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Renewable energy targets: the importance of system and resource costs

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Introduction

Early decarbonisation of the electricity industry has been identified by the UK Climate Change Committee as a first step towards the government's (legally binding) target of an 80% reduction in greenhouse gas emissions by 2050. The government has broadly accepted this aim and has introduced a package of Electricity Market Reforms (EMR) designed to encourage investment in low and zero carbon generation. All EU countries have renewables and carbon emissions targets so all are facing broadly the same set of challenges.

This Comment looks at one aspect of this issue, which has been a cause of some debate and confusion – the cost of renewables. Renewables are not the only generation sources which involve uncertainties, of course. The cost of generation from gas plants depends heavily on the future price of gas; the cost of nuclear generation will be largely determined by the capital costs of nuclear plant (which sometimes seem like a moving target in Europe today). But renewables as a class have special characteristics, making the uncertainties rather different in nature from those relating to conventional generation. The issues have often been obscured by the polarised nature of the public debate. On the one hand, renewables advocates have argued that the cost of renewables is falling; that many are now more or less competitive; that in future they are likely to be below the cost of conventional generation; and that they are one of the best ways of reducing emissions. On the other hand opponents of renewables have argued that the cost of renewables support is rising; that they are unlikely ever to be competitive; and that they represent an expensive and inefficient way of reducing emissions. Can both these positions be true – can the cost of renewables be both falling and rising? Can they be both expensive and cheap? Paradoxically, the answer is "yes".

The core of the issue is that there is really no such thing as the cost of renewable power. There are instead the different costs of particular renewable sources, in particular locations, at particular times, within particular electricity systems. So a given renewable source might indeed be fully competitive at a particular site, within one system at a particular point in time. But it does not follow that the same source will be competitive at another site, in other systems, or at other times. This problem does not affect other generation sources to nearly the same extent. The cost of a new Combined Cycle Gas Turbine plant (CCGT) is broadly similar anywhere in the world; gas prices vary, but with any given gas price the cost of electricity produced from the CCGT is broadly comparable wherever it is located; the cost is also roughly scalable – ie the cost per unit generated will be much the same whether you are building one plant or several (and much the same as the costs of your competitors).

None of this applies to renewables, because of their dependence on natural forces. These forces are stronger at some locations than others and at some times than others so that the cost of, say, wind or solar power will depend on where the plant concerned is built and what time of the day or year it is generating. This much is obvious (though sometimes ignored). But the cost also depends on the characteristics of the electricity system concerned and the degree of penetration of renewables.[1] There are two aspects to this – one is the impact on the system as a whole; the other is the shape of the resource cost curve for renewables. Both are discussed below.

System costs

The costs of electricity generation from different sources are often compared on the basis of what are known as "levelised costs". These represent the average cost per unit generated during the lifetime of the plant concerned after factoring in (and discounting) all capital, fuel, operating and other costs; they thus encapsulate all these costs in a single number – eg 5p/kWh. This is not an ideal way of looking at generation costs. In principle, it is more accurate to look at incremental system costs – ie at how the costs of an electricity system as a whole are affected by the addition of a given increment of generation. These incremental costs depend on the nature of the system into which they are introduced as well as on the particular generating source being added – for instance, putting more nuclear plant on the French system, which is already dominated (over 75%) by nuclear generation would have very different implications from adding more nuclear to the UK system, which has less than 20% nuclear. However, calculating such incremental system costs is complicated and in the case of conventional fossil fuels, levelised cost comparisons are still broadly informative.

Levelised cost comparisons can however be misleading when it comes to **non-dispatchable** plants (ie plants which cannot reliably be called on to supply electricity when the system needs that power to meet demand – because electricity is difficult to store, supply and demand have to be kept in balance at all times). Most "new" renewable sources are non-dispatchable, because of their dependence on natural forces; they generate when those forces are active and not at other times.

One way of looking at this is that the **value of electricity generation** is different at different times of day (or more precisely in different states of the system). In competitive markets, such differences in value are reflected in price differences, which are usually significant (ie prices may be two or three times as high during peak times as at times of low demand). In

[1] In fact, the full picture is even more complex. For instance, a recent report from the International Renewable Energy Agency on *Renewable Power Generation Costs* (IRENA 2012) lists seven major cost components. This Comment is not designed to be comprehensive, only to underline some important, but often neglected, issues concerning renewable costs.

some situations, and especially in systems with a high proportion of new renewables, the price differentials can be huge (ie the price at some points can be 10s or 100s of times higher than at other points in time). Obviously, generating plants that can be relied on to generate at times when their output is most valuable have a higher value than those that cannot be relied on to do so; a single levelised cost cannot cover all these complications.

Another way of looking at the issue is that generating plants do not produce just one output but a whole range of outputs – kWh plus a set of other services such as reliable capacity which can be brought together under the general heading of **system support**. Because they are not usually dispatchable, new renewables are usually less able to provide such support; in fact, they increase the need for support from the rest of the system. An example is the need for balancing and back up for intermittent wind power. A major, and much cited, report on the issue by the UK Energy Research Centre (*The costs and impacts of intermittency* UKERC 2006) put these costs at 0.5 -0.8p/kWh for each unit of wind generation (which would be a much smaller amount – around 0.1p/kWh when spread across output as a whole). However, this does not give a full picture of the cost of meeting the UK's renewables target. The Report makes it clear (para 28) that:

"These estimates assume that intermittent generation is primarily wind, that it is geographically widespread, and that it accounts for no more than about 20% of electricity supply. At current penetration levels costs are much lower, since the costs of intermittency rise as penetrations increase. If intermittent generation were clustered geographically, or if the market share were to rise above 20%, intermittency costs would rise above these estimates, and/or more radical changes would be needed in order to accommodate renewables."

In other words, although at present the costs are not very significant, the position will change in future. Since the calculations in the Report are based on a 20% renewables scenario, they do not give a full picture of the impact of the UK renewables target, which implies a market share of well above 30%; furthermore, UK wind plants are not likely to be geographically dispersed, for environmental reasons. The cost could well therefore be significantly higher. For instance, a study for the then Department of Business and Enterprise in 2008[2] showed that in an aggressive scenario of increasing renewables penetration the cost of back-up and balancing could be from 0.6-0.8p/kWh in 2020 for the system as a whole (as compared with 0.17p for a conventional system).

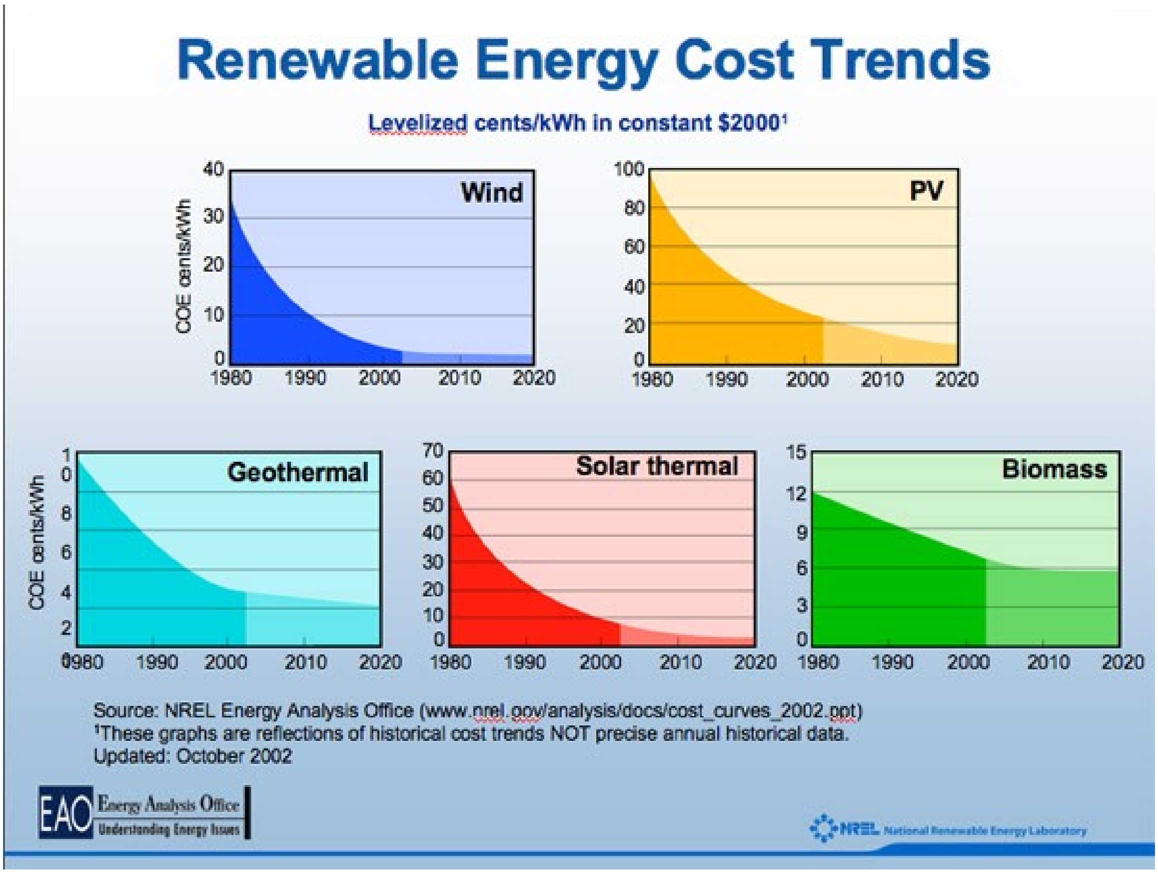
A further significant factor affecting system costs is the need for extra transmission and installation costs. Because of their reliance on natural forces, renewable generation plants have to be sited where the resource is-they cannot be relocated closer to existing transmission lines or centres of demand. The consequential installation and transmission costs can be considerable, especially when offshore wind power comes into play. The UK government has played down or ignored these costs in talking about the impact of its renewables targets[3]. Its argument is that the costs of individual transmission upgrading projects cannot easily be allocated to particular renewables schemes. But this is disingenuous. Again, a systems

[2] BERR Publication URN 08/1021 *Growth scenarios for UK renewables generation and Implications for future developments and operation of electricity networks* Sinclair Knight Merz June 2008
[3] See OIES Comment *UK Electricity Market Reforms: Cash is King* November 2012

approach provides a clearer answer – ie a comparison of the grid investment requirements of a system with a given level of renewables against a conventional system. The SKM Report referenced above provided such a comparison – in the renewables scenarios, grid investment costs ranged from £73-106 billion, compared with £18 billion for the conventional generation case. This could be a high-end estimate – the calculations assumed that a significant amount of transmission capacity would have to be built underground for environmental reasons. But in a way this is an indication of costs that will have to be borne somehow – either in damage to the environment or in higher economic costs. Furthermore, the calculations only go out to 2020; beyond that total system costs would go up steeply as the penetration of renewables increased. Levelised costs give only part of the picture as regards total system costs.

Resources costs

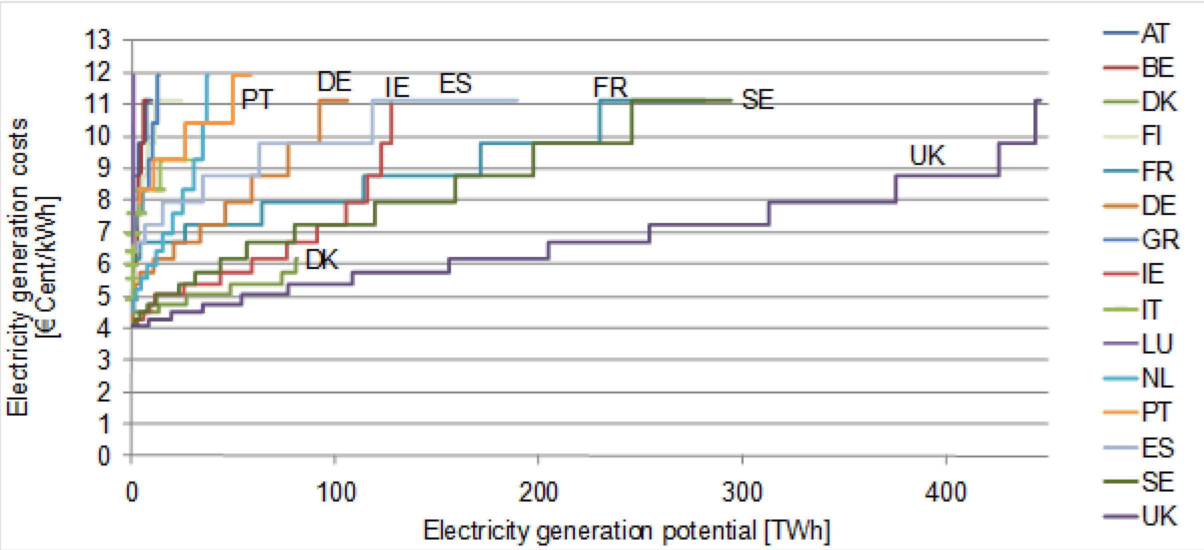
The second main issue which is often left out of calculations is that of rising resource costs. One main complication in calculating future renewables costs is that they are subject to two major, but different, cost trends. The first is the technical cost of renewables generation equipment. This tends to go down over time with technological advances, as in the chart below.



Source: NREL

Broadly speaking, most renewable sources show a somewhat similar technical equipment cost trend – steeply falling levelised costs over time followed by something of a flattening off. Indeed, since many renewable sources are less mature than conventional sources, the cost declines have in many cases been faster than for conventional sources (though this tendency should not be exaggerated – for instance, Jamasb and Kohler 2007, as cited by Thema in a report for the Norwegian Ministry of the Environment[4], conclude that "Learning rates for renewables are on par with those of fossil-fuel technologies").

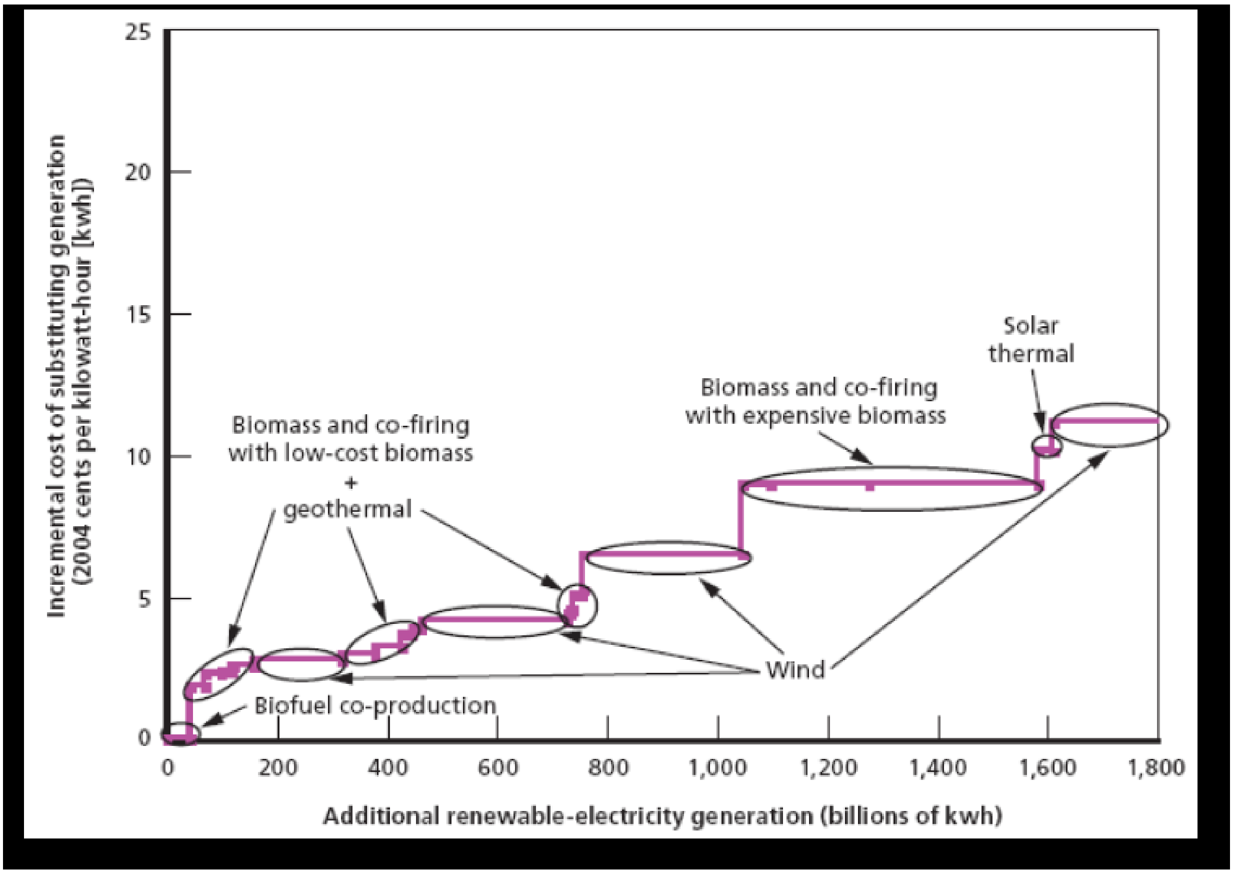
By and large, these technical equipment costs (like those of more conventional sources) are broadly comparable world-wide. But of course this does not mean that generation costs are much the same worldwide, since they depend on the resource available. Even within a particular country, and even where there is a good resource, there will still be geographical variations in the quality of the resource, closeness to demand centres and transmission infrastructure, environmental sensitivity and so on. For obvious reasons, there is a tendency to use the best and easiest sites first. This produces a rising resource cost curve – ie at any particular point in time the cost of any particular renewable resource depends on how much of that resource is already being exploited. The following chart shows wind potential in various European countries. All the cost curves have essentially the same rising shape; the resource gets costlier the more it is exploited. Furthermore, the curves are based on theoretical potential; in practice, the cheapest sites may not be available due to environmental opposition so the curve may be steeper in practice than in theory.



Source: (Held 2011)

The situation is not significantly affected by bringing other renewable sources into the picture; after the lowest cost resource has been exploited, the next tranche, whether of the same source or some different variety of renewable energy, will come into play, producing a composite graph like the following US example, which shows the incremental cost of substituting renewables for conventional generation at particular levels.

[4] *Renewables and Emissions* Thema Report 2011-2

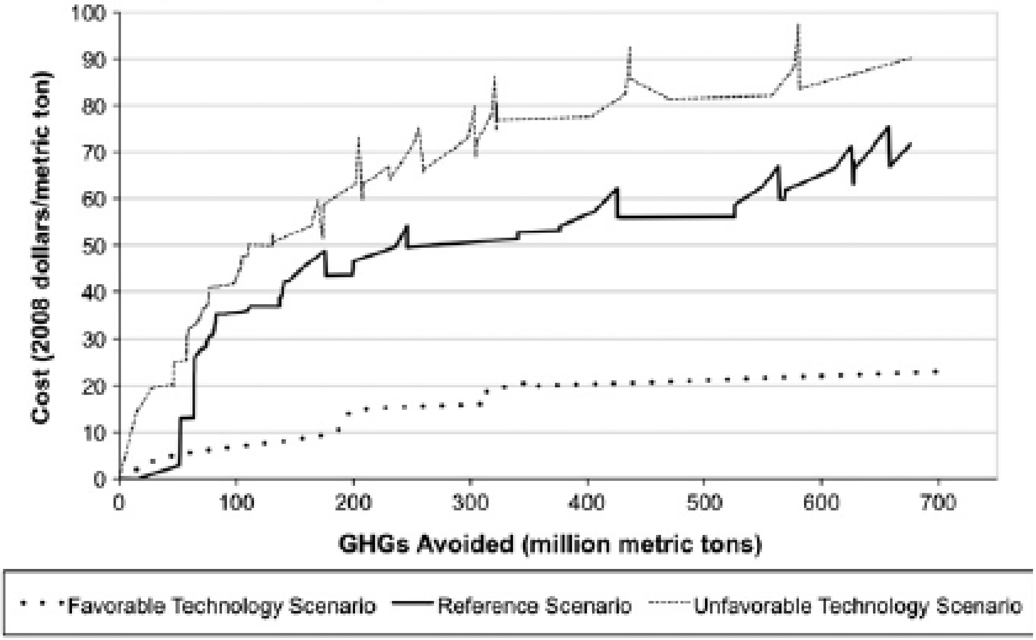


Source: Rand Corporation

Again the graph shows a rising cost curve – small increments of renewables are quite cheap but with increasing volumes, whether of the same or different sources, costs rise.

Overall costs

The complications come in trying to combine these two sorts of curve over time. Falling technical equipment costs may override rising resource costs, producing a falling overall cost trend; but the opposite is also possible. The graph below shows the cost of carbon mitigation via renewables in the US; favourable assumptions on technology reduce the overall cost but still leave the basic picture of rising costs as the volume of renewables increases.



Source: Crane et al 2011

So to know the future cost of meeting renewables targets in the UK, or across Europe generally, you would need to have good information about the likely movement in the technical equipment costs of renewables over time and the shape of the resource cost curve, both now and into the future, for each of the renewable sources, as well as the likely system costs. No-one has perfect information on all these factors, so it is impossible to be definitive about whether the overall cost curve is indeed rising or falling. However, it is at least highly suggestive that the level of support, both in absolute and unit terms, is tending to rise in those European countries which have strong renewables programmes. In the UK, for instance, as the stock of relatively cheap and easy onshore sites diminishes, development is having to move to more distant and difficult sites, for instance in the north of Scotland, where very significant transmission costs will be incurred, or offshore sites where the costs of development are high. The cost of direct renewables support is therefore increasing – from under £2 billion pa today to £7.6 billion pa in 2020 (the latter number is precise because it is a government imposed cap, but it does not include the full costs, as noted earlier). Support for each incremental unit of renewables is also tending to increase – originally the UK scheme of support via Renewables Obligation Certificates (ROCs) gave just one ROC for each unit of renewable generation. Now certain sources, such as offshore wind, get more than one ROC and, although other sources get less than one ROC, the average number of ROCs per unit of renewables generation has increased as have the associated system and transmission costs (while the ROC price has also varied over time). Denmark and other European countries are also moving offshore for wind power, leading to higher unit costs. In Germany, the renewables premium in the consumer price has jumped from 0.88€c in 2006 to 3.6€c in 2012 and 5.3€c in 2013, leading to calls for a cap there too. This huge increase has not been driven by a commensurate rise in the volume of renewables, but by the increasing share of expensive solar power.

Policy lessons

None of the above should be taken as an argument against renewables or against the need for measures to encourage renewables in the move to a low carbon electricity system. Renewables will undoubtedly be a, or the, major component of such a system. Technical equipment costs are indeed still falling for many renewable sources. The prospects for competing forms of low carbon generation (like nuclear and carbon capture and storage) do not look particularly attractive at present. So the basic case for renewable generation (and measures to encourage demand response, a different but related issue) remains very strong.
Nonetheless, it is suggested that some policy lessons can be drawn from the discussion:

- One is the importance of **honesty** and **transparency.** This does not always seem to be on display – for instance, the government appears to be trying to obscure the significance of major cost elements like extra transmission capacity, while some renewables advocates cite only figures for falling technical equipment costs, without acknowledging that they do not give a realistic picture of the overall cost of meeting a given renewables target. (Indeed as the International Renewable Energy Agency has noted[5], as technical equipment costs fall other costs take on greater importance, so it becomes more important to take them into account.) Avoiding significant issues in this way is not a good basis for creating the level of trust necessary for a sustainable long term programme of renewables support. The nuclear industry is an object lesson here. Nuclear was originally oversold in terms of cheapness and safety. This makes it much more difficult for the industry to argue today, on cost and safety grounds, that nuclear power should have a central role in the move to decarbonisation. Similarly, the case for promoting renewables should not be based on half-truths but on a considered and comprehensive knowledge base.

- A second lesson is to do with the **design of support schemes** for renewables. If governments want to continue on broadly the present lines, they should try to develop a more sophisticated understanding of the costs of renewables and adapt their support schemes accordingly. The UK government seems to have adopted the Feed-in Tariff (FiT) approach which underlies the present EMR proposals on the basis that it has proved very successful in encouraging wind power in countries like Germany. But this arguably reflects a fairly specific set of circumstances – Germany was at a relatively stable part of the resource cost curve with considerable amounts of land available in the north German plain, subject to a broadly similar wind regime and not presenting any acute environmental sensitivities. At the same time it was also on a relatively flat part of the wind technical cost curve, with the equipment costs of wind power falling only slowly (as on the right hand side of the wind cost curve above). In such circumstances it is possible to set an effective FiT, with a falling price over time, which will generate significant amounts of capacity at a reasonable price.

[5] IRENA 2012

The UK is not in this position – the resource cost curve is increasing, as discussed above, and the technical cost of offshore wind generation is subject to considerable uncertainties. When the special circumstances described above do not apply, FiTs may be less effective. For instance, in a number of countries across Europe (eg Germany, Italy, Spain, the UK, the Czech Republic) solar power support schemes have been withdrawn, or reduced. The main reason is that there have recently been sharp falls in the technical cost of solar power installations, and relatively little change in the resource cost, since solar power tends to be fairly homogeneous across wide areas. The result has been that the price in the support schemes was set too high leading to a huge (and apparently unacceptable) surge in demand.

Such problems will always tend to arise under FiT schemes when the cost trend is uncertain. If the price is set too high, there will be too much demand; if too low, the scheme will fail in its aim of encouraging renewables development.

- **Incentives** Costs and cost trends are not easy to establish; indeed, it may well be too difficult a task, given all the complications discussed above and the fact that developers of renewable sources are likely to have better information about costs than governments – any negotiation is likely to end up biased in their favour. A third significant message is therefore that governments should give more attention to **incentives** for cost reduction and long term **innovation**. One problem with the FiTs approach is that it does little to provide incentives for cost reductions. An alternative is to go for a quantity approach like the current system of tradable ROCs in the UK – this may be appropriate when the government expects to be on a falling part of the technical cost curve (so that competition will help realise the benefits of falling costs for consumers) but does not believe that the country has yet reached the steeply rising part of the resource curve (which would raise costs for consumers, perhaps to an unacceptable extent). The problem with this approach, as in the UK, is that different levels of support are needed when the low cost part of the resource is exhausted (leading to the need for the "Banded" ROCs introduced in 2009 which give different levels of support for different sorts of renewable generation). This risks complicating the approach unduly, converting it into a form of "picking winners", creating opportunities for gaming, compounding the inherent uncertainties over how much ROCs will be worth in future, and thereby discouraging investment.

  So the incentives provided by ROCs schemes, especially for long term innovation, may still be inadequate. It is beyond the scope of this Comment to look at the range of possible alternatives (though some were discussed in an earlier OIES paper *Decarbonisation of the Electricity Sector; is there still a place for markets?* November 2012). However, in view of the problems with price and quantity based systems, more radical approaches may need to be considered. One which seems to this author to have considerable attractions would be to restructure renewables support to concentrate on research, development and demonstration, while delivering low carbon objectives via a technology neutral instrument like the carbon intensity target discussed in the OIES paper referred to.

- A fourth message is that any **market barriers** to the development and operation of renewables should be removed. In present electricity systems, as the paper referred to above indicates, there are some inherent biases against renewable sources (such as incumbent advantage) in wholesale market structures, which are not well adapted for low carbon sources. Reforming markets themselves (rather than simply introducing new investment support systems, which is what the EMR does) should therefore be a priority.

- **Europe** This Comment has focused on the position within particular systems, mainly the UK, and it does not attempt to look at all the issues raised in the move towards European electricity markets. However, it is clear that many of the costs discussed above would be reduced by effective market integration across Europe. System costs would be less, as the problems of balancing would be easier to manage within a larger system, while the greater diversity of renewable sources would help promote energy security – for instance, the wider the area across which wind generation is spread, the more likely that a significant number of wind plants will be operating at any particular time. The resource costs curve should also be less steep since (as in the US case above) a wider range of different renewable options would come into play. However, to achieve these savings efficiently would require more commonality of approach across Europe. At the moment, when each country has its own separate support scheme and different prices for different renewable sources, the market for renewables is highly fragmented.

Conclusion

The costs of renewables are highly site specific; generic statements about the growing competitiveness of particular renewable sources do not give a realistic picture of the costs involved in meeting a country's renewables targets. In general, the more ambitious the target, the higher the absolute and unit costs of meeting that target, because of the higher system and resource costs involved. This is not in itself an argument against renewables, which will almost certainly be at the heart of the move to low carbon electricity systems. However, a proper understanding of these cost issues should underlie the consideration of any renewables target; furthermore, transparency and honesty are needed in the presentation of these costs if governments are to retain the public trust needed to underpin sustainable policies in this area. There are also a number of important policy lessons for the design of future support schemes. Unfortunately, the confrontational nature of the public debate has obscured some important messages.