

Part 1 – Winning entries of the “Fourth Annual Student Essay Competition” (by year of study)**Should the provision of renewable energy be a government priority, or can it be provided by the free market?****First Prize – 1st Year Undergraduate Category****By Steven Ram^{*}**

Renewable (green) energy cannot be provided by the free market because there are three considerable market failures. These failures consist in 1. high costs of green generation, 2. revenue risks for green generation, and 3. diminishing marginal efficiency of green technology. In each of the three paragraphs of this essay I will uncover the roots of those problems one by one. 1. Empirical evidence shows that high costs for green energy are a problem, because existing suppliers of conventional (black) energy set the market price, and so determine the profitability of green suppliers. 2. Resulting too from the price setting circumstances through black suppliers, potential investors are deterred from investing in green energy because of volatility of revenues. 3. Diminishing returns leave questioned how far even large investments in green energy will take us in the long-term. Despite these problems, energy provision does not need to be nationalised again to provide green energy. There are several directions in which policymakers may be able to correct the three market failures. At the end of each paragraph, I will thus briefly point in directions in which each failure might be corrected with familiar tools.

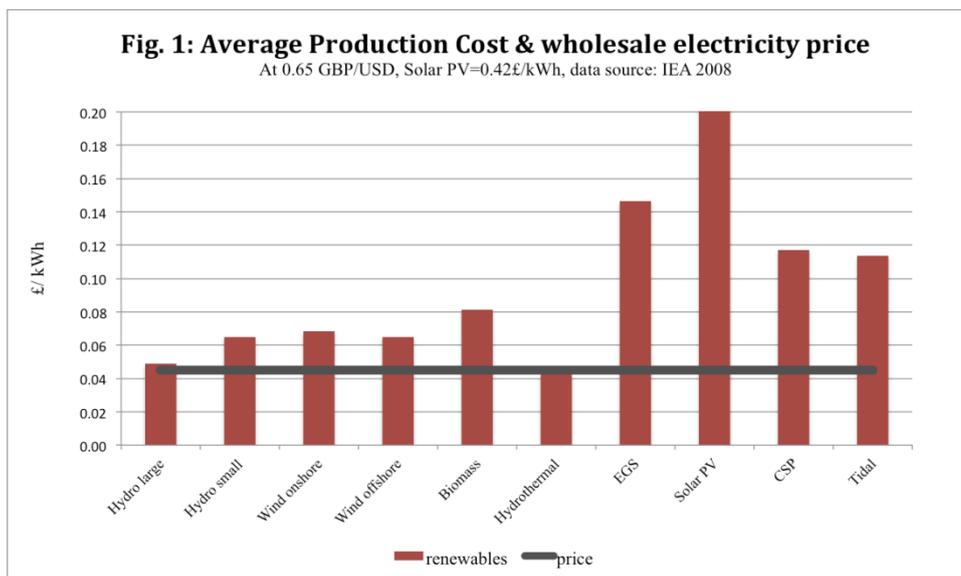
1.***High costs***

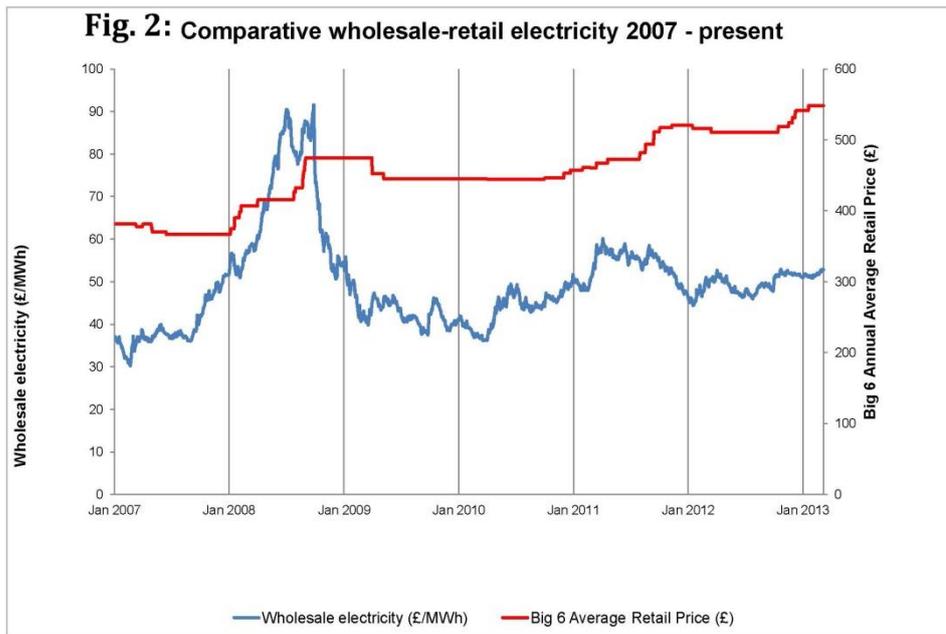
The UK wholesale electricity market is comprised of six electricity generators with large market shares that together make up for over 99% of the electricity supplied, two of which account for 45% of all (Ofgem 2003:43). Competition on this market is thus imperfect, and the price of electricity is determined by the six large suppliers. Suppliers of green energy would enter the market as price takers, because of their comparatively small market share, and because there is no product differentiation in electricity to enable setting a higher price. Whether the green supplier is in fact the same firm as one of the black suppliers or whether it is a new firm, does not alter the

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picture here, because a large green & black supplier could still only set one price for both types of generation. That price would still have to be high enough to make also the deployment of green technology profitable. If that price is then higher than the price set by a solely black supplier, the green & black supplier will lose its market share. Similarly, if the price a small new green firm has to 'take' is below a profitable level, it will not enter the market. The question that remains is then, what would a profitable electricity price for the deployment of green technologies be?

The theoretical framework for assessing the profitability runs like this. A green firm would attain (super)normal profits, if their revenue per unit (kWh) of output AR_g , at the level of output that maximises their profit, is equal to or above the cost per kWh ATC_g incurred at this level of output. If ATC_g is greater than AR_g at any level of output, no profits could be made, and the firm would not enter the market. Moreover, the average total cost is made up of average variable cost AVC and average fixed cost AFC (Sloman 2012). Because of its situation as a small price taker, their average revenue AR_g is always equal to the market price. This market price is determined by the six large generators. The lower the price they set, the more retail suppliers will demand their output. But with lower price and higher output, the revenue per kWh AR_b will decrease. If sinking revenues per kWh are approaching the total cost per kWh ATC_b , their profits will flatten. The price will thus be set at a level that allows the amount of output to be sold, at which the difference between revenues per kWh AR_b and costs per kWh ATC_b is maximised.





Source: Consumer Focus

Now, what does empirical evidence tell us about costs and revenues? The IEA provides estimates for the average variable costs of different green technologies isolated from fixed costs (Fig. 1). All values are cleared of any tax or subsidy influence. Furthermore, I will here assume a wholesale electricity price of 0.045 £/kWh. A record of past wholesale electricity prices is plotted in Fig. 2. However, these values are first of all not cleared of tax or subsidy influences, and also fluctuate considerably, and thus they are to be taken with a pinch of salt. The grey beam in Fig. 1 represents this price. All green technologies have a higher average variable cost. But, in some cases like hydrothermal and hydropower generation, and to a lesser extent also wind generation, the variable cost is almost as low as the price. Given the vagueness of this electricity price, the variable cost of those technologies might in fact sometimes lie below it.

Fig. 3b: Cost & revenue - black suppliers
Qualitative curves, data source: IEA 2008, Consumer Focus

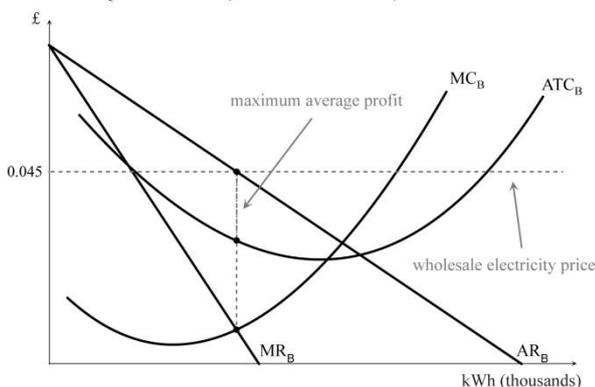
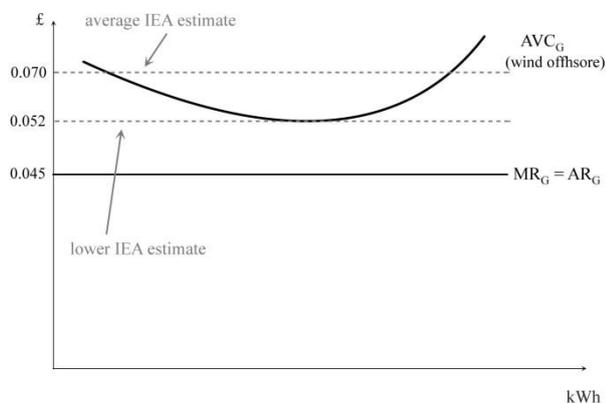


Fig. 3a: Cost & revenue - green entrants
Qualitative curves, data source: IEA 2008, Consumer Focus



When feeding these observations into a diagrammatic representation of the theoretical framework laid out before, following picture emerges. Fig. 3a displays a possible qualitative curve of the average variable cost for offshore wind generation. The values in Fig. 1 are the averages of a whole range of estimates for variable costs. For offshore wind, estimates actually ranged from 0.052 - 0.078 £/kWh. The diagram assumes the lower bound of this range to be the minimal average variable cost. Fig. 3b displays a possible scenario for the internal price setting of the black suppliers, which determines the wholesale electricity price. The value of it is continued to be assumed at 0.045 £/kWh. A comparison of the two diagrams proves, that the revenue per kWh for green suppliers AR_g is below the cost per kWh, and thus unprofitable. Note that here the variable cost is displayed, without taking into account fixed costs. Total costs per kWh would exceed average revenue even further. Depending on the capacity of the plant, there are, for instance, considerable investment costs of 1,430 – 1,950 £/kW of capacity to be added on top of the plotted variable cost. A typical offshore wind turbine of 1.5 - 5.0 MW capacity would incur total investment costs of 2.1m – 9.75m £ (IEA 2008, at 0.65 GBP/USD).

The first problem is then this: Variable cost for many green technologies is higher than the price set by black suppliers. But only when total cost, i.e. variable plus fixed cost, are at or below this price, can green suppliers be profitable. Therefore, in a situation like this, the free market is unable to provide green energy generation. Interestingly, however, it is only the fixed cost that pushes total costs above a profitable level. What can policymakers do in response?

Looking again at Fig. 3, there seem to be two different approaches:

- I. The cost of the black generation (MC_b and ATC_b) could be increased. This corresponds to policies like carbon taxes, emission certificates etc. In effect the price charged by black suppliers rises and increases the average revenue of green suppliers (AR_g) potentially above their average total cost (ATC_g) and thus making green generation profitable. There would also be a decline in black quantity. Considering the inelastic demand for electricity though (Ballard 2001), this decline would not be large, and may be offset by the increase in green quantity.
- II. The average total cost of green suppliers (ATC_g) could be reduced. Variable cost (AVC_g) depends largely on technological parameters and can thus only be reduced by promoting innovation through R&D grants for instance. Fixed cost (AFC_g), on the other hand, could be reduced more directly. Part of the fixed costs are interest payments for debt financed capital. This can easily be reduced for example by government guarantees that lower the risk premium lenders require, or government equity stakes in the capital of the plant, so called Private Finance Initiatives (Gross 2009). There is also another adverse effect on total costs due to financing obstacles discussed in part 2.

2.

Revenue Risk

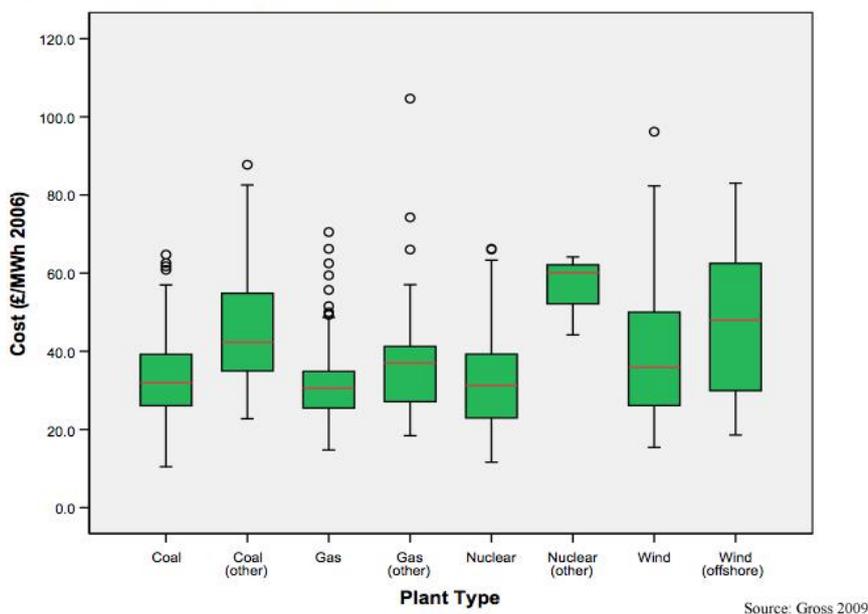
As we have seen, there are some ways for the government to tackle the problem of high costs. However, when it comes to the decision of making an investment to enter the electricity market with green technology or not, costs are not the only consideration. They also have to be weighed against future revenues. But how can the current value of future revenues be assessed?

Supposing the decision is made against the investment. The money can instead yield interest, if deposited in the bank. So, if an investment shall be worthwhile, its revenues must be competitive with these interest yields. In other words, any revenue the investment would yield over the period until it expires has to be discounted by the interest it could have otherwise earned during that period. The result is then the present value of the investment PV . At an annual interest rate r , the revenue in each particular year R_t , and the number of years until expiry t , the present value is given by

$$PV = \sum \frac{R_t}{(1+r)^t}.$$

When this is now the entire return the investment would throw off over its whole lifespan, it still has to be weighed against how much the project actually costs. Thus the net present value is given by $NPV = PV - C$, where C is the total cost of the investment.

So, in calculating the NPV we have found a way of considering not only costs but also the revenue side of an investment decision. But what is the risk that leads to a market failure now? Gross describes in his 2009 paper how the uncertainty of revenue for nuclear and green energy poses a substantial problem. Supposing that policies to either push down costs for green generation (II.) or push up costs for black generation (I.) are in place to make green generation profitable, there remains an obstacle that can still hinder the market penetration of green energy: revenue risk due to price fluctuations.

Fig. 4: Cost ranges for predominant technologies

In Fig. 4 there are stochastic estimates of $NPVs$ for black and nuclear generation. The values for nuclear generation reach far into the negative, which means that there is a larger probability of a negative return on a nuclear investment than for a black investment. This is largely due to volatility in raw material prices. If, for instance, gas generation suppliers face falling input prices, they may want to pass on most of the price decrease onto the output price to capture more demand, in order to maximise their profit. And so the wholesale electricity price set by the large suppliers also becomes volatile, which is consistent with the earlier observations in Fig. 2. Price takers as nuclear and green suppliers, however, will then experience lower revenues and flattening profits. The probability of a loss during such periods rises and the stochastic range of $NPVs$ extends downwards. Therefore, the revenue risk due to price fluctuations deters potential investors to enter the electricity market with green technology.

Revenue risk may also adversely affect fixed costs. When potential lenders are aware of revenue risks, fewer lenders may be willing to lend at all, and those who are still willing can demand a higher interest rate as a risk premium. The former causes the financing of green projects to rely to a larger proportion on more expensive equity funding, while the latter causes also the usually cheaper funding source of debt to be more expensive now (Gross 2009).

The second problem is then this: Although there are policies to increase the cost of black generation, the output price of black suppliers is still volatile due to, for instance, fluctuating raw material prices. As takers of this volatile price, the revenues of green suppliers AR_g are just as volatile, too. Although the cost C part of the NPV calculation may be minimised and even be competitive with black costs, and although the revenue R_t part of the calculation might on average enable profits, revenues are too volatile, leaving too high a probability for losses. As such,

the free market fails to incentivise investment in green generation.

Again the question arises, can policymakers correct this market failure? Going back to Fig. 3, the average revenue of green suppliers AR_g could perhaps be targeted and stabilised directly, without having to increase the cost of black suppliers via emission certificates etc. By introducing feed-in tariffs, for example, the price green suppliers receive as their average revenue becomes less dependent on the price set by black suppliers. Alternatively, instead of influencing the price green suppliers take, quotas on green quantity may have a similar effect, when they create a highly price-inelastic demand around the quoted green quantity. This would enable green suppliers to set a profitable price themselves, without policymakers 'second guessing' what price would be profitable (Gross 2009).

3.

Long-run marginal efficiency

If the market failures, both from a cost perspective (1.) and a revenue perspective (2.), can successfully be corrected, then suppose investment in green technology goes ahead and the market provides some green energy. Somewhere down the line, there will arise another problem, however. The more green suppliers have already entered the market, the less efficient another green power plant will be. How can this be explained? And what problems does it pose?

Going back once more to the calculation of the NPV in order to assess whether an investment is worthwhile,

$$NPV = \sum \frac{R_t}{(1+r)^t} - C.$$

Comparing different green power plants of the same technology, capacity and lifespan, there are still variations in how much revenue they throw off until expiry (the factors that cause these differences will follow shortly). Highly efficient plants will yield more revenue than less efficient ones. And so more efficient plants will translate into a higher present value, if the interest rate is the same for all. The particular rate of return, that makes the present value equal to the cost, determined by how efficient the plant is, is the marginal efficiency of capital *MEC*. Plants that are even less efficient will not be invested in, as their present value will be lower than their costs. This is because we have assumed the interest rate to stay constant. If it falls, then the present value of plants that have previously been too inefficient increases, making investing in them worthwhile (Sloman 2012:274-75). But changes in interest rates aside, why does the marginal efficiency diminish with higher penetration of green energy?

Faundez supposes that the (marginal) efficiency is mostly affected by the productivity of the geographical site where the project is located s (for wind energy that is simply the average wind speed on site), and of the energy transport distance d , so $MEC(s, d)$. Plotting s against d in a diagram, all pairs of s and d that form the same value of MEC lie on the same curve (Fig. 5). The higher s , the higher the MEC , because on a more productive, windy site each unit of capital, i.e. each turbine produces relatively more. The higher d , the lower the MEC , because the longer the distance of transport, the larger the share of capital that has to go towards network connection instead of productive capital. Therefore, the highest MEC value will be formed by the s and d pair located in the bottom-right corner of the diagram, decreasing towards the top-left corner (Faundez 2007).

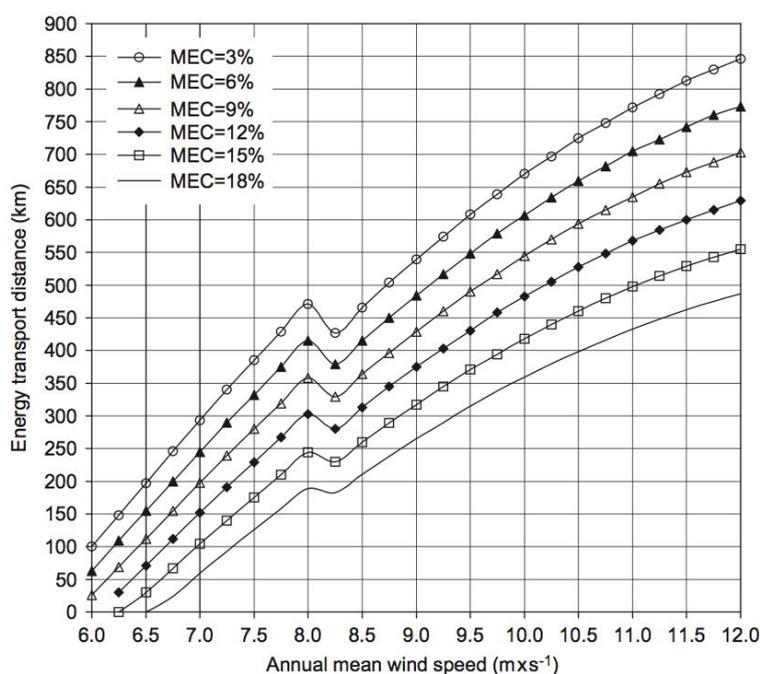


Fig. 5: Isoprofits for a 50 MW model wind farm.

Source: Faundez 2007

Now, suppose that the interest rate is $r = 3\%$. The NPV of an investment will decrease in the same fashion as the MEC , because it expresses a particular rate of return R_t . And thus the earliest investors will choose a site with maximal productivity s and minimal transport distance d . When all sites with high productivity and low transport distance are occupied, investors will move to less profitable sites, diagrammatically up-left, until the MEC that is equal to the interest rate r is hit. As we assumed a low interest rate, even relatively inefficient plants will be built. At an even

lower interest rate, output could not be increased much anymore, so electricity output will be close to its maximum. The doubt that arises now is: How large is this output, that can be produced at the diagrammatically highest MEC curve attainable? Might the amount of green energy generation come to an early halt despite optimal investment circumstances and low interest rates?

The third problem is then this: All the sites that exhibit desirable marginal efficiency of capital, will go first and cannot be used by other investors. Thus marginal efficiency will diminish, the more green suppliers have entered the market. If interest rates are low and also all other investment circumstances are optimal (e.g. 1. and 2.), investment will continue but green electricity output will converge to a maximum. The extent of this maximum is determined by how sharply the MEC diminishes, i.e. how many profitable sites there are. Now, can policymakers do anything about that?

They cannot change geography or weather. They can, however, encourage technological progress towards a generally higher efficiency of capital, that will enable a higher maximum green electricity output. The long-run prospects of green energy provision do therefore advocate the use of policy instruments like R&D grants.

Conclusion

Summing up, 1. green energy suppliers face barriers to entry, because the wholesale price of electricity is determined by the existing suppliers, that can set the price below a profitable level for green suppliers, because of lower total costs for black generation. Looking at variable costs, however, green technologies are almost competitive. Focusing policies on reducing fixed costs of green technologies thus seems viable. 2. Investors consider the probability of negative returns on their investment. Because of volatilities in the revenue, caused by volatilities in the price set by black suppliers, decisions are often made against investing in green generation. Therefore, policies aimed directly at revenues of green projects would have a stabilising effect, encouraging more green investment. 3. In the long-term, if more green suppliers have already entered the market, returns on additional green projects will diminish. Even if optimal circumstances for more and more investment are created, green energy output will converge to a maximum. We do not know whether that maximum will be enough. The only possibility for policymakers to expand this maximum, is to foster technological progress. Overall, renewable energy cannot be provided by the free market. But the market provision can be induced using the right policies.

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