A letter in the Financial Times gave an opportunity to clear up some confusions about wind power. I must confess to having felt rather pleased with myself when I compressed what I thought needed to be said into a 700 word letter to the editor. I took advice on the draft, and soon learnt from John French, William Stanton and Martin Desvaux, among others, that the exposition would be too cryptic even for the cerebral readers of the FT. What follows will, I hope, make for easier reading, and perhaps will serve as a basis for pieces by other organizations aiming to encourage realistic thinking about wind. I advise them not to try to compress the ideas into 700 words, although they may improve on the following 1900 plus spreadsheet!

GETTING THE MEASURE OF WIND

by Andrew R.B. Ferguson

Abstract: A realistic way to express what 1 MW of rated wind capacity will do in the UK is to say that it will provide 20% of the electrical demand for 1600 people. The reason for putting the limit at 20% is because it is impossible, in the UK and USA, for wind to *ever* supply more than 20% of average total demand. It is also important to note that, in the UK, using wind turbines actually *increases* fossil fuel use by 20%. For the USA, data are less firm, but the 1600 figure is likely to be around 800 people; see Table 2 page xx.

A faulty measure

In a letter to the Financial Times, 29 December 2004, C.J. French correctly depicted the usual measure of wind output as "ridiculous." This is an example of what he complains about, taken from *Renew* 153 (p. 9), the bimonthly newsletter of the Energy and Environment Research Unit of the OU. It referred to: "A 234 turbine wind farm with a capacity of 702MW that would supply enough green energy to meet the average electricity needs of around 1.1 million people."

Let us start by seeing how realistic that is. The UK uses about 45 GW of electricity, so with 60 million people, each person uses, directly and indirectly, 0.75 kW. As an average, UK wind turbines would feed into the grid 24% of their rated capacity. Thus 702 MW of rated capacity would — when spread around 1.1 million people — provide each person with 0.15 kW. Were the 702 MW installation mentioned above to be just a standard installation (actually it is in a particularly windy site), it would provide 1.1 million people with 20% (0.15 / 0.75) of their average electrical demand, not the 100% indicated.

Dividing the work between the wind turbines and the dominant in-harness backup.

We can work towards a better measure by first making a calculation based on 1000 MW (1000 million watts or 1 million kW) of rated wind turbine capacity. Then, of course, we can divide by 1000 to determine how usefully each MW of rated capacity of wind turbine satisfies electrical demand.

To tackle that, one needs first to know the 'infeed factor', that is the ratio of the amount of electricity fed into the grid, in the course of a year, in comparison to the rated capacity. Using figures based on Renewable Obligation Certificates, the Renewable Energy Foundation calculated infeed factors of 25% for Scotland, 24% for England, and 23% for Wales (*Renew* 153, p. 16). The DTI gives an overall figure of 24.1%. We will use a round 24% for this calculation. It only serves for the UK and USA, but can easily be adjusted for other infeed factors, as is apparent from the spreadsheet on page xx).

In their *Wind Report 2004*, the grid company E.ON Netz GmbH, which covers over 40% of Germany's wind installations, with their grid spanning a distance of 800 km across

Germany, from Denmark to Austria, gave a statistic for their *peak* infeed factor. The *peak* infeed factor was 80% — that is 80% of the total rated capacity.

The *peak* infeed factor (80%) together with the infeed factor (24%) allow us to say how much electricity can be supplied by wind power and how much will have to be supplied by 'dominant in-harness backup' (N.B. the implicit meaning of 'infeed factor' is that it is the average, or as mathematicians prefer to say the 'mean' value, *over a year*). A more common word for the plant which operates in conjunction with wind turbines is 'backup'; the phrase 'shadow power station' is also used, but neither of these terms fully covers the function of the flexible plant that is operating 'in harness' with the wind turbines. Moreover, as we will see, it is the so-called backup which has to do most of the work. The phrase 'dominant in-harness backup', or 'DIB' for short, serves as a constant reminder of the true function of 'shadow power stations'

The 'dominance' of the dominant in-harness backup is apparent from the fact that with a 24% infeed factor, the wind turbines will be able to satisfy (100 / 0.80) x 0.24 = 30% of the total supply. The remaining 70% will have to be covered by 'dominant in-harness backup'. Perhaps that needs some amplification. If a widely spread group of wind turbines sometimes produce 80% of their rated capacity, then if our aim is to produce 100 MW, then we can install 100 / 0.80 = 125 MW of rated capacity. That 125 MW of rated capacity, at an infeed factor of 24%, will produce 125 x 0.24 = 30 MW. In order to flatten out the 100 MW that we are aiming to supply — rather than just supply it on those odd occasions when the wind is optimum over the whole area, and 80% of rated capacity is being produced— we need to fill in the remaining 100 - 30 = 70 MW from a flexible power source using the dominant in-harness backup.

Dividing the *total* supply

We have now defined what the wind turbines can do in the process of producing a steady output. In UK wind conditions, where a 24% infeed factor can be expected and an 80% *peak* infeed factor is a good guesstimate, wind, as noted, can provide 30% of that steady supply while the dominant in-harness backup provides the other 70%. But we consumers don't want just a steady supply. We tend to use much more electricity by day than by night, and there are many other factors which cause almost every day to be different. The operators of grids have become skilled at forecasting demand, but of course wind turbines can play no part in satisfying the demand according to the forecast. Indeed E.ON Netz demonstrated, in their report, that wind is often absent at the very time that it is needed, namely extreme heat or cold. Thus while wind, operating in conjunction with a DIB, can provide a steady demand, there has to be 'sitting on top' (as it might be called with a graph in mind, see OPT Journal 4/1, p. 25) a further flexible power supply.

So how can we decide how much has to be 'sitting on top'? The essential point is that it would make no sense to install so much wind power that when it was producing at its *peak* infeed factor it was producing more than the 'valley' demand of the grid. The 'valley' demand is the opposite of the *peak* demand. As a rough estimate, one can say that about a third of total electrical demand falls above the 'valley' demand. In other words, the wind, helped by its dominant in-harness backup, can be designed to satisfy *two-thirds* of the total demand. Since the wind itself satisfies only 30% of that two-thirds, then looking at electrical supply as a whole, wind, of the type experienced in the UK and USA, can only satisfy 0.30 x 0.66 = 20% of the total electrical demand.

That is an important point because it gives us a clue as to the right answer to the question that John French posed. When attempting to express simply and realistically what a specific group of wind turbines can actually do, it is necessary to say how many people will be satisfied *as to 20% of their electrical demand*. As French points out, it is ridiculous to say that wind can supply any given number of people with 100% of their demand. Claims become less and less ridiculous as the percentage claim is reduced. At 20% the claim actually becomes realistic!

The answer to the question posed by John French

We can now pick up our calculation based on 1000 MW of rated capacity of wind turbines. At a 24% infeed factor, 1000 MW of capacity will produce 240 MW of wind power. The 'dominant in-harness backup' will have to provide the remaining 240 x (70 / 30) = 560 MW (for a total of 800 MW, the *peak* infeed of the turbines).

You will recall that each person has a demand for 0.75 kW. We have also determined that only two-thirds of this can be satisfied by the wind combined with its dominant in-harness backup. Thus the wind with its dominant in-harness backup can satisfy 0.75 x 2/3 = 0.50 kW of each person's total demand.

So now we can determine how many people can be satisfied by 800 MW, or 800,000 kW, produced by wind and dominant in-harness backup when it is providing 0.50 kW to each person. The answer is 800,000 / 0.5 = 1.6 million people, but we must not lose sight of the fact that wind is only providing them with 20% of their total supply.

That is really all we need to know, although for future use it may be more helpful to divide by 1000 and express the output per MW of rated capacity of the wind turbines, and say that *1 MW of rated capacity of wind turbine will, under the wind conditions we have posited, satisfy 1600 people to the extent of 20% of their electrical demand.*

Other considerations.

Although we have arrived at a full answer to the question posed by John French, and we may reasonably hope that journalists will gradually be weaned away from their infantile descriptions of wind potential, there is another important point to note about using wind as a renewable energy source.

In the UK, the dominant in-harness backup is almost certain to be provided by open cycle (conventional) gas turbines. In order to operate 'in harness' with wind power, they are almost the only flexible plant with a sufficiently rapid response time. Their mean efficiency is about 40%, which would be somewhat degraded by having to operate in harness with wind power.

The alternative is to not use wind power at all. Since we are only seeking to replace a steady infeed, amounting to two-thirds of total demand, we could use Combined Cycle Gas Turbines (CCGT). They are very inflexible, and need to be kept going at a steady output, but that is just what we are trying to obtain, so they are ideal, and we can take advantage of their high efficiency of about 60%. The overall result is that the first option, that is using wind combined with dominant in-harness backup, *uses about 20% more fossil fuel than would be used by forgoing the wind turbines* and just using CCGT (Table 3, p. xx)

I made this point broadly in a one page piece in *Renew* 153, p. 22, but that was before I knew about *Wind Report 2004* from E.ON Netz. That report has made it possible to me to be more quantitative, and say that using wind turbines increases fossil fuel use by 20%.

There were attempts, on the opposite page, to refute my argument, but when inspected closely, it was apparent that none of them were addressing the point at issue. They were saying, well perhaps there were other ways of accommodating the intermittency of wind. Perhaps one could use pumped storage. Perhaps batteries would improve. Perhaps biomass would come to the rescue. But apart from the fact that none of those suggestions stand up to scrutiny, none of them are actually happening, so the fact remains that, *in practice, using wind turbines increases fossil fuel use by 20%.*