An initial analysis of options for a UK feed-in tariff for photovoltaic energy, from an array owner’s viewpoint

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Abstract

The UK government has announced the introduction from April 2010 of a feed-in tariff (FIT) for renewable energy, and initiated a consultation on its design. This paper compares three possible variants of a UK FIT for rooftop photovoltaic (PV) arrays, on the basis of calculated income and array cost payback time, and for three locations (north, central and southern England) and various levels of household electricity consumption. This modelling is based on an FIT rate equivalent to Germany’s. It concludes that an FIT which paid only for PV electricity surplus to on-site needs, and exported to the grid, would mean a simple payback time too long to make array purchase appealing. Preferable would be either export to the grid of all PV electricity for FIT payment; or a lower FIT rate for electricity used on-site, plus full FIT for any surplus exported. The latter would involve significantly lower costs in feed-in tariff payments. Finally, the effect of the UK government’s illustrative FIT rate for consultation is examined for the same locations and annual consumption levels.

Keywords: solar PV, rooftop, feed-in tariff, UK policy

1. Feed-in tariffs

Feed-in tariffs (FITs) have been adopted in over twenty countries, following Germany’s lead, and are widely recognized as an effective means to promote growth of renewable energy capacity. There is an extensive literature on the merits of FITs, including their superiority to quota-based (e.g. Renewable Portfolio Standard) schemes. See, for instance, Meyer (2003), Butler and Neuhoff (2004), Lauber (2004), Michel (2007), Smith (2008). Scheer (2004), Büssgen and Dürrschmidt (2009) describe the German FIT approach and its track record. Mendonça (2009) provides a recent and comprehensive survey of FITs. Mitchell et al (2006) and Elliott (2008) set out the shortcomings of previous UK government policy and arguments for changing to an FIT approach.

The UK solar industry’s ‘We Support Solar’ campaign envisages a UK FIT payable for every kWh generated, without bonus, for in-house use of photovoltaic (PV) electricity (We Support Solar 2009). It gives only one example calculation, at an illustrative FIT rate of 40 p kWh\(^{-1}\) and an array output of 850 kWh yr\(^{-1}\) kWp\(^{-1}\). The study by consultants Pöyry for the UK government (Pöyry 2009a) sets out in detail the qualitative issues in FIT design, but without modelling specific variants and FIT rates. Their companion report (Pöyry 2009b) estimates the cost of achieving a given UK-wide level of capacity in PV, among other renewables; but while it assumes an FIT rate of 40 p kWh\(^{-1}\) for domestic PV electricity, it does not model FIT scheme variants from the array owner’s viewpoint. A review of the recent academic literature found no published papers which examine possible forms of a UK FIT. The present paper offers a modest contribution to filling that gap.

2. Purpose

The purpose of this paper is to compare three possible variants of a UK feed-in tariff for solar PV energy and their respective outcomes, from the point of view of a household with a rooftop PV array installed.

As Wolfe (2008) observes, ‘... technologies exist for the on-site production of renewable electricity ... though some are not widely used in the UK at present’. That certainly
includes PV arrays. However, the UK government in autumn 2008 amended its landmark Climate Act to include powers to introduce a feed-in tariff (FIT) to promote the installation of small scale renewable energy systems (up to 5 MW peak).

The government has, since the first submission of this paper, announced the proposed terms for the FIT as the basis of a consultation process. For PV systems of up to 4 kWp retrofitted to houses, they are: 36.5 p kWh$^{-1}$ generated, whether exported to the grid or used in-house, plus an ‘export tariff’ for any electricity fed into the grid, variable depending on the wholesale price—typically around 4 p kWh$^{-1}$. While the main rate is thus very similar to the 2009 German FIT (€0.43 kWh$^{-1} \approx$ €0.37, at £1:€1.16), the proposed UK tariff would exceed that in several respects. It would pay more for PV electricity used in-house, 36.5 p instead of €0.25 $\approx$ 21.5 p. Moreover, the German FIT rate will decrease by 9% in 2010, when the UK scheme is to commence.

3. Approach
This research examined three variants of a feed-in tariff scheme applying to PV energy.

Variant A: a premium payment for electricity surplus to on-site needs and fed into the grid, and payment, at a lower rate, for PV electricity used on-site. The array owner additionally gains the avoided cost of buying in that electricity from the grid.

Variant B: a feed-in tariff only for surplus electricity above on-site use. The array owner saves the grid retail price value of the electricity from the array used in-house and receives FIT income for the surplus exported to the grid.

Variant C: all electricity from a PV array is fed into the grid and receives the full rate feed-in tariff, and the array owner buys in at grid retail price all the electricity the household consumes.

As the base case against which to compare, the house has no PV array and buys in all the electricity that it consumes at the grid retail price.

4. Methodology

4.1. Household electricity consumption
As variants A and B both involve FIT payments for electricity from a PV array which is surplus to household (‘in-house’) consumption and is fed into the grid, it is necessary to calculate PV electricity generation and consumption on at least a monthly basis, in order to identify those months in which a surplus arises—and conversely in the other months of the year to calculate the shortfall of PV array output below household consumption, hence the cost of buying in that electricity from the grid.

In comparing the variants, the modelling uses three figures for average annual household consumption in the UK:

- 4677 kWh, derived from the then UK Department for Business, Enterprise and Regulatory Reform (BERR) figure for total UK domestic sector consumption in 2006 of 116 449 GWh (BERR 2008a), divided by the number of UK households in that year, 24.5 million (Statistics UK 2009);
- 3300 kWh, the figure on which BERR based its data for average household electricity bills (BERR 2008b);
- and 4000 kWh, as a credible level of annual consumption intermediate between the first two.

Consumption is not level during the year, as demand, for example, for lighting varies. BERR published data on UK domestic sector electricity consumption by month (BERR 2008c). From these can be calculated monthly consumption, averaged over the four years 2005–2008 in order to even out any variations such as unusually high television use during major sports tournaments; and thus monthly ‘shares’ of total annual consumption, set out in table 1.

4.2. PV array output
The EU-supported Photovoltaic Geographical Information System (PVGIS 2008) website provides estimated output from a 4 kWp array, typical of the size installed in Germany. The figures for three towns in northern England (Durham), central England (Shrewsbury) and southern England (Bromley) are set out in table 2.

Comparison of projected and actual observed output at the EU Joint Research Centre at Ispra confirms that PVGIS projections are accurate to within 5% (Kenny et al 2008).

### Table 1. UK domestic sector monthly consumption in TWh, averaged over 2005–2008; and proportion of total annual consumption.

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| TWh   | 12.12 | 10.76 | 11.05 | 9.19 | 8.33 | 7.85 | 7.86 | 7.89 | 8.16 | 9.74 | 10.88 | 12.38 |
| %     | 10.4% | 9.3% | 9.5% | 7.9% | 7.2% | 6.8% | 6.8% | 6.8% | 7.0% | 8.4% | 9.4% | 10.7% |

### Table 2. Projected electricity production in kWh from a rooftop 4 kWp PV array.

| Location | Durham | Shrewsbury | Bromley |
|----------|--------|-----------|---------|
| Latitude + longitude | 54.78°N, 1.56°W | 52.71°N, 2.75°W | 51.41°N, 0.01°E |
| January | 120.4 | 111.6 | 128.0 |
| February | 185.2 | 172.8 | 185.2 |
| March | 287.6 | 271.2 | 275.6 |
| April | 357.6 | 377.6 | 385.2 |
| May | 436.0 | 464.0 | 440.0 |
| June | 404.0 | 424.0 | 420.0 |
| July | 420.0 | 448.0 | 448.0 |
| August | 376.4 | 391.6 | 416.0 |
| September | 314.8 | 316.0 | 319.6 |
| October | 218.0 | 217.2 | 238.8 |
| November | 135.2 | 124.4 | 147.6 |
| December | 80.4 | 79.2 | 92.8 |
| Annual total | 3335.6 | 3397.6 | 3496.8 |
4.3. Assumptions
The calculation of feed-in tariff income is based on PVGIS output estimates for a PV array with a capacity of 4 kWp, employing standard silicon crystal modules, installed on a house rooftop at optimal facing (due south) and tilt angle. Its calculation of estimated output includes losses owing to temperature, angular reflectance and Balance of System components (cables, inverters, etc). Details are available from: http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php#.

PVGIS makes no assumptions about module efficiency or type. It assumes instead that the array owner selects modules which provide the specified peak capacity. The actual output from a particular rooftop PV array will, of course, depend on a number of parameters, such as module area installable, efficiency of modules, shading by trees, etc. It is impracticable to include in the present paper modelling results for a wide range of such parameters. Anyone considering installation of a PV array should factor in their individual conditions. The reported results, based on PVGIS output estimates, nonetheless permit valid comparison between FIT variants.

German prices for small rooftop PV arrays in 2009 are forecast to be around €4000 kWp$^{-1}$ installed (Photovoltaik 2009, BSW 2009), £3450 at an exchange rate £1 = €1.16 as in late August 2009. Since competition in the UK is less intense, margins may be higher and exchange rate variable, the modelling assumes a somewhat (16%) higher array cost of £4000 kWp$^{-1}$ installed. Different price levels would affect the payback time, but not the comparison between the different FIT variants.

4.4. Feed-in tariff rates
German rates for 2009 are €43 kWh$^{-1}$ for electricity fed into the grid (‘full FIT’); €25 for electricity used in-house, under a new provision in the revised version of its Renewable Energy Sources Act (EEG), in force from 1 January 2009; and €20 typical grid retail price. At an exchange rate of £1 = €1.16, that equates to 37 p kWh$^{-1}$ for full FIT and 21.5 p kWh$^{-1}$ for in-house use.

To simplify comparison, the modelling assumes that income from a feed-in tariff is not subject to taxation, whether income tax or VAT. A tax liability would obviously affect net income and thus array cost payback time; but individual circumstances vary widely.

4.5. Grid retail electricity price
BERR data in table QEP 2.2.1(St) (BERR 2008b) gave the average UK household electricity bill for 3300 kWh annual consumption as £405, for payment by the standard credit method. Those figures yield a UK average price per kWh of 12.3 p. It would be impracticable to model using each of the plethora of different electricity tariffs available, which include, for example, reduced nighttime rates.

4.6. Calculation
The modelling calculated for each month:
- the kWh of PV array output used in-house and either attracting the ‘in-house use’ rate of feed-in tariff (variant A) or saving the grid retail purchase price (variant B);
- the surplus, if any, of PV output sold to the grid at the full feed-in tariff;
- the shortfall, if any, of PV array output below electricity consumption, and the cost of buying in electricity from the grid to make it up.

Variant C simply involves calculating the income from feeding the entire PV array output into the grid at full FIT rate, e.g. for the Durham case 3336 kWh × 38 p = £1267.68; and the cost of buying in at grid retail price all the electricity that the household consumes, namely either 4677 kWh × 12.3 p = £575.27, 4000 kWh × 12.3 p = £492.00 or 3300 kWh × 12.3 p = £405.90.

The base case is simply that there is no PV array, and all electricity consumed is bought in from the grid, at the same cost as above, namely £575.27, £492 or £405.90. That figure is the same for a given level of annual consumption, regardless of the location.

5. Results
The relevant comparison is between what the PV array owner pays, or receives, net for the electricity that the household uses, or produces. Both payment and receipt are measured against the base case, of paying the grid retail price for all electricity used—since that is the position of a householder without a PV array, and therefore the basis of assessment of whether having an array would be worthwhile.

In all cases the PV array produces in certain months a surplus of electricity above that required in the household, earning feed-in tariff income at the full rate. That surplus is least in the northerly location with higher annual electricity consumption; and most in the south, with lower consumption.
However, lower consumption also means lower FIT income for in-house use of PV electricity, under variant A. The combination of the two produces only a marginal increase in net income, and hence in saving over the base case.

As a basis of comparison between variants, it is instructive to calculate for each case the simple payback time (array cost divided by saving over base case) and the cost of FIT payments. Figures 2–4 show the results for each level of annual consumption.

Table A.1 in the appendix contains the detailed figures for FIT payments and simple array cost payback times for variants A–C, and for the UK government’s proposal, at the three UK locations and the three levels of annual household electricity consumption considered. Tables A.2–A.4 set out the month-by-month calculations.

6. Net metering

For comparison, data from the modelling can be used to calculate array cost raw payback time in the case of ‘net metering’. That means that electricity from a PV array is used in-house, substituting for and thus saving the cost of purchasing from the grid; and any surplus over in-house needs is exported to the grid at the same retail tariff, 12.3 p kWh$^{-1}$ as established above. That analysis gives payback times for the three locations of: Durham 39.1 yr at all three consumption levels; Shrewsbury 38.3–38.5 yr and Bromley 37.3 yr at all consumption levels. Clearly, the PV array cost would have to fall considerably, or the grid retail electricity price rise sharply, or both, for a net metering regime to make investment in PV arrays attractive.

7. Analysis

The figures (table A.1) for variant A, where PV electricity is used in-house as far as possible and only surplus power exported to the grid, show that for a given location the level of annual household electricity consumption makes virtually no difference to the array owner’s gain relative to the base case (no PV array), nor therefore to the simple array cost payback time. That is because reduction in annual consumption, while it increases in-house use and the surplus PV electricity available to export, at the same time reduces the ‘base case’ cost of buying from the grid, and therefore the gain relative to that cost.

There is a significant improvement in the array owner’s position under variant B, where only PV electricity surplus
A, depending on array output, and the simple payback time base case is approximately half (44–56%) of that under variant grid and earns the full feed-in tariff. The gain relative to the array and surplus to in-house consumption is exported to the grid. Variant B.

The payback time reduces by 5.4–6.3 yr, both depending on the location. This is because the increase in array output, surplus to household needs, increases: and conversely the amount of electricity bought in from the grid to cover shortfalls reduces. However, the payback time is still over 20 yr, even in the most favourable case.

Under variant C, feeding into the grid all PV electricity and buying from the grid all household consumption, the gain over the base case ranges from 6.1 to 9.4% higher than in variant A. This reflects the relatively small difference in income per kWh between (feed-in at full FIT rate minus buy in at grid retail price) and (use in-house at lower FIT rate), between 25.7 p and 22 p.

The difference in array cost payback time between the locations with the lower and the higher PV array output is very similar, at 0.6–1.0 yr, across all three levels of annual electricity consumption and for both variants A and C.

The payback time is consistently shorter, by 0.8–1.2 yr, under variant C as compared with variant A. There is only a very slight trend to narrowing of the difference as annual electricity consumption reduces, from 0.8–1.2 yr at 4677 kWh yr\(^{-1}\) to 0.9–1.2 yr at 3300 kWh yr\(^{-1}\). This suggests that the consumption level would have to become extraordinarily low for the outcomes under variants A and C to converge.

Variant A. The provision to pay a feed-in tariff, albeit at reduced level, for electricity from a PV array used in-house both saves the array owner the cost of the electricity, which would otherwise have to be bought in at grid retail price, and provides an income. That combination more than offsets the cost of buying in the residual electricity needed, not supplied by the array. The simple payback time ranges from 12.9 to 13.8 yr for the three levels of total household electricity consumption, depending on array output.

Variant B. In this case, only electricity generated by the PV array and surplus to in-house consumption is exported to the grid and earns the full feed-in tariff. The gain relative to the base case is approximately half (44–56%) of that under variant A, depending on array output, and the simple payback time accordingly doubles or more at 23.1–31.6 yr. The shorter time is at the lower consumption level, which might constitute an incentive to reduce consumption; but the length of payback time is still likely to be a deterrent to investment.

Variant C. All of the PV array output is exported to the grid at the full FIT rate. Income is therefore the same, regardless of the household consumption level. All electricity consumed in-house is bought in from the grid. If there were no PV array, the household would still buy from the grid that same quantity of electricity. The difference between the two cases, i.e. between variant C and the base case, is therefore always equal to the feed-in tariff income.

Interestingly, this variant is better for the PV array owner at all levels of household electricity consumption considered, and all three levels of projected array output. The figures indicate a slight trend towards reducing that advantage as household consumption falls for the locations with lower array output, but not at such a rate as to suggest that they would converge at any plausible level of household electricity consumption. In the higher array output case, the advantage of C over A increases with decreasing household consumption.

What happens if array output equals or exceeds total annual consumption? Table A.5 in the appendix sets out the figures for Bromley (projected array output 3496 kWh yr\(^{-1}\)) for annual consumption of from 3500 to 500 kWh, in 500 kWh steps.

Two points are noteworthy. Firstly, even at such very low electricity consumption as 500 kWh yr\(^{-1}\), variant C produces a higher gain for the array owner than variant A, albeit the difference reduces from 6.6% at 3500 kWh yr\(^{-1}\) to 1.4% at 500 kWh yr\(^{-1}\).

Secondly, as figure 5 below illustrates, the array cost payback time under variant B (feed-in tariff only for PV electricity surplus to on-site needs) steadily shortens as annual consumption reduces, while that under variant A (feed-in payment for on-site use as well as exported surplus) scarcely changes. The payback times converge, however, only at an extraordinarily low level of annual electricity consumption; at 500 kWh yr\(^{-1}\) that for variant B is still 1.1 yr longer than for variant A. More interesting is that, at 2000 kWh annual consumption, the simple payback time under variant B is clearly below the putative 20 yr duration of the feed-in tariff,
Figure 5. PV array cost payback time in years (Y axis) at different levels of annual electricity consumption in kWh (X axis), at Bromley.

Table 3. Array cost payback time (yr) under UK government PV FIT proposals.

| Payback time (yr) and FIT cost (£) | Annual electricity consumption |
|-----------------------------------|-------------------------------|
|                                   | 3300 kWh | 4000 kWh | 4677 kWh |
| Durham                            | 9.8 yr   | 10.2     | 10.0     |
|                                  | £1254    | £1242    | £1232    |
| Shrewsbury                        | 9.2      | 9.5      | 9.9      |
|                                  | £1282    | £1270    | £1259    |
| Bromley                           | 8.9      | 9.3      | 9.6      |
|                                  | £1317    | £1305    | £1294    |

which might bring investment in a PV array into a cost range perceived as ‘affordable’.

8. UK government proposals

It is straightforward also to calculate, on the basis of the same data for monthly PV array output and household electricity consumption for each location, the array cost payback time on the basis of the UK Department for Energy and Climate Change’s core proposal for PV FIT. To recall, it is: ‘generation tariff’ of 36.5 p kWh\(^{-1}\) for all PV electricity; plus ‘export tariff’ of the wholesale price (here assumed to be 4 p kWh\(^{-1}\)) for any surplus exported to the grid; plus avoided cost of buying from the grid through in-house use of PV electricity.

Comparing with the base case—no PV array and all electricity used bought in from the grid—the simple payback times are as in table 3. They are clearly shorter than under FIT scheme variants A–C as discussed above, as they range from 10.2 down to 8.9 yr.

9. Limitations of the research

For each variant the raw payback time, shown in figures 1–3, is simply the array cost divided by the annual gain relative to the base case of no PV array. That is, of course, a somewhat crude calculation, omitting on the one hand financing costs, possible tax liability on income and any interest that the array buyer’s own capital could otherwise have earned; and on the other hand the income from remaining years of the feed-in tariff period and any further grant or other support available from local or national authorities. Nonetheless it may serve as an indication of the relative attractiveness of the investment. The rate of return on the array owner’s investment would depend on several factors, including array cost, percentage of it financed by borrowing, interest rate and whether feed-in tariff income was taxable.

A fuller sensitivity analysis could usefully examine the effect on array cost payback time of varying such factors as array output, array cost and grid retail electricity price, as well as considering a wider range of UK locations and household electricity consumption levels. Refinements of this analysis would be to obtain more precise annual electricity consumption data for the three sample locations, or at least regional averages for northern, central and southern England, and to apply the same model to a smaller PV array capacity, and lower electricity consumption, such as might correspond to a smaller size of house with a lower number of occupants.

10. Conclusions

10.1. Which is the better FIT variant?

That question immediately prompts another: better for whom? The focus of this paper is on which variant would be more advantageous for a PV array owner. Policy makers will, however, no doubt also want to consider the overall cost of the FIT scheme, in relation to its effect in promoting an increase in installed PV capacity.

Recent research in the UK by Mark Watson (reported in New Energy Focus 2009) finds that 23% of households would invest in PV, and 90% would consider it, if the feed-in tariff rate was set at 50 p kWh\(^{-1}\). That is significantly above the successful German rate, which the analysis in this paper indicates would produce payback times well within the 20 yr duration of an FIT. The disparity may stem from attitudes to long term investment, the degree of understanding of how an FIT makes it predictable and secure, and therefore the length of payback time readily acceptable.

10.2. Payback time

An important point in relation to promotion of PV capacity growth in the UK is that, under either of variants A or C and for
all locations and levels of electricity consumption considered, the raw payback time is less than 14 yr. This is significant because the UK government is proposing a feed-in tariff which is fixed for 25 yr (cf 20 yr in the German scheme). The prospect of recovering the cost of a PV array in significantly less time than that may be expected to encourage investment.

How long it would take in practice to recover the cost, and the level of return on investment in a PV array, would, of course, depend on several factors, especially: rate of feed-in tariff, cost of PV array, projected array output, availability and terms of loan finance, percentage of array cost borrowed, grid retail electricity price, tax position and ‘bonus’ feed-in tariff income for several years after the array cost is recovered. A feed-in tariff fixed for a long period makes it, however, straightforward to ‘run the numbers’ and calculate whether the investment in a PV array is worthwhile—whatever the prospective buyer’s requirements in terms of return on investment. It thus provides confidence, which tends to facilitate a positive decision.

The payback time under variant B, however, becomes less than the anticipated 20 yr duration of the feed-in tariff only at an annual consumption level of 2180 kWh, less than half of the average level for the UK at 2006 (4677 kWh). Furthermore, these comparisons are for a location in southern England. PV array output would, as a rule, be less, and payback time therefore longer, at locations further north.

This indicates that variant B, feed-in tariff only for PV electricity surplus to on-site needs, would not be sufficiently attractive to promote investment in rooftop PV arrays. Accordingly the UK government should opt for variant C, feed-in tariff for all electricity from a PV array; or variant A, lower rate feed-in tariff for electricity used on-site plus full feed-in tariff for any electricity surplus to on-site needs; or of course a further variant similar to those.

### 10.3. Trade-off between payback time and feed-in tariff payments

Potentially of particular interest to government is that, as table A.1 (in the appendix) shows, the difference in payback time, as between variants A and C, is substantially less than the difference in the cost of feed-in tariff payments involved. Variant C produces a payback time only 10–14 months shorter than variant A, but requires payments from £386 (41%) to £472 (59.5%) higher.

Let us assume that FIT payments would be spread across all electricity users (possibly with exemptions for some categories) as an addition to bills, as under the German and other systems. German experience is that the extra cost amounted in 2007 to only £3 per household each month (BMU 2008). If the UK government is nonetheless concerned about the potential burden on electricity consumers of that addition to their bills, then it may conclude that the slightly longer payback time under variant A is an acceptable trade-off for the markedly lower cost in feed-in tariff payments.

### 10.4. Is the proposed UK FIT too generous?

It is apparent from tables 3 and A.1 in the appendix that, under the scheme proposed by the UK government (DECC), the cost of feed-in tariff payments would be substantially higher than under variant A or variant B described in this paper. The cost would be similar to that under variant C, which is essentially the German FIT scheme without a lesser tariff for in-house use—which has been very successful in building PV capacity.

In one view, the DECC proposal would involve a similar level of FIT costs to the German scheme, but deliver shorter payback times. That could be significant in terms of consumer psychology. That is beyond the scope of the present paper; however, there is an extensive literature, a recent example being Hardisty and Weber (2009). It is nonetheless worth observing that, if a shorter payback time is considered necessary in terms of making PV attractive to UK householders, then the DECC proposals offer a cost-effective approach to achieving that. That can be seen from table 4, which shows that in all except the ‘southern England/high annual consumption’ case, the DECC proposal costs slightly less in FIT payments for each year by which the payback time is reduced below 20 yr; and considerably less for shortening payback time below a 15 yr threshold.

In another view, payback times only a year longer than under a German-style FIT are achievable at much lower cost in tariff payouts (variant A). Given that the DECC proposal is for a 25 yr FIT life, it is arguable that a 12–13 yr payback time, as opposed to one of 9–10 yr, should be sufficient to attract UK householders to invest in PV arrays.

### Table 4.

| Location + kWh yr \(^{-1}\) use | Cost per year shorter below 20 | Cost per year shorter below 15 |
|--------------------------------|-------------------------------|-------------------------------|
|                               | Variant A | Variant C | UK govt proposal | Variant A | Variant C | UK govt proposal |
| North 3300                    | 137.94    | 170.95    | 122.94           | 668.46    | 527.08    | 241.15           |
| Mid 3300                      | 138.15    | 170.00    | 118.70           | 598.67    | 496.92    | 221.03           |
| South 3300                    | 130.83    | 166.00    | 118.65           | 428.18    | 442.67    | 215.90           |
| North 4000                    | 133.71    | 170.95    | 126.73           | 690.83    | 527.08    | 258.75           |
| Mid 4000                      | 132.00    | 170.00    | 120.95           | 572.00    | 496.92    | 230.91           |
| South 4000                    | 122.84    | 166.00    | 121.96           | 378.75    | 442.67    | 228.95           |
| North 4677                    | 127.90    | 170.95    | 123.20           | 660.83    | 527.08    | 246.40           |
| Mid 4677                      | 126.00    | 170.00    | 124.65           | 546.00    | 496.92    | 246.86           |
| South 4677                    | 121.94    | 166.00    | 124.42           | 399.09    | 442.67    | 239.63           |
### Appendix

**Table A.1.** Cost of feed-in tariff payments (£) and array cost simple payback time (yr) for three locations in England, and for three annual household electricity consumption levels, under three feed-in tariff scenarios, and the UK government proposed tariff.

| Variant | 4677 kWh yr⁻¹ | 4000 kWh yr⁻¹ | 3300 kWh yr⁻¹ |
|---------|---------------|---------------|---------------|
|         | North| Mid| South | North| Mid| South | North| Mid| South |
| A       | £793  |£819 |£878 | £829 |£858 |£909 | £869 |£898 |£942  |
|         | 13.8 yr |13.5 yr |12.8 yr | 13.8 yr |13.5 yr |12.6 yr | 13.7 yr |13.5 yr |12.8 yr |
| B       | £141  |£170 |£171 | £228 |£261 |£277 | £322 |£355 |£390  |
|         | 31.6 yr |30.1 yr |29.4 yr | 28.6 yr |27.2 yr |25.0 yr | 25.9 yr |24.7 yr |22.8 yr |
| C       | £1265 |£1292 |£1328 | £1265 |£1292 |£1328 | £1265 |£1292 |£1328 |
|         | 12.6 yr |12.4 yr |12.0 yr | 12.6 yr |12.4 yr |12.0 yr | 12.6 yr |12.4 yr |12.0 yr |
| UK govt proposal | £1232 |£1259 |£1294 | £1242 |£1270 |£1305 | £1254 |£1282 |£1317 |
|         | 10.0 yr | 9.9 yr | 9.6 yr | 10.2 yr | 9.5 yr | 9.3 yr | 9.8 yr | 9.2 yr | 8.9 yr |
| Base    | Cost of grid electricity £575 | Cost of grid electricity £492 | Cost of grid electricity £406 |

**Table A.2.** Net gain/cost under alternative FIT schemes, comparison with base case and pure FIT system, for annual household consumption 4677, 4000 and 3300 kWh cases. PV array 4 kWp generating 3336 kWh (Durham, northern England).

| Variant | FIT income | Buy from grid | Net gain/cost | Gain over base case | PV array cost payback time |
|---------|------------|---------------|---------------|---------------------|--------------------------|
|         | 4677 kWh yr⁻¹ |               |               |                     |                         |
| A       | £792.70    | £211.87      | £580.84      | £1156.11           | 13.84 yr                 |
| B       | £140.66    | £211.87      | £71.21       | £504.04            | 31.64 yr                 |
| C       | £1265.40   | £575.27      | £690.13      | £1265.40           | 12.64 yr                 |
| Base case: all bought in | 0 | £575.27 | £575.27 | — | — |
|         | 4000 kWh yr⁻¹ |               |               |                     |                         |
| A       | £829.48    | £160.76      | £668.72      | £1160.72           | 13.78 yr                 |
| B       | £228.00    | £160.76      | £67.24       | £559.24            | 28.61 yr                 |
| C       | £1265.40   | £575.27      | £690.13      | £1265.40           | 12.64 yr                 |
| Base case: all bought in | 0 | £492.00 | £492.00 | — | — |
|         | 3300 kWh yr⁻¹ |               |               |                     |                         |
| A       | £869.24    | £111.08      | £758.16      | £1164.06           | 13.74 yr                 |
| B       | £322.43    | £111.08      | £211.35      | £617.25            | 25.92 yr                 |
| C       | £1265.40   | £575.27      | £690.13      | £1265.40           | 12.64 yr                 |
| Base case: all bought in | 0 | £405.90 | £405.90 | — | — |

**Table A.3.** Net gain/cost under alternative FIT schemes, comparison with base case and pure FIT system, for annual household consumption 4677, 4000 and 3300 kWh cases. PV array 4 kWp generating 3400 kWh (Shrewsbury, central England).

| Variant | FIT income | Buy from grid | Net gain/cost | Gain over base case | PV array cost payback time |
|---------|------------|---------------|---------------|---------------------|--------------------------|
|         | 4677 kWh yr⁻¹ |               |               |                     |                         |
| A       | £819.31    | £213.25      | £606.06      | £1181.33           | 13.54 yr                 |
| B       | £169.73    | £213.25      | £43.51       | £531.76            | 30.09 yr                 |
| C       | £1292.00   | £575.27      | £716.73      | £1292.00           | 12.38 yr                 |
| Base case: all bought in | 0 | £575.27 | £575.27 | — | — |
|         | 4000 kWh yr⁻¹ |               |               |                     |                         |
| A       | £857.77    | £163.80      | £693.97      | £1185.97           | 13.49 yr                 |
| B       | £261.06    | £163.80      | £97.26       | £589.26            | 27.15 yr                 |
| C       | £1292.00   | £492.00      | £800.00      | £1292.00           | 12.38 yr                 |
| Base case: all bought in | 0 | £492.00 | £492.00 | — | — |
|         | 3300 kWh yr⁻¹ |               |               |                     |                         |
| A       | £897.53    | £114.12      | £783.41      | £1189.31           | yr                        |
| B       | £355.49    | £1114.12     | £241.37      | £647.27            | yr                        |
| C       | £1292.00   | £405.90      | £886.10      | £1292.00           | 12.38 yr                 |
| Base case: all bought in | 0 | £405.90 | £405.90 | — | — |
Table A.4. Net gain/cost under alternative FIT schemes, comparison with base case and pure FIT system, for annual household consumption 4677, 4000 and 3300 kWh cases. PV array 4 kWp generating 3496 kWh (Bromley, southern England).

| Variant | FIT income | Buy from grid | Net gain/cost | Gain over base case | PV array cost payable time |
|---------|------------|---------------|---------------|---------------------|--------------------------|
| A: FIT for export and in-house use | £878.23 | £201.53 | £676.71 | £1251.98 | 12.78 yr |
| B: FIT for export surplus only | £170.57 | £201.53 | £30.96 | £544.31 | 29.40 yr |
| C: all PV fed in, all used bought in base case: all bought in | £1328.48 | £575.27 | £532.21 | £1328.48 | 12.04 yr |

4677 kWh yr⁻¹

| Variant | FIT income | Buy from grid | Net gain/cost | Gain over base case | PV array cost payable time |
|---------|------------|---------------|---------------|---------------------|--------------------------|
| A: FIT for export and in-house use | £908.87 | £152.52 | £756.35 | £1248.35 | 12.82 yr |
| B: FIT for export surplus only | £276.94 | £152.42 | £124.62 | £616.42 | 25.96 yr |
| C: all PV fed in, all used bought in base case: all bought in | £1328.48 | £572.10 | £636.48 | £1328.48 | 12.04 yr |

4000 kWh yr⁻¹

| Variant | FIT income | Buy from grid | Net gain/cost | Gain over base case | PV array cost payable time |
|---------|------------|---------------|---------------|---------------------|--------------------------|
| A: FIT for export and in-house use | £941.84 | £102.84 | £839.00 | £1244.90 | 12.85 yr |
| B: FIT for export surplus only | £389.99 | £102.84 | £287.15 | £693.05 | 23.09 yr |
| C: all PV fed in, all used bought in base case: all bought in | £1328.48 | £405.90 | £922.58 | £1328.48 | 12.04 yr |

3300 kWh yr⁻¹

Table A.5. Net gain over base case, and simple array cost payback time, for annual household consumption levels ranging from 3500 to 5000 kWh; PV array generating 3496 kWh yr⁻¹, in Bromley (southern England).

| kWh yr⁻¹ | Variant A | Variant B | Variant C |
|----------|-----------|-----------|-----------|
| 3500 | £1246 | £516 | £1328 |
| 3000 | £1243 | £726 | £1328 |
| 2500 | £1252 | £798 | £1328 |
| 2000 | £1263 | £876 | £1328 |
| 1500 | £1276 | £967 | £1328 |
| 1000 | £1283 | £1054 | £1328 |
| 500  | £1310 | £1200 | £1328 |
| 12.2 yr | 13.3 yr | 12.0 yr |

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