primary research

I have mentioned this chapter in other parts of the book and my main idea when I started the research was to find out if the preconceptions I held about my home-generation system were correct or whether they were a pile of horse manure five feet deep. This is not a laboratory-style research project and so includes all the imprecise elements of a real interactive system. I will try to highlight the areas where external forces have influenced the results, and this in itself may give greater understanding of how a combined wind and solar generation system works. It is worth noting that my system is situated at 53° latitude and so day length in the heart of winter is quite short, as can been seen from fig 20 (page 63).

study questions

1. We have already said that if the site is wrong for wind power then forget it. However if the site is right then do you:

    - go for one large, expensive turbine and a large tower, or
    - have a series of smaller turbines that are less obtrusive with towers are that are lighter and less expensive?

2. Having decided to fit photovoltaic solar panels, do you:
    - fit tracking for extra output, or
    - fix the orientation and spend the cash that would have gone on tracking on extra panels?

3.
    - what output do you actually get from panels and turbines,
    - what are reasonable expectations?

the systems studied

System A consisted of a 48 volt wind and solar battery system with:

- 1 x Proven 2.5 kilowatt (kW) 48 volt wind turbine
- 1 x 48 volt sun-tracking solar panel array containing 4 x 12 volt Kyocera 130 watt panels giving 520 watts of installed capacity
- 1 x 48 volt fixed solar panel array containing 2 x 24 volt Kyocera 200 watt panels giving 400 watts of installed capacity

- 1 x 48 volt lead acid, deep-cycle traction battery pack of 1500 Ah

This is the system that provides power for our home and the Ecolodge that we built a few years ago in the Home Fields Meadow.

System B consisted of a 24 volt wind battery system with:

- 1 x FuturEnergy 1kilowatt (kW) 24 volt turbine
- 1 x 24 volt lead acid deep-cycle traction battery pack of 1000 Ah

fig 65: recording watt meter

This system also had 750 watts of photovoltaic panels, the output of which was not monitored. It belongs to a mate of mine, Alan McDowell who, like me, is a backyard technologist and inveterate tinkerer with mechanical and electrical technology. I take time to thank him for his patience and considerable contribution to this research.

the turbines

The two turbines used in this study are totally different in that the FuturEnergy one is small, lightweight and relatively easy to install. The Proven is much larger, heavier, more robust and difficult to install.

- the FuturEnergy turbine has five composite blades which are less than 2 metres in diameter and mounted in an adjustable hub. The blades and generator can be bought separately and mounted on a home-produced chassis, or the whole thing can be purchased as a package, including the mounting pole. The brushless, permanent-magnet generator produces three-phase alternating current electricity. It is an upwind turbine and uses a folding tail as a speed and output regulator.

- The Proven turbine comes from a family with three generator sizes: 2.5, 6, and 15 kilowatts, all of which are downwind machines with furling blades for speed and output regulation. The three blades used to be made of polypropylene, but the improved twintex blades are now made from a composite of materials. Anyone with a 2.5 kilowatt turbine that has the old-style blades should try to replace them with the new blades because my investigations have shown that the old blades only produced 1.5 kilowatts, whereas the new blades will produce 2.5 kilowatts, although they are operating at 360 rpm, which is above the rated output speed given by Proven. The design is very robust with greaseable main and pivot (yaw) bearings, and three-phase alternating current output from the brushless permanent-magnet generator.

data recording

The outputs of each of the separate charging elements were recorded using watt meters showing total watt hours produced. The outputs were recorded separately on a weekly basis, on Friday afternoon just after tea. The recording meters were provided and subsidised by Eltime Controls, see *resources* (page 177), and are fitted to the direct current input side of each charging system. The meters take their signal from a shunt wired into the positive power cable. The supply to run the meter-recording circuitry is separate and can either be battery voltage or mains voltage from mains or inverter. I bought meters that are run from the battery

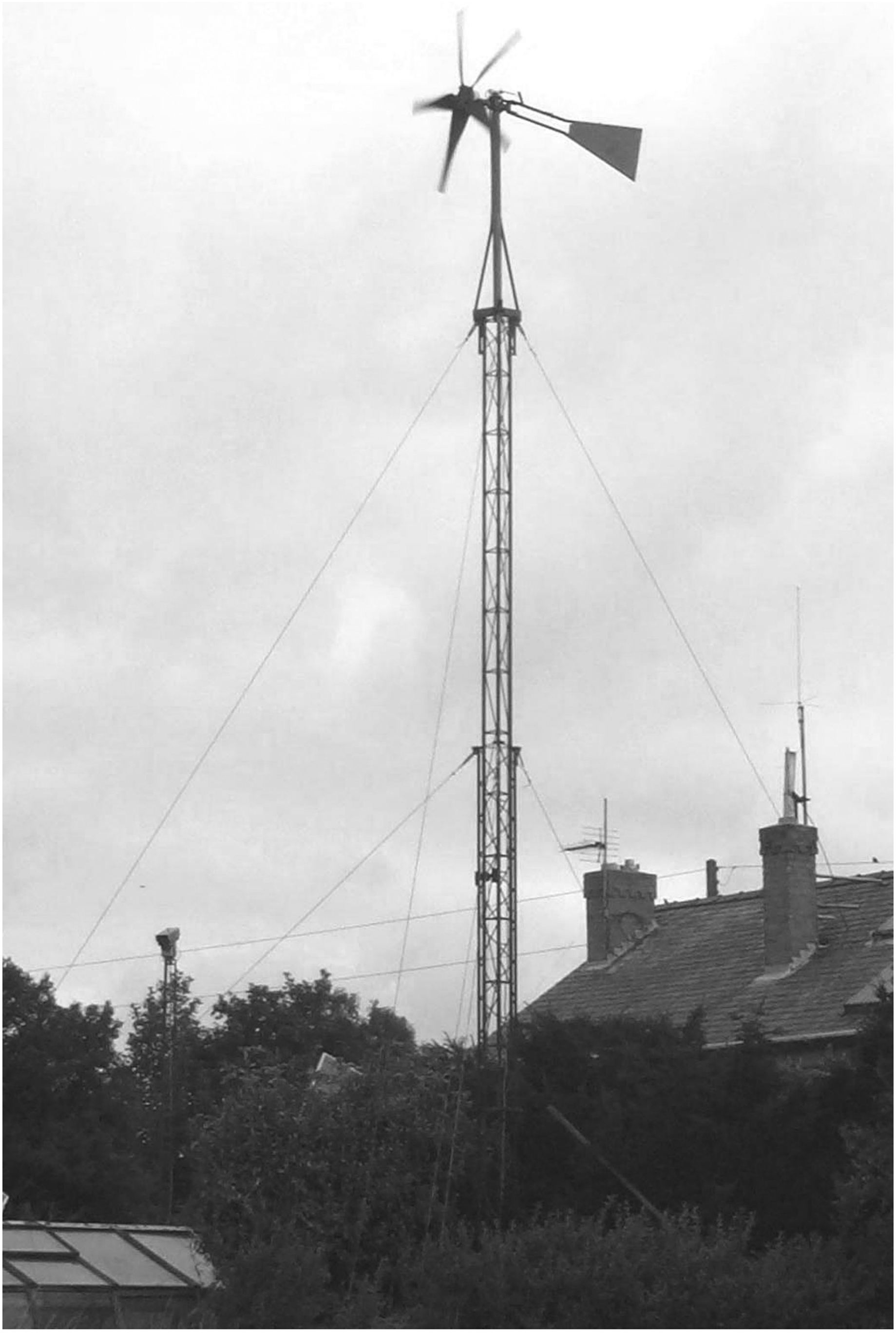

fig 66: FuturEnergy 1 kilowatt turbine on a 12 metre mast

pack, which in retrospect was not a good idea because it means that any unusual battery voltage spikes can damage the meter. This happened with the FuturEnergy 24 volt system; the meter was repaired but a voltage regulator was also fitted just to make sure. It would have been better to have the meter on 240 volt mains supply.

study duration

It was important to ensure that the research covered at least the cycle from shortest day to longest day. The first readings were taken on the 28th December 2007 and continued until 1st August 2008. The study continues and the results will be updated in future editions.

preconceptions

For the solar panels it was thought that the tracked panel array would give much more power than the fixed array. The difference would be more evident in summer than in winter due to the longer days and the greater movement of the sun across the sky. It was considered that the difference would be in the order of 50 per cent.

The solar panels are of different installed capacities and so allowance is made for this when comparing results by increasing the fixed panel output figures by 30 per cent.

For the wind turbines we worked on the fact that the Proven turbine was expensive and had to be installed by a Proven installer at a cost in the region of £9000 without batteries, inverter etc. The FuturEnergy turbine cost approximately £700 with a pole for a tower, delivered but not fitted.

For the sake of argument, taking into account that a different tower from the one supplied may well be required for the FuturEnergy turbine and that the system would need to be fitted, it was assumed that at least five FuturEnergy 1 kilowatt turbines would cost about the same as one Proven 2.5 kilowatt turbine. This is very vague, but it doesn't matter as it gives a base line for comparison purposes only. You could use the poles provided with the FuturEnergy turbine and wire everything up yourself in which case the add-on costs would be half nothing, but you could get a contractor to fit everything and incur labour and new materials costs.

fig 67: Proven 2.5 kilowatt turbine on a 15 metre mast

results

wind turbines

The first graph shows the Proven and the FuturEnergy turbine outputs. You will notice that the Proven's output seems to improve after mid-April. This is because new, improved blades were fitted under warranty from Proven. The standard blades fitted to this turbine only produced 1.5 kilowatts and were very noisy. It was interesting that after the new blades were fitted we had six days of unprecedented calm, with not a breath of breeze. This is the type of thing that happens when you are keen to get results, and Jack Park, see *resources* (page 177) warns wind turbine builders against impatience that he calls 'fireitupitis' – a phrase I have borrowed and used a few times already.

The second graph shows the Proven output compared to the FuturEnergy output multiplied by a factor of 4.

As you can see the outputs of both systems converge beyond April. I can hypothesise that the cause for some of the differences before this date is that the Proven continues to give greater output in higher wind speed because it is a downwind machine. The FuturEnergy is an upwind machine and the blades move out of the wind to regulate the output in higher winds and so considerably reduce output. It seems that the outputs only converge in moderate to low winds.

solar panels

As you will remember, we expected the tracked-panel array to give up to 50 per cent more power in the summer months. This seemed to be the case as you can see from the graph below.

The third graph, fig 70 shows the actual output of both solar panel arrays. There is a problem when interpreting these results as the fixed panels have a smaller installed capacity than those on the tracking system and the results for this array need to be adjusted by 30 per cent so that we can make a useful comparison. This gives a considerably different set of results as can be seen in the next graph, fig 71. As you can see there are still some large differences, but the major output

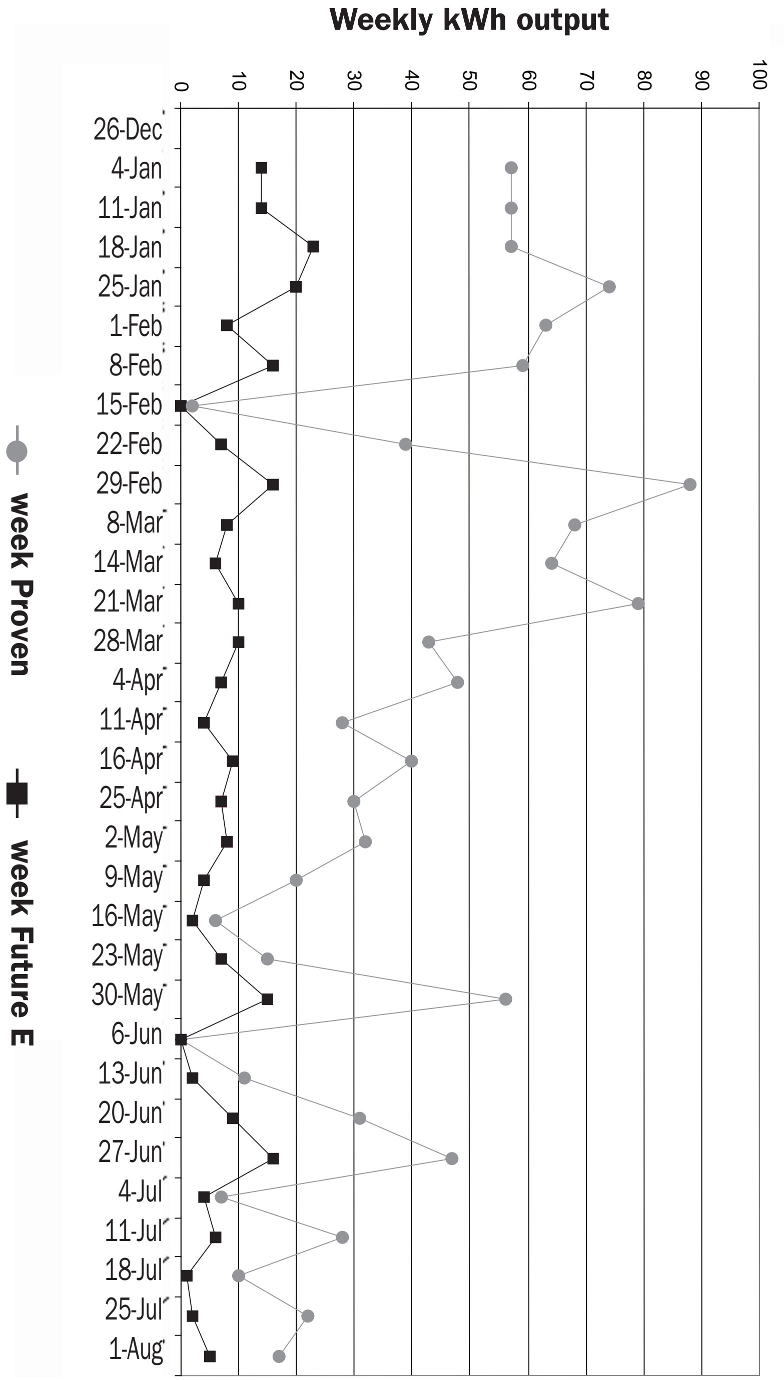

fig 68: Proven 2.5 kilowatt turbine and FuturEnergy output by week

improvements from the tracking are only seen when there is good bright sunshine. In fact the correlation between the two sets of figures for the duration of the study comes out at 0.95, which shows that both panel arrays were responding to the variations in sunlight in a very similar fashion. The output of the tracking panels and the adjusted fixed panels were 394 and 325 kilowatt hours respectively for the period, which gives a difference of 69 kilowatt hours. In other words there is 17.5 per cent improvement in output by using tracking at this latitude for the period studied.

The next question is about the cost of tracking in relation to the cost of more panels, and the amount of maintenance needed for the tracking.

To try and see what the differences would be under brighter conditions we could take the figures from a series of high output weeks. If we average these out we could then get an idea of the average summer increase of output from the panels on the tracking system in parts of the temperate world were there is a greater proportion of summer sun.

See the following chart:

	solar tracking kWh per week	solar fixed kWh per week	solar fixed (x 30 %) kWh per week
09-May	25	13	16.9
23-May	21	12	15.6
13-Jun	18	12	15.6
20-Jun	18	12	15.6
04-Jul	21	13	16.9
25-Jul	27	12	15.6
total	130		96
average	21.6		16

fig 69: selected high solar output weeks

As we can see the average increased output from solar panels on a tracking system and from fixed solar panels in bright sunlight are 21.6 and 16 kW hours per week respectively. This means that the tracking system gives 35 per cent more energy under these better conditions. So

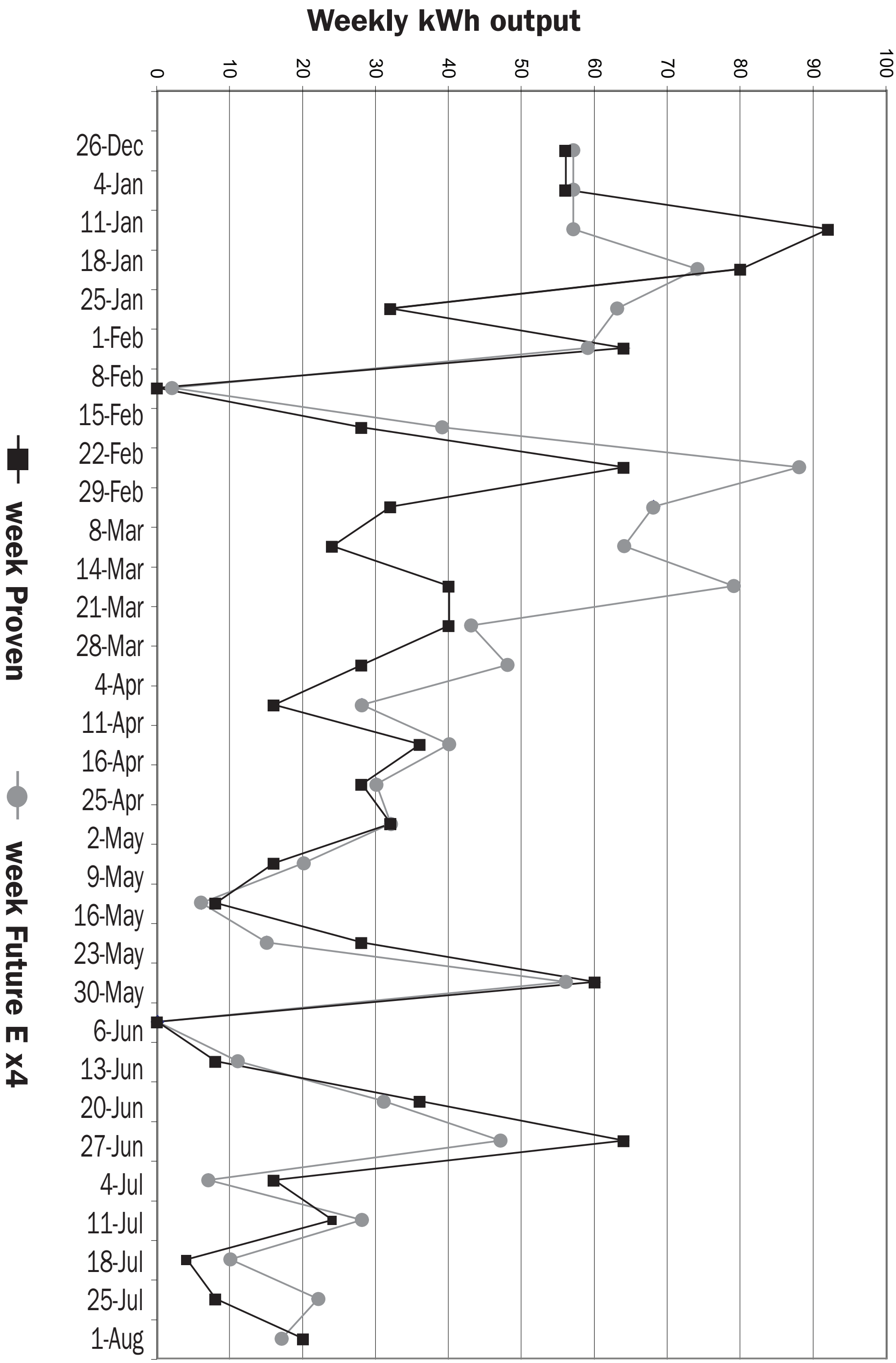

fig 70: Proven 2.5 kilowatt turbine compared with four FuturEnergy 1 kilowatt turbines

if you live in an area where there is blazing sunshine all day long you will get at least 35 per cent more power from a tracked panel. If, however, you just take the figures from the week 25th July then this shows an increase of 71 per cent: but it was an awful hot rip-snorter of a week where we got most of the hay cut and baled.

the tracking question

Making the decision to install a tracking system for the solar panels on a new system will be based on several important factors, some of them electrical and some site based. This means that yet again there is no definitive answer but only shades of yes and no.

The factors include such diverse elements as:

- the general weather patterns for the site and the position on the globe: the frequency of bright days will affect the percentage increase
- the position of any shade on the site: local shade may mean that tracking is either essential or pointless
- whether you make your own tracking or buy it: if you make your own tracker it will be less expensive, but you have to have the skills. If you don't use a tracker you still need to buy or make a panel-mounting frame.
- system voltage: if the voltage is high then it takes more panels to make up a system voltage array, and so it's not just a matter of buying one extra panel. For example for a 12 volt system you just need one extra panel, but for 48 volts you will need either 4 x 12 volt or 2 x 24 volt panels, which, of course, needs a greater investment.

I'm going to think this one through a bit more. Let's say a tracker and a panel are roughly the same cost. Now with a 12 volt system if you have two 12 volt panels on the tracker then using an extra panel instead of the tracker will give you 33 per cent more power. So now the site position and conditions come into the equation. However if you have a 48 volt system with two 24 volt panels then you will have to buy 2 more panels to get the right voltage. These will cost twice as much as the tracker but you will get 100 per cent more power instead of maybe 17 per cent as seen with the study. Again local conditions apply as a final factor. The system voltage choices are covered in detail in the *building a system* chapter (page 127).

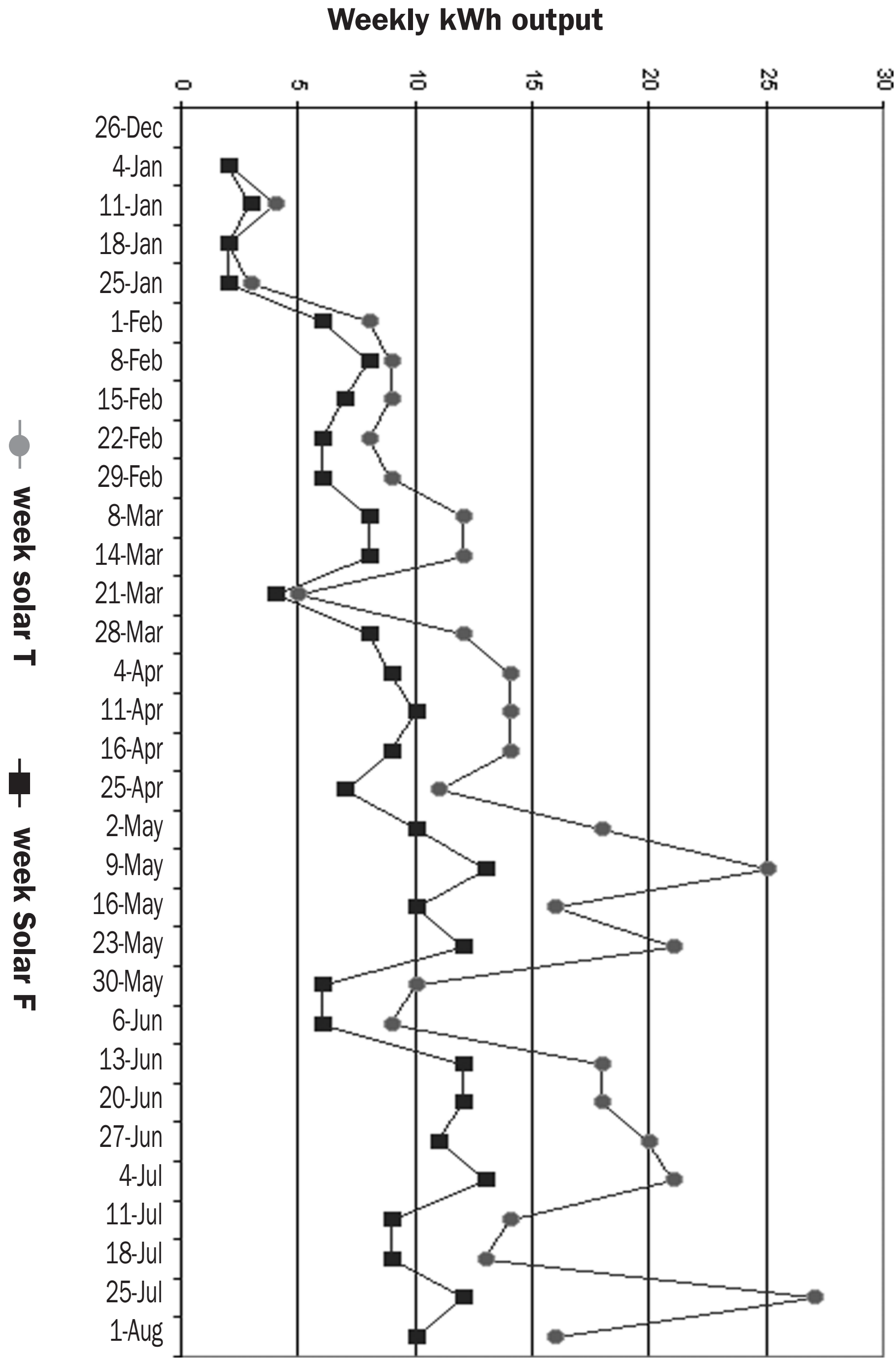

fig 71 solar panel with tracking compared to fixed panel

study limitations

As with all studies of this nature we are only taking a snapshot of the weather conditions for this year in this location. If the study were taking place in Spain it would give a totally different set of results. Both systems have wind and solar generation, and each charging system has an effect on the performance of the other (voltage drives current remember). This is especially seen in the 24 volt system where the installed capacities of wind and sun are similar. The solar panels have a direct effect in summer on the output of the FuturEnergy turbine because the solar system keeps the battery voltage high, and so reduces the charge level of the wind turbine.

The other problem was that the Proven turbine blades were changed for the new, more efficient type, in February, after much hassle and company denial. This has had an effect on the early results but, because the change happened in the windy part of the year its overall effect on the general trends was less than if the change had happened in calmer times.

The turbines studied are sited in a large area of flat fenland close to the east coast of England, and have no hills to interfere with the wind. The area, according to the Proven website wind speed estimate, gives an average wind speed of 5 metres per second at a height of 10 metres. This is not a high average and anything below this figure would be a reason for considering whether the site would be suitable for a turbine. The fact that the location for both turbines is open and flat, and that the Proven turbine is on a 15 metre tower makes the systems viable.

conclusions

From the research results and analysis it could be possible to gain some idea of how the various system components will behave under differing climatic and topographical situations. The factors that seem to be clear are listed below under turbines and solar panels. Before investing in any one system it would be worth taking some time to see how these output characteristics could be affected by your site.

turbines

For the wind turbine side of the study it seems that four FuturEnergy 1 kilowatt turbines would give a similar output to one Proven 2.5 kilowatt turbine. The benefits of the FuturEnergy are in the visual impact, with

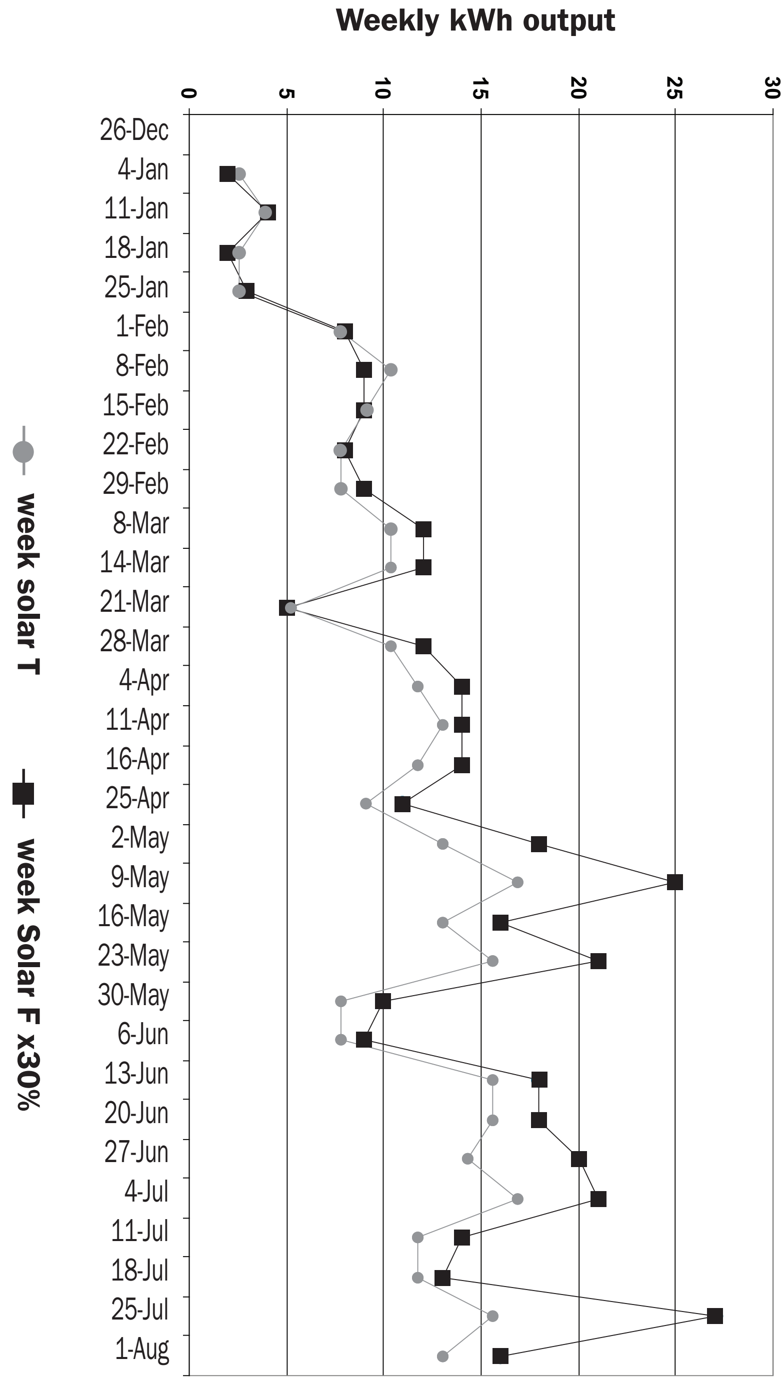

fig 72: solar panel with tracking compared to fixed panel (x 30%)

four small turbines, and the infrastructure costs, as they only require low-cost towers. But the Proven turbine is a more robust, downwind machine that continues to give good output at higher wind speeds. According to the British Wind Energy Association (BWEA) website there are moves afoot to make planning permission for turbines with blades under 2 metres in diameter unnecessary. If this is ratified then the argument in favour of FuturEnergy turbines would be stronger.

Proven turbine

- relatively expensive
- large heavy tower with associated large concrete footings
- lowering the tower over for maintenance is a time-consuming job
- good robust design
- downwind performance
- blade governing

FuturEnergy turbine

- small and lightweight
- five blades for good balance
- relatively inexpensive
- relatively easy to erect
- no large concrete footings required
- guy wires needed for the standard pole that can get in the way
- you cannot fit the pole on a boundary because guy wires are needed
- you would not have to buy all four at once
- less local visual impact
- lower output of upwind machine in high winds

solar panels

The results of the study can be summarised as follows:

- tracking gives a significant benefit when the panels are in direct full sun
- tracking has moving parts and so will need maintenance and may give reliability problems in the future
- fixed panels will have fewer problems from high winds
- roof-mounted panels need to be facing the right way and access is needed for routine cleaning
- on my site it has proved better to use tracking rather than static panels but on other sites in the UK it may be best to buy more panels than to buy tracking