) per year, and in 2011 the UK's net gas production from the UK continental shelf was about 42.5 bcm (1500 bcf; 450 TWh) per year. The pad might occupy 2 hectares (not including the land area for water storage) and would have a single drilling rig, 26 m high. To roughly estimate an "area of visual influence", I've computed the land area within which this rig would be higher than an angle of θ (eg, 3°) above the horizon, assuming a flat landscape. The area, for a single rig of height h, is

$$A_{\text{v.i.}} = \pi \frac{h^2}{(\tan\theta)^2}$$

For $h = 26$ m and $\theta = 3°$, $A_{\text{v.i.}} = 77$ ha. The rig might be in place for only the first few years of operations.

A wind farm

A fairly typical British windfarm is Red Tile wind farm, which consists of twelve 2-MW turbines with a hub height of 59 m and a turbine diameter of 82 m (thus a tip height of 100 m), situated in an area of 2 km^2 (200 ha) of farm land. The area of visual influence for a single turbine of this height $h = 100$ m, taking $\theta = 3°$ again, is 1100 ha; the area of visual influence of a windfarm of area A is roughly πr^2 where $r = h/\tan\theta + \sqrt{(A/\pi)}$, which comes to $A_{\text{v.i,}} = 2300$ ha for Red Tile windfarm. Red Tile's average output is about 6 MW, which is 25% of its capacity of 24 MW. So to match the average output of the shale gas pad (43.3 MW), roughly seven Red Tile windfarms would be needed, occupying roughly 1450 ha (14.5 km^2). If these roughly-seven windfarms were all of the same size as Red Tile then the area of visual influence would be about 17 000 ha. If, on the other

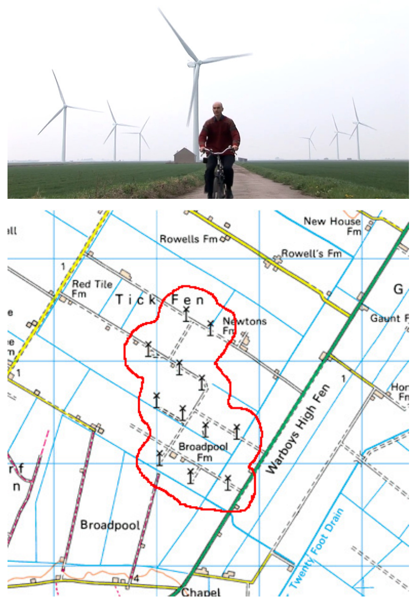

Figure 1.2. Red Tile wind farm, East Anglia, and its associated land area. The blue grid's spacing is 1 km. Each turbine has a diameter of 82 m and a capacity of 2 MW. Map © Crown copyright; Ordnance Survey.

	shale gas pad 10 wells, 10 laterals	wind farm (87 turbines, 174 MW capacity)
energy delivered over 25 years	9.5 TWh chemical energy	9.5 TWh electrical energy
average power output	43.3 MW	43.5 MW
number of drilling rigs or turbines	1	87
height of drilling rig or turbine	26 m	100 m
land area	2 ha	1450 ha
of which area actually occupied by turbine-foundations and roads		36 ha
"area of visual influence"	77 ha	5200–17 000 ha
truck movements	2900	435 *minimum*

Table 1.3. Comparison of a shale gas pad with wind farms having equivalent average power output. *(More to come here.)*

hand, 87 turbines with a capacity of 174 MW were arranged in a single large windfarm then the area of visual influence would be about 5200 ha.

I don't yet have a source for the number of truck movements required for a wind farm. The number in the table (435) is a minimum, assuming five movements per turbine, but if building materials must be brought in for foundations and roads then the number could be much larger.

Comments and clarifications

The comparison in table 1.3 is based on deeming 1 kWh of electrical output from the wind to be 'equivalent' to 1 kWh of chemical energy in the form of gas. This is the conventional equivalence used for example in DUKES and in MacKay (2008). The following differences between the energy sources should be noted.

1. The two sources of power have different profiles of power generation. On an annual scale, a single shale gas well produces most power when it is newly fractured, whereas a wind farm produces a relatively constant average power over its life. On an hour-by-hour scale, the gas from the well is dispatchable – its flow can be turned up and down at will – whereas the power from a wind farm is intermittent.

2. In a world in which the only conceivable use for gas is making electricity in a power station with an efficiency of about 50%, one might prefer to deem each 1 kWh of gas as 'equivalent' to just 0.5 kWh of electricity.

3. On the other hand, in a world that values gas highly relative to electricity that is generated at times when the wind blows, one might imagine planning (as Germany is said to be planning) to use electricity from wind farms to synthesize methane with an efficiency of

38–48%; then one might deem each 1 kWh of wind-electricity as being 'equivalent' to 0.38–0.48 kWh of gas.

4. If one wished to make a comparison in which both power sources are constrained to have very low carbon emissions, the shale-gas well must be accompanied by other assets. For example, if the gas is sent to a power station that performs carbon capture and storage, the gas-to-carbon-free-electricity efficiency might be about 42%, and the land area for the power station and the carbon transport and storage infrastructure should be included; assuming that these assets have an area-to-power ratio of 100 ha per GW(e) (DJCM's very rough estimate, no source), each 43.4-MW gas well (which would yield 18.2 MW of electricity) would require an extra 1.82 ha of land, which roughly doubles the 2-ha land area mentioned in table 1.3.

Further wind data

See figure overleaf.

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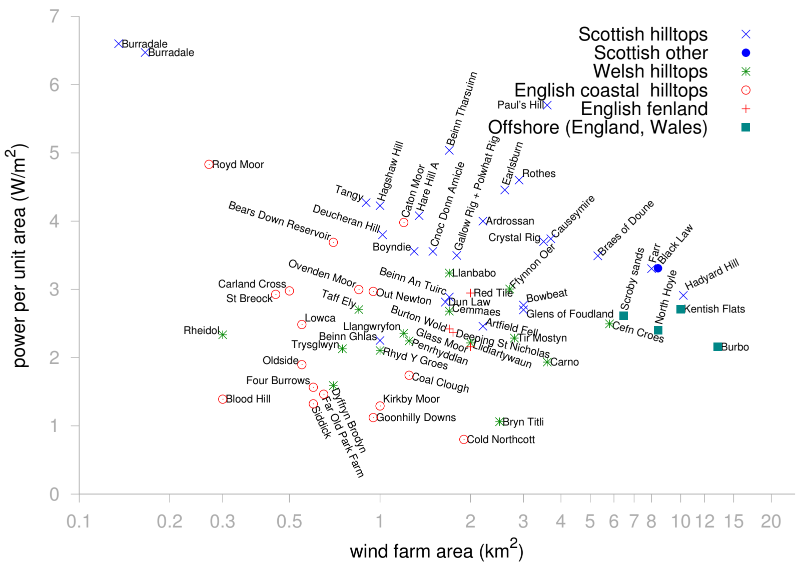
(a)



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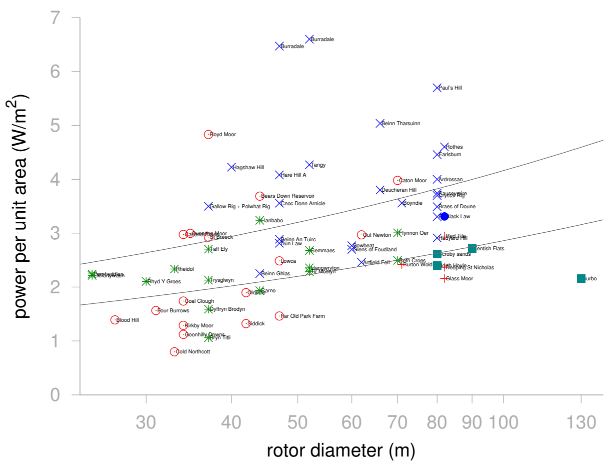

Figure 1.4. (a) Power per unit area of UK windfarms versus their size. The horizontal scale is logarithmic. (b) Power per unit area versus turbine diameter. The horizontal scale is logarithmic. The black curves in (b) show the trend that would be expected (within any single region) on the basis of the rule of thumb "doubling turbine size increases wind-speed by 10% and increases power by 30%", and assuming wind turbines' spacings are proportional to their diameters. From MacKay (2013).