UPDATES TO THE FEED-IN TARIFFS MODEL
DOCUMENTATION OF CHANGES FOR SOLAR PV CONSULTATION

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FINAL

Submitted by:

Cambridge Economic Policy Associates Ltd
and Parsons Brinckerhoff

CONTENTS

1. SCOPE OF WORK, AND SUMMARY OF CHANGES

This report documents the changes that PB and CEPA made to DECC's Feed-in Tariffs (FITs) model during July and August 2011. It is an abridged version of the full report prepared by PB and CEPA, focussing on updates relevant for the solar PV consultation. Updates to functionality, and technology specific issues for other technologies eligible for FITs, are not included in this document, but will be in the full report.

1.1. Structure of document

Following this introduction, we set out how we have updated the model's input assumptions. Section 2 documents the updates we have made to the technology input assumptions. This includes updates to the technology costs and the potential for technology deployment. Section 3 documents how we have arrived at revised hurdle rates for investors. This includes a discussion of how those rates are treated within the model and the implications for how the inputs should be set. Data tables showing all the updated inputs are included in Annex C.

2. TECHNOLOGY INPUTS

This section describes the revisions we have made to the input cost and technology data used in the FITs model. Following discussion with DECC, we reviewed data for those technologies that are currently eligible for FITs, including solar PV, the subject of this report. For those technologies, we have revisited the range of assumptions, including:

- The technology banding, including the size of each band and the number of bands, and what a typical installation within each band might be.
- The export fraction – that is, the percentage of the output of a typical installation that would be sold back to the national electricity grid, rather than used onsite.
- Capital costs, both current and projected.
- Operating costs, again both current and expected.
- Load factors.
- The technical potential of the technology. This is a theoretical maximum, and is very unlikely to be approached or achieved in practice. It is however used within the model as a key input for uptake and supply chain development.
- The expected lifetime of an installation.
- Uptake to date.

A range of different sources have been used to develop the revised input data. These sources are listed in Annex B. In general, our approach has been to combine data from industry discussions with recent independent reports and our own project experience to derive updated values. The data used was collected during July 2011. As noted above, part of the scope of our work has been to provide future cost projections to 2030. While we have sought to provide reasonable estimates based on possible future technology and market developments, such estimates are by nature uncertain, particularly over the 20 year timespan to 2030.

Capital and operating costs have been derived with Low, Medium and High cases. The Low and High cases are based on the range of data received, plus our own experience and judgement as to what values would be reasonable. The Medium case values are based on where the data "clusters", i.e. where the majority of the data points lie. The Medium case value is not the mean of the Low and High case values, although in some cases it may result in a value close to the mean.

2.1. Solar PV

Solar PV has seen the largest uptake of all technologies since the introduction of the FIT scheme. Details on the solar PV systems registered under the FIT and the market characteristics which have developed have provided an evidence base to inform this review. The bandings for solar PV have been updated to reflect the changes introduced during the Fast Track Review. As well as this the capital cost data has been revised due to the significant cost reductions witnessed over the last two years. It should be noted that the solar PV market has continued to change rapidly over the period since the data used in this report was gathered. A category for solar PV

Aggregators has been introduced to address the potential advantage of developers buying in bulk and receiving discounted prices due to economies of scale.

Details of how inputs to the model have been derived are provided below.

2.1.1. Bands

The PV bands have been updated to reflect the new size bands established following DECC's recent Fast Track Review.

Bands for aggregators have been added at DECC's request. Bands for aggregation at both <4kW and 4-10kW have been added, although indications are that the majority of installations will be less than 4kW in capacity.

2.1.2. Technology size

The size of a typical installation within each band has been based on the average size of installations registered for FITs to date (where a significant number of installations have taken place). For the larger size bands there have been few installations to date. In these cases the typical size has been based on:

- 150-250kW – the middle of the band, i.e. 200kW.
- 250-5000kW – we have assumed that roof space constraints mean that the majority of large roof top systems will be towards the lower end of this band, and have therefore used a typical size of 350kW.
- Stand alone systems – despite the likely existence of some multi-megawatt systems, we have assumed that the majority of future stand alone systems will make use of smaller areas of otherwise under-used land and have therefore applied a typical size of 200kW.

2.1.3. Export fraction

For domestic installations we have assumed an export fraction of 50% on the basis that daytime PV generation may exceed daytime on-site demand on a regular basis, although clearly a wide range of values will occur in practice depending on the demand profiles of individual households and actual generation levels from each installation. For larger installations we consider that on-site demand will be more significant in relation to the size of the installation, and that there will be significant demand during the day (e.g. for commercial buildings); that is, at the same time as the majority of PV generation. This would result in a reduced export fraction. This reflects our judgment, however, rather than being based on data from actual installations and is therefore subject to considerable uncertainty. At this stage we have therefore used two export fraction cases (20/ 25% and 50%), except in the case of stand-alone systems which by definition are exporters of all their generation. Real data from operating installations would be helpful in clarifying these export fraction values.

2.1.4. Capex

Installed costs of PV systems have reduced significantly over the last two years and are continuing to fall, driven by falling PV module costs worldwide and by the development of the

UK market for supply and installation. This is reflected in the capex numbers we have used which are significantly lower than those in the previous version of the model.

We have set capex for retro-fit and new build domestic PV at the same level (new build was slightly cheaper in the previous model). This is on the basis that the bulk of the market has been for retro-fit installations and this has driven down prices more quickly than in the new build sector.

Data on the costs for PV Aggregators show values ranging from around £1,600/kW to £4,000/kW[1], with a wide range of different values expressed. This may be as a result of different business and financing models being adopted by different Aggregators. For example, one firm reported that they need to use high quality modules in order to obtain bank financing, resulting in higher costs than might otherwise be the case. While individual domestic installations also showed a relatively wide range of capex values (approximately £3,000 - £4,960/kW[2]), there was more agreement in the data that an appropriate Medium value was approximately £4,000/kW. Our Medium estimate for Aggregator PV capex is approximately 64% of the Medium case cost for individual installations[3].

Future capex costs have been estimated based on continuing significant falls in prices for PV modules, smaller declines in the costs of other components and further learning and development of the UK installation market. Medium estimates are for a fall of approximately 25-30% to 2015, with ongoing but less rapid reductions after that. Costs for large installations are expected to fall slightly more quickly than for domestic installations as this market sector develops and greater economies of scale are achieved.

Although the industry expectation is for falling module prices, there was concern expressed from one source that the rapid price falls seen in early 2011 may be as a result of discounting (as demand cools in some European countries). This may lead to increased short term volatility, although the longer term downward trend is expected to continue.

2.1.5. Opex

Operating costs for PV are similar to those in the previous report, with the exception of <4kW systems where costs are assumed to be lower. This is on the basis of anecdotal evidence from the industry that most domestic systems will not have regular maintenance checks, reducing the costs to an annual allocation for eventual inverter replacement.

Aggregator costs again show a wide variation. Costs are assumed to be slightly higher than for individual installations due to the need to regularly inspect their assets, insurance costs etc.

Operating costs are expected to decline in future, though at a slower rate than in the previous model. This is based on the assumption that the costs of non-module spares and components will fall only slowly and that manpower and other opex costs will remain steady.

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[1] For aggregated <4kW systems, based on 2.6kW system

[2] Using High case capex costs for a 2.6kW system

[3] Using Medium case 2010 data from Annex C for a 2.6kW system results in total capex of £6,400 for an aggregator system compared to £9,950 for an individual system, i.e. 64%.

2.1.6. Load factors

Load factors for PV are generally similar to the previous model.

2.1.7. Technical potential

We have maintained the same total technical potential for solar PV as the previous model. Allocations between the bands have been adjusted to reflect the new bands and the addition of aggregators – this has been on the basis of the sizes and number of installations currently registered for FITs.

2.1.8. Lifetime

Typical lifetime for PV systems has been increased compared to the previous model (from 25 to 35 years) to reflect the robust nature of PV modules. Note that inverter replacement is included within the operating costs – we have considered that the inverter represents a small enough proportion of the overall capital cost for its replacement to be considered an operating cost.

2.1.9. Uptake

Uptake values use data from Ofgem for installations up to the end of March 2011. These have been allocated to the new PV bands as required. In line with data received from Ofgem, 15% of <4kW retro-fit PV installations have been assumed to be from Aggregators.

2.2. Issues identified with PV in the model

PV received some capital grants in the period before 2010 but the rates for these in the model were incorrect. The model also assumed that the grants were available to all, but in reality there was a limit on total grant spending. We have removed these grant rates as they overstated the attractiveness of these installations before the start of the FITs scheme, resulting in an artificially loose installation constraint for PV once the scheme started. This effect became more pronounced with updated assumptions on their useful asset lives and performance.

This does however mean that calibration of unobserved coefficients in the model is difficult. In particular, the "market barrier" within the model can only be calibrated based on 2010 data. The growth factor ("shape parameter") that drives the future evolution of the market barrier has been set to be broadly consistent with other technologies. This is not necessarily a good proxy, however, and we recommend sensitivity analysis on this important input.

3. INVESTOR HURDLE RATES

In this section we set out the approach we have taken to: (i) determining reasonable investor hurdle rates for small-scale FITs for different groups of investors, specifically households and different types of investor from the corporate sector; and (ii) estimating hurdle rates that might then be applied within DECC's existing model. As we will show, these need to be two distinct exercises given the way that the model has been constructed, especially as regards domestic investors.

We therefore begin by providing a short explanation of how hurdle rates work within DECC's model and some of the issues that this gives rise to. Not least of these, is the fact that the model calculates take-up of investments on a full population basis, rather than from estimated groups that have a combination of either the financial resources and / or motivation to invest in small-scale low carbon generation, which is especially relevant to the domestic sector.

We then set out our approach to establishing target hurdle rates for the different investor groups identified in terms of the factors that might be taken into account in developing an appropriate range of hurdle rates. This range is one that we would anticipate that the vast majority of target investors might fall within, in terms of a level of return that would trigger investment. It is important to note that this is **not** a recommendation on what level of return should be offered. It may be, for instance, that any target level of investment could be achieved more efficiently by capping returns at levels below the top of the range. In other words, setting the range too high would be economically inefficient as many investors would be offered a return well in excess of that needed to trigger investment.

For each investor group, we then turn to an analysis of hurdle rate assumptions that might be imputed into the model, that might as far as possible produce meaningful results, notwithstanding the limitations discussed above.

Finally, within our conclusions sub-section, we provide some suggestions on how this topic might be addressed in future, which we believe would provide a better insight into, and modelling of, different investor behaviours.

3.1. Using hurdle rates within the DECC model

Hurdle rates within the DECC model are used to determine what proportion of the potential for a technology to be deployed in any one year is actually taken up. The model assumes that there is some limit ("potential") on the amount of any one technology that can be deployed in the UK in any one year. This is driven in part by the technical lifetime potential (the maximum amount of the technology that could ever be installed in the UK, ignoring cost). However, a more important driver is the supply chain (which combines the number of technology units that can be either made or imported in the UK in a year with the number of installations that installers in the UK can do in twelve months if they work flat out). It also takes into account public knowledge of and acceptance of small-scale renewables. The hurdle rates are expressed as a range, which the model compares to the return from a given technology, taking into account any subsidy. There is zero uptake if the return on the technology is less than the lower end of the range, and the full in-year potential[4] is taken up if the return is above the top end, subject to sufficient installation capacity being available. Deployment increases linearly as the return increases from the lower end to the upper end. This assumption in particular – of linear growth as the return increases – must be taken into account when setting hurdle rates.

Some simple examples might help illustrate this. Suppose that the hurdle rate range is 5-10%. The uptake as a proportion of the potential in any one year is then as shown in Table 3.1 below.

Table 3.1: Uptake relative to return

Return given by FIT	Uptake in year as proportion of the potential in that year
5% or under	0%
6%	20%
7%	40%
8%	60%
9%	80%
10%+	100%

In terms of inputs, DECC's FIT model requires **real, pre-tax, project returns for commercial investors, and real post-tax returns for households**[5]. However, many investors think in terms of post tax, nominal, equity returns (less sophisticated investors may think in pre-tax terms). This means that there is a need to take what is observed and work back to project, real pre-tax (or post-tax, for households) for purposes of applying what is observed to the model. This involves having to make assumptions on inflation, project gearing[6] and the "tax wedge". Whilst gearing assumptions have been made on the basis of market observation and the tax wedge via tables, we have assumed an inflation rate of 2.7%, as per the Treasury's current forecast[7].

Once hurdle rates have been determined, they then have to be applied to the model. As far as possible, the aim is to try to replicate the real world within the given model parameters, to try to obtain the results that the real world hurdle rates identified might give rise to. We have therefore followed a two-stage process. We started by identifying appropriate ranges based on economic analysis and the available market intelligence. We then considered how those ranges should be adjusted to fit within the approach used in the model – in particular, the assumption of uptake growing linearly as the return on the technology increases.

[4] After allowing for the other barriers (market and social) in the model.

[5] Since FIT revenue is taxable for commercial property but not for households (this is a slight simplification for households since the revenue from exported electricity may be taxable, but given the relatively low rate for the export tariff we assume this is negligible).
Source: HMRC http://www.hmrc.gov.uk/manuals/bimmanual/bim40510.htm

[6] Which may be zero in some cases e.g. households that use only their existing equity to finance installation

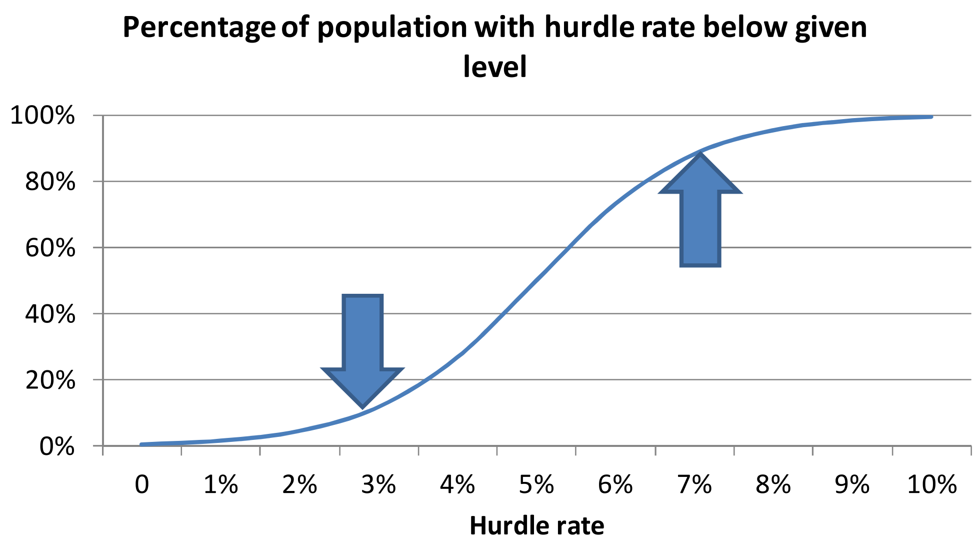
[7] http://www.hm-treasury.gov.uk/data_gdp_fig.htm

3.2. Approach to determining and applying rates

The first stage of our two-stage approach involves seeking to understand how different types of investors are likely to approach small scale renewable investment decisions and the different factors that they are likely to take into consideration, not least alternative investment opportunities. This provides us with a range of hurdle rates based on these considerations.

We then, in a second stage, adjust those ranges to be appropriate to the overall approach taken in the model. As noted earlier, the fact that the model assumes that take-up increases linearly between the lower and upper end of the hurdle rate ranges means that we need to take care in setting the upper bound. Put another way, how the rates need to be applied to the model means that they can differ significantly from the ranges identified initially. We need to choose a range of hurdle rates that cover the majority of the population where the assumption of linear take-up is reasonably close to reality. For example, suppose actual required hurdle rate is distributed across the population as in Figure 3.1 below.

Figure 3.1: Choosing a hurdle rate range



Judgment would be required in setting the hurdle rate range, but the two arrows above point to a possible choice of range that captures the majority of the population and within which uptake is relatively linear.

3.2.1. Determining hurdle rates

Our overall approach has been to first identify, for each investor type, a rate based purely on rate of return financial considerations. This rate has largely been established taking into account the nature of *alternative* investments with similar characteristics open to each investor group - in other words, the likely opportunity cost of capital. We have then considered other factors that will be likely to create a distribution or range around such an 'anchor' range of values; for instance, a desire to invest for environmental as opposed to purely financial reasons.

In assessing any investment, most investors look at the investment's risk and return profile and compare it to the expected returns from other investments with similar characteristics, in particular; the magnitude and nature of the *risks* faced, together with the length of time for which capital is tied up; that is, the *liquidity* of the investment[8]. In other words, investors consider the opportunity cost of capital when determining the returns they are targeting (their "hurdle rates") as opposed to just their cost of capital (or equity returns).

We therefore start by considering the degree of risk associated with investment in small-scale renewables under the FIT scheme. Whilst these investments are not risk-free, in many ways the risks are relatively low. The income from the projects is in the form of a guaranteed revenue per unit of electricity produced, and the payments are made by a party (Government) that represents a low credit risk. There is some weather risk, because of the reliance on sunlight or wind speeds. Some technological risk may remain, particularly with newer technologies. Operational, or reliability, risk will also need to be considered, since some technologies do not have many years of operating experience in the UK. Other risks may arise for specific projects. There is also policy risk, for instance in the event of Government "moving the goal-posts" once investors have committed to an investment, although this is partially mitigated by a track record of Government "grandfathering" previous investors, even when it has changed its policies.

The question then becomes what reasonable alternative investments might be. At this point, we need to separate commercial from domestic or household investors, as they are likely to have different alternatives. In both cases, we need to find reasonable comparator investments with similar risk profiles and investment lifetimes. An exact match is unlikely to be available, so we will need to look at the range of similar alternatives and use judgment to suggest what this might mean for appropriate hurdle rates for FITs.

3.3. Investor groups

We have been asked to consider three types of investor: (i) domestic households; (ii) corporate investors from a range of sectors looking to benefit from the FITs investment opportunity; and (iii) so-called Aggregators who are interested in developing a stand-alone renewables business, in which renewables installations such as solar panels are provided to customers, who receive the electricity generated, but where FITs payments are taken by the Aggregator. The different motivations of these groups help determine the level of hurdle rate that they seeking. In order to understand these motivations further, however, it is first important to determine who within these groups is likely to be most interested or amenable to making small-scale low carbon generation investments – this is often termed the "addressable market".

In determining the likely range of target returns we then consider the alternative range of investment opportunities that the identified group is likely to face, taking into account how each of the respective groups might appraise such opportunities.

3.3.1. Differences between corporate and domestic investors

The two main types of corporate investor are those whose main line of business is separate from renewables, but who would like the opportunity to invest in the FIT scheme none-the-less, and

[8] An alternative approach used by some groups is the concept of 'payback periods'.

Aggregators or other project developers who are interested in developing a business within the renewables space.

Both types of business are also likely have the potential to gear up (i.e. raise debt) in financing FITs investments, an option that may not be open to all households, except for wealthier ones. However, the returns targeted are likely to be different between those investors who are really looking at the opportunistic basis and those who are more committed to the market.

In either case, we therefore need to be clear about whether we are considering the *project* (overall) return from investing in small-scale renewables or the *equity* return, which is the return on the capital that the firm obtains after gearing up with debt. It is possible that more opportunistic investors might adopt a project-based approach, whereas investors in a full business will typically work on a nominal, post tax, equity return.

3.3.2. Domestic households

The starting point for analysing domestic households is to consider which households are most likely to be interested in micro-generation; that is, the characteristics that they exhibit in terms of financial capacity and other relevant factors. In determining this, we can then go on to see what these characteristics might imply in terms of the level of return required and the potential range around this.

PV and other forms of micro-generation are relatively lumpy to self-finance, of the order of several thousand pounds. This is a significant sum of capital to raise and then to tie up for a long period of time. We would suggest that, on the whole, the households able to undertake such investments are likely to be characterised by:

- a high level of disposable household income; and /or
- a relatively low level mortgage to house value ratio – that is, the ability to increase an existing mortgage to finance the micro-generation investment. At the moment, this can be done at a rate of 1.5% over the Bank of England Base rate[9], which is effectively negative in real terms.

In considering investments, those households with "spare" capital available for investment are most likely to compare the returns, risks and required term commitment of the available opportunities, against the other uses for that cash (for instance, unforeseen circumstances in which cash is required). Those who need to raise capital through a mortgage extension will need to take these costs – and risks of an increase in mortgage – into account in evaluating micro-generation opportunities.

As set out, micro-generation investments tend to involve tying up capital for significant periods of time – that is, once capital is committed it is difficult to release. We have therefore identified a range of investments that would tend to have similar characteristics to this and the returns that

[9] For example, the Co-operative Bank allows a mortgage to be extended by up to £20,000 to finance a range of technologies including micro-renewables. http://www.co-operativebank.co.uk/servlet/Satellite/1193206369165,CFSweb/Page/Bank-Mortgages?WT.svl=copy

are currently available. These are listed in the table below which shows different return metrics. The FIT returns currently available are shown for comparison purposes.

Table 3.2: Investment alternatives

Investment	Capital tied up for	Tax free	Key risks	Return	Equivalent rates		
					Pre-tax nominal	**Post-tax nominal**	**Post-tax real**
Pensions	Up to 40 years	Yes[10]	Economic growth	4%[11]-8%[12] (post-tax, nominal)	6.7-13.3%	**4-8%**	1.3-5.3%
Index-linked National Savings Bonds[13]	5 years	Yes	Essentially risk-free	0.5% (post-tax, real)	5.3%	3.2%	**0.5%**
Buy to Let	Effectively 5 years or more	No	Rental values, growth in property prices	9% (pre-tax, nominal)[14]	**9.0%**	5.4%	2.7%
Repayment of mortgage	Several years (until owner moves house)	Yes	Interest rates	4.8% (post-tax, nominal)	8.0%[15]	**4.8%**	2.1%
Small-scale FITs	As for property	Yes	Operational	5-8%[16] (real post-tax)	12.8-17.8%	7.7%-12.3%	**5-8%**

Note: Investments can be tax-free or taxable, and have returns specified in real or nominal terms. To allow different investments to be compared, we show in the table above the equivalent rates in real, nominal, pre- and post-tax terms. Tax is assumed to be at 40%, and inflation is 2.7% (source: HMT assumption post 2013).

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[10] Contributions to pension schemes are eligible for tax relief, although pensions are not tax-free when paid out. Source: HMRC http://www.hmrc.gov.uk/incometax/relief-pension.htm

[11] Recent returns on BBC pension assets: http://downloads.bbc.co.uk/mypension/en/report_and_accounts_2011.pdf . We assume that these returns are net of fees – if not, it would further reduce the return.

[12] Typical rate of return on US pension assets http://www.reuters.com/article/2011/04/21/us-usa-states-pensions-idUSTRE73K59S20110421

[13] National Savings and Investments: http://www.nsandi.com/savings-index-linked-savings-certificates

[14] This ignores any capital gains.

[15] Average mortgage rate over last five years was 4.8% (Source: Bank of England). At 40% tax, this is equivalent to a pre-tax investment paying 8%.

[16] The original FITs scheme, as introduced in April 2010, aimed to provide a real rate of return of approximately 5-8%.

Target returns

The table above suggests that real post tax returns of common financial savings products – even after taking into account their tax benefits are barely positive – although in part this reflects current historically low interest rates.

Pensions provide an example of the returns expected from very long term, tax-free, investments, although the returns are arguably more risky than from FITs, the range presented here is a broad one of 1.3-5.3% real[17].

An attractive form of risk-free and tax effective investment is early mortgage repayment – especially for those with high levels of disposable incomes, which we have calculated as being equivalent to approximately 2% in real terms. Buy-to-let investments, which are also arguably more risky and a more involved, time-consuming investment than micro-generation (also probably requiring more capital), but with similar liquidity features to a renewables investment, would be around 2.7%, post tax real. In comparison, the comparable returns from existing micro-generation opportunities are relatively generous, with a lower investment threshold requirement and lower market risk.

Given this evidence, we would suggest that a return of no more than around 4% (real, post-tax), would be a competitive "offer" for the households in question, based purely on financial considerations. Moreover, it is also arguable that a significant proportion of the total quantum of investment opportunities open to the identified household investor groups, would be covered by the investment types identified. As such on pure financial grounds, a range of 0.5% to 4% post-tax real would therefore appear to cover the range of financial hurdle rates. The bottom end of this would increase if real interest rates were to increase, either through an upward movement in base rates, or a fall in inflation, but we also assume that some of the investors identified above might be prepared to invest for non-financial reasons, such as concern for the environment or support for renewables in general. We also note the option to finance through extending one's mortgage, which can be done at interest rates that are negative in real terms. It would therefore be reasonable to stay with a range (rounded to the nearest percentage point) of 1-4%.

Key assumptions

The above analysis is based on some important assumptions in determining the rates set out. A crucial one is the ability to release the cash invested in micro-renewables installations, which will affect the overall return. This encompasses the time taken to do so, and the extent to which the owner might recover the full amount of the cash investment. Unless a market develops for the sale of installations to third parties, separately to the house they are attached to, the cash invested can only be realised by selling the house. This depends, in effect, on the value that the owner of the installation might expect to get when selling their house, in the form of a higher price than for the same house without the installation.

In theory, this price premium should be the discounted stream of cash flows from the installation, and there is some evidence[18] that this happens in practice, at least for energy

[17] A recent survey of the range of returns on offer to households (Sunday Times, 21 August) suggested a *pre-tax nominal* range of 0.9-8.1%.

[18] ICF*, Evidence of Rational Market Valuations for Home Energy Efficiency,* 1998

efficiency. In reality, however, the home-owner might not count on realising this full value, for example because of the relative novelty of micro-renewables compared to energy efficiency measures, but the question of what they might bank on realising is difficult to answer. In our analysis, we assume that this premium is realised. If it were not, the effective return required would arguably need to increase[19].

Review of existing rates within the model

We now turn to what ranges of hurdle rate we might apply within the model. In doing so, we begin by considering differences between the rates we have determined and those which have been imputed before. In the next section, we then go on to suggest, to the extent possible, what rates might best be used given differences in the approaches.

As set out, we have proposed a range of hurdle rates for households of between 1% and 4% real post-tax. This is essentially reflecting the slope of the supply of capital / investment curve for the households that we have identified as being most likely to invest in micro-generation.

This compares with a range of 3-20% used in the current model, which arguably reflects the supply curve for a much greater range of house-holds, with numbers at the high end reflecting those households who would struggle to raise capital except at high rates[20]. We now consider the basis for each end of that 3-20% range, as set out in the original report[21] for DECC.

We can see that the 3% figure is close to the social discount rate of 3.5%[22]. While there is some justification for this, in that it is intended to represent those households which install renewables for the benefit of society as a whole, our view based on opportunity cost is that it is too high for the lower bound on domestic discount rates. *Even purely on financial grounds,* 3% real post-tax is a reasonably attractive prospect for households, in the current investment climate. Including the desire of some households to install renewables for environmental or other altruistic reasons would tend to push this figure down even further, which we would argue makes 1% (close to what is effectively the risk-free rate for households) a more reasonable lower bound.

The 20% figure chosen as the upper end of the range is based on the effective discount rates that consumers are believed to use when deciding whether to install energy efficiency measures (such as insulation, or more efficient new appliances).

While the figure is within the range of those included in the literature, we have a concern that it is attempting to capture several different effects, some of which may not be applicable, or amenable to being captured in a hurdle rate.

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http://www.solarbysec.com/apj1098.pdf "*residential real estate markets assign to energy-efficient homes an incremental value that reflects the discounted value of annual fuel savings. The ...rate used...was expected to be 4%-10%, reflecting the range of after-tax mortgage interest rates during the 1990s...*"

[19] In the extreme case where a homeowner assumes no additional value from micro-renewables, they might look for the technology to payback within the period they expect to be in their home (perhaps around 5 years). This is equivalent to a hurdle rate well above 20%.

[20] This in itself is a brave assumption that households would be able to raise the capital at any price.

[21] Pöyry, Element Energy, *Design of Feed-in Tariffs for sub-5MW Electricity in Great Britain: Quantitative Analysis for DECC,* July 2009

[22] Source: HM Treasury Green Book

Table 3.3 below looks at some of these effects[23].

Table 3.3: Other effects which could be captured by consumer hurdle rate

Effect	Applicable?
Desire to be environmentally friendly	Yes, in some cases. Would tend to reduce the lower end of the range.
Hassle of installation	Yes
Visual impact/ amenity	Yes. More of an issue for some technologies than others
Lack of access to capital	Yes, although the effect is likely to be that the majority of adopters are those with significant capital, or with the ability to extend their mortgage at low rates to finance installation.
Misplaced incentive/ principal-agent problem	Questionable. Unlike for energy efficiency (where for rented houses the owner pays for installation and tenants receive the benefits of lower bills) the owner receives the FIT in all cases.
Lack of information	Yes
Market structure/ power	Unclear.
Inseparability of features	Questionable. This refers to the problem that for energy efficiency, consumers are often buying a whole appliance and not just a reduction in their energy bills, and so the efficiency aspect of the appliance is only one factor in the decision. For micro-renewables, the whole purpose of the installation is to reduce bills.
Uncertainty over future electricity prices	To some extent, although most indications are that prices are more likely to rise than to fall, which would make micro-renewables more attractive

Most of the factors in the table above would (if applicable) tend to push rates up. The question is whether 20% is an appropriate upper bound, remembering that the 20% figure is for the population as a whole. The figure is also for much less lumpy investments which are open to large groups of household investors. Indeed, given that expected uptake of micro-renewables is likely to be a relatively small proportion of the UK housing stock (c. 25m homes[24]), this figure may not be applicable[25].

As discussed, those investing in micro-renewables are likely to be those with more capital, and who might make decisions more on economic grounds. The range of hurdle rates in the model needs to capture the range in which the overwhelming majority of those likely to take up the technology would sit, rather than the population as a whole. In other words, to the extent possible, it is important to apply the hurdle rate to the addressable market – not the general population. In the next few years, this is likely to be biased towards those with relatively lower discount rates, which would tend to be wealthier homes. Even relatively low uptake by the

[23] The table draws on: Golove & Eto, *Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency*, 1996

[24] Source: National Statistics

[25] For example, the technical potential figure in the model for domestic PV alone is just over 21 TWh per year (excluding aggregators). Annual output is assumed to be just under 1MWh per kW, giving a total of around 21 GW. Domestic PV is 0-10kW, which implies that there are over 2 m homes in the UK that have the potential for PV alone.

wealthier half[26] of UK households would still lead to significant uptake. This suggests that we should choose a rate well below 20%.

Applying hurdle rates to the model

Our analysis suggests that a combination of rational investment and environmental motivations, would mean that real, post-tax rates of 1-4%, would be consistent with alternative investment opportunities.

We now need to adjust this rate to fit with how the existing model works. The key question is whether the range of hurdle rates in the model is intended to cover all consumers, or only the majority where linearly increasing uptake between the lower and upper end of the range is a reasonable assumption. As it covers all consumers, ideally we need to impute a range that if applied to the full population, would achieve a similar uptake to the 1-4% targeted on the most addressable group.

If the range is intended to cover all consumers, the energy efficiency evidence discussed above suggests that 20% for the top of the range would be reasonable. However, including a range of 1-20% would mean that (given a 5% rate of return from the FIT tariffs) just over 25% of the potential (after all other barriers were accounted for) would be taken up in any one year. This is due to the model's assumption of take-up increasing linearly through the range of hurdle rates.

We therefore have two possible values for the upper end of the range, 4% and 20%, each taking account of different factors. The question is how best to combine them into an appropriate upper bound for the model.

There is no perfect solution to this issue, and there is a risk of spurious accuracy in trying to come up with a hurdle rate that takes account of factors such as those in Table 2; hurdle rates are arguably not a good proxy for those factors. In setting the upper bound, therefore, we propose to use an average of the two upper bounds. This gives an upper bound of (4+20)/2=12%, and hence a range of hurdle rates of **1-12% (post-tax, real) for households**.

3.3.3. Commercial (non-domestic investors)

The arguments regarding the opportunity cost of capital also apply to corporate investors looking to install small-scale renewables, although the type of alternative investments will differ, probably as regards the returns associated with their core businesses. They are most likely to have either capital available or else easy access to additional capital – in other words, they are likely to be better performing companies. These investors are also likely to have sufficient amounts of roof space and are likely to include storage businesses, assembly plants, large supermarkets or other retailers and large offices, for example.

A possible way in which such investments might be considered is the project return from investing in renewables relative to alternatives investments in the company's core business (although the investment scale is likely to be relatively small relative to other uses). If such a company is knowledgeable regarding its WACC, it may see how renewables investment

[26] Net wealth for the 3rd quartile (by net wealth) of households was an average of £145,000, excluding pension assets, in 2006/08. Source: National Statistics http://www.statistics.gov.uk/downloads/theme_economy/wealth-assets-2006-2008/Wealth_in_GB_2006_2008.pdf

compares to other uses of the same capital, after making any adjustments for any higher or lower risk premia. We would suggest that given the relatively riskless nature of small-scale renewable generation investments, this should amount to a relatively small premium, if at all, which in any event might be offset by additional rationale for making such investments.

Market intelligence suggests that, historically, a broad range of businesses have considered installing small-scale renewables, and that the renewables industry has been active in approaching those businesses with sufficient space that might consider installation. It is therefore difficult to provide a "typical" WACC for those businesses that might consider installation.

As the ability of companies to install small-scale renewables is often related to their ownership of property, as a proxy, we have looked at the range of costs of capital for investors focusing on real estate. Typical values range from 5.2% to 11% (pre-tax, nominal)[27], reflecting perhaps turbulence in real estate markets, which is equivalent to around 2.5% to 8.3% real, pre-tax (assuming anticipated inflation of 2.7%). We have also looked at the cost of capital for three major supermarket chains, as an example of the type of organisation that might consider installing small-scale renewables on their land or buildings. The values range from 8.1% to 9.2%[28] (pre-tax, nominal), and for a group of utilities 6.6% to 8.8% in nominal, pre-tax terms. As a further reference point, reflecting the fact that the range of companies taking up small-scale FITs is very broad, we have analysed the WACCs (where available) of all UK-based companies quoted on the FTSE. This gives an average nominal, post tax WACC of 8.8% (or 6.1% real).

As with households, the expected financial return is not the only factor influencing firms' decisions, but we would expect it to have a greater weight with commercial organisations than with households. Other factors that could influence firms' decisions could include corporate social responsibility, or a desire to improve their environmental performance or credentials. For firms where energy is a large proportion of their costs, the guaranteed price offered by renewables might be seen as a useful hedge against future rises in retail electricity prices. Both of these factors would tend to push down the required hurdle rate. On the other hand, small firms are likely to face a higher corporate cost of capital, because of their reduced ability to gear. This could drive up the required hurdle rates. The practical difficulties of installation on commercial roofs (such as disruption to a store's customers, or health and safety considerations) may also weigh in the decision, pushing up the required rates.

Target range

Given the above, an investor target range of returns, based on alternative, risk adjusted investment opportunities, measured as a WACC, might be in the range of **5-8%** pre-tax, real. While it could be argued that the lower end should be reduced substantially, to account for those firms that put a high value on their environmental credentials, this needs to be balanced against their concerns about the disruption and other issues associated with installation. We therefore recommend that the lower end of the range should remain at 5% real pre-tax.

[27] Source: Bloomberg

[28] Source: Bloomberg. Figures are for Sainsburys, Tesco and Marks & Spencer

Applying within the model

We then need to consider, in the second stage of our analysis, how the upper end of the range should be set to strike the correct balance between assuming that the range covers the full investor population and that uptake within the range increases more or less linearly. Unlike in the case of households, the broad range of returns presented is probably sufficient to largely cover the investor group. We therefore propose leaving the **5-8%** range unchanged.

This is significantly lower than the current range in the model of 6-15% for commercial operators. It is however in line with the rates of return targeted in the original FIT rates of between 5% real (for PV) and 8% (for anaerobic digestion)[29].

3.4. Aggregators

The third group of investors are aggregators, who are renewables businesses that essentially purchase PV[30] equipment and then lease it to households in return for the FIT payment (with households keeping the benefits of the free electricity generated). Evidence from the US suggests that this is a very popular route[31] for households that cannot afford to buy equipment outright.

The considerations for aggregators are, if anything, driven even more by expected financial returns than for commercial organisations, since corporate social responsibility or price hedging objectives do not apply to them. However, they may obtain benefits from employment income, especially where companies are smaller and possibly owner managed, which may serve to lower pure investment hurdle rates.

Such investors will target *equity* returns. Making the assumption that equity returns are similar across different renewables investments with a similar risk profile, we have considered onshore wind as a starting point to establish a benchmark return, given the similarities between it and investment in solar PV. Work previously undertaken for DECC by CEPA suggested that the target (post-tax, nominal) project rate of return for these projects is currently around 8.4-9%[32], which delivers a **post tax nominal equity return** of 17% to 22%, once gearing is taken into account.

This is equivalent to a real *post tax* project rate of between **5.7%** to **6.3%,** given an expected inflation rate of 2.7% and gearing levels of 70% to 75%[33]. This is then equivalent to a *real pre-tax* range of **8.7%** to **9.6%.** We can also look at the expected project returns published in other research. A recent study[34] for the Committee on Climate Change suggested (real, pre-tax) project rates of 6-9% for large-scale PV, and 7-10% for large-scale onshore wind.

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[29] DECC, *Feed-in Tariffs: Government's Response to the Summer 2009 Consultation*, February 2010, http://www.decc.gov.uk/assets/decc/Consultations/Renewable%20Electricity%20Financial%20Incentives/1_20100204120204_e_@@_FITsconsultationresponseandGovdecisions.pdf

[30] To date, aggregation has focused on PV, although there is some evidence of it emerging in the micro-wind sector.

[31] http://blogs.reuters.com/environment/2010/12/15/california-solar-installer-raises-15-million-to-expand-to-the-east-coast/

[32] CEPA, *Note on impacts of the CfD FIT support package on costs and availability of capital, and on existing discounts in power purchase agreements,* June 2011, available at www.decc.gov.uk

[33] Similar to the levels achieved by onshore wind (source: CEPA, op. cit.)

[34] Oxera, *Discount rates for low-carbon and renewable generation technologies,* April 2011, available at www.theccc.org.uk. Figures sourced from table 4.1

The question is then what might be appropriate from the perspective of Aggregators, in part, taking into account these benchmarks. All of the above are arguably riskier than aggregation; especially large scale wind. Even large scale solar is likely to be more risky from both a construction and technology perspective; larger scale applications also face more market-based risks. Moreover, we have confidential anecdotal evidence that suggests that nominal post tax equity returns are in the order of 13%. If we assume similar a similar cost of debt and gearing levels, this would suggest a real, pre-tax project rate of around 7%. If we assume lower gearing, this would suggest a rate of over 7.5%.

As regards the lower end, as aggregator businesses could be relatively small scale, even family businesses, the required return could be relatively low, as owner-managed businesses also provide revenue from self employment as well as pure investment returns.

We therefore consider that a range of, say, 5-7% (real, pre-tax**)** would provide an aggressive range, but increasing the top end of the range to take account of more conservative gearing levels of, say 65% would provide a range of **5-8%** (note that the these numbers are highly sensitive to the gearing assumption).

Applying to the model

Given that this is a narrow range, the exact shape of the uptake distribution within it is relatively unimportant; we therefore do not consider that any modifications are needed to make it fit within the model.

3.5. Views on rates previously applied in the model

Documentation of the model assumptions[35] notes that in calculating the resource costs of installing renewables, a figure of 10% has been used as "a standard cost of capital that might be applied to renewable energy projects". Our analysis in the previous section (on aggregators) suggests that a mid-point rate of **6% (real, pre-tax)** is more appropriate based on the latest market evidence and by implication that the 10% figure may be too generous.

3.6. Summary and conclusions

Table *3.4* below summarises the rates that we consider should be used in the model for each type of investor in FITs.

Table 3.4: Summary of proposed input hurdle rates

Investor type	Lower hurdle rate	Upper hurdle rate
Households	1%	12%
Commercial property	5%	8%
Aggregators/ developers/ utilities	5%	8%

[35] Pöyry/ Element, op. cit., section 3.7.2

Each range is based on an anchor rate, determined by financial considerations, that is then adjusted to allow for non-financial factors as appropriate. It is then adjusted to fit within the model's requirement for uptake to increase approximately linearly within the range. Whilst the corporate rates are in line with reality, the domestic rates look far too high. This reflects the problems associated with fitting reality to the model.

3.6.1. Alternative approaches

We are somewhat critical of this type of approach taken to model uptake, particularly when applied to households (although clients have also requested us to develop similar approaches). This is separate from any views that we might have on the quality of the modelling itself. In particular we have significant concerns in driving household uptake largely from a hurdle rate, without a more detailed understanding of the real drivers for such uptake and without taking into account other important factors such as availability and ease of access to capital, which is not well proxied just by increasing the hurdle rate.

The main problem with such modelling approaches is that they run significant risks of spurious accuracy just because the model is complicated. In fact, when it comes to households, a simpler, transparent approach is likely to be warranted, based on approaches used in customer marketing. A commercial organisation seeking to understand what the uptake for its product might be, would begin by obtaining a good understanding of its potential market, through for instance understanding the requirements / desires of different consumer segments in terms of pricing points, price and income elasticities, financing (consumer credit) requirements and so on. Such market research would include primary and secondary data research, as well as the use of customer focus groups. Models of consumer behaviour would then be built to reflect these findings. Arguably, the same techniques could be used to develop an understanding of consumer uptake as regards renewables; but it would seem that in this instance it has been more a case of seeking to apply a corporate investor model to households.

ANNEX A: BASIS OF BUY-TO-LET RETURNS

We consider the likely returns received by an investor in property, with a deposit of 25%. The investor is assumed to be a higher rate (40%) taxpayer, with no opportunities for capital gains tax relief. Rental income, and the value of the property, are assumed to grow in line with inflation. The property is assumed to be worth between £250,000 and £500,000, which means that it is eligible for stamp duty at 3%.

Key assumptions are given in Table A1 below.

Table A1: Key assumptions behind "buy-to-let" comparator rate

Assumption	Assumed value	Source
Proportion of equity required to purchase	25%	
Yield (rental income as a proportion of cost of property)	5.2%	http://www.lslps.co.uk/documents/buy_to_let_index_jun11.pdf
Mortgage rate	4.8%	Bank of England
Estate agent's fees	2%	http://www.home.co.uk/guides/selling/estateagents.htm
Stamp duty	3%	http://www.hmrc.gov.uk/sdlt/intro/rates-thresholds.htm Rate for property between £250,000 and £500,000 used
Occupancy rate	90%	US rate used as assumed floor on occupancy http://uk.reuters.com/article/2011/01/31/us-usa-economy-vacancies-idUKTRE70U4EF20110131
Annual maintenance costs as % of rent	10%	Taken from recommended value of 'sinking fund' for repairs in http://www.propertyhawk.co.uk/index.php?page=magazine&id=463.
Long-run inflation	2.7%	GDP deflator used as estimate of long run (2011-2016) inflation taken from HM Treasury website: http://www.hm-treasury.gov.uk/data_gdp_fig.htm

ANNEX B: REFERENCES FOR COST AND POTENTIAL DATA UPDATES

In addition to PB's own recent project experience, the following external references have been used to help derive the updated cost and performance data.

- "Design of Feed-in Tariffs for Sub-5MW Electricity in Great Britain - Quantitative analysis for DECC - Final Report", Element Energy/Poyry for DECC, July 2009
- Input data used in previous version of model, provided by DECC
- Spreadsheet "Mott MacDonald data 010711.xls" provided by DECC
- Spreadsheet "EY and Arup data 010711.xls" provided by DECC
- Ofgem spreadsheet "Feed in Tariffs monthly update to June 2011.xlsx" provided by DECC
- Ofgem spreadsheet "Feed-in Tariff Installation Report 30 June 2011.xlsx", downloaded 14th July 2011
- "Review of the generation costs and deployment potential of renewable electricity technologies in the UK", Arup for DECC, June 2011
- "World Energy Outlook 2010", IEA, November 2010
- "Digest of UK Energy Statistics", DECC, 2010
- "Ernst & Young UK solar PV industry outlook - the UK 50kW to 5MW solar PV market", Ernst & Young, June 2011
- "Solar Generation 6", Greenpeace/EPIA, October 2010
- Informal quotes and discussions with a number of PV system suppliers, July 2011
- Cost data from a major tier 1 PV module supplier, July 2011
- Cost data from a UK "rent-a-roof" company, July 2011
- Cost data on a UK local authority aggregated PV framework contract, July 2011
- Informal data from other PV aggregators, July 2011
- Ofgem data on aggregated PV FIT installations up to 13th May 2011, provided by DECC

ANNEX C: DATA TABLES

Table C.1: PV reference site capacity kW

Size	Low	Medium	High
New build domestic (<=4kW)	2.0	2.6	3.0
Retrofit domestic (<=4kW)	2.0	2.6	3.0
New build 4–10kW	4.4	5.5	6.0
Retrofit 4–10kW	4.4	5.5	6.0
New build 10–50kW	15.0	20.0	25.0
Retrofit 10–50kW	15.0	20.0	25.0
New build 50–150kW	60.0	80.0	100.0
Retrofit 50–150kW	60.0	80.0	100.0
New build 150–250kW	175.0	200.0	225.0
Retrofit 150–250kW	175.0	200.0	225.0
New build 250–5000kW	300.0	350.0	500.0
Retrofit 250–5000kW	300.0	350.0	500.0
Stand alone system	150.0	200.0	1,000.0
Aggregators<4kW	2.0	2.6	3.0
Aggregators>4kW	5.0	6.0	8.0

Table C.2: PV export fraction (percentage of output exported to grid)

Size	Low	Medium	High
New build domestic (<=4kW)	10.0	50.0	75.0
Retrofit domestic (<=4kW)	10.0	50.0	75.0
New build 4–10kW		25.0/50.0	
Retrofit 4–10kW		25.0/50.0	
New build 10–50kW		20.0/50.0	
Retrofit 10–50kW		20.0/50.0	
New build 50–150kW		20.0/50.0	
Retrofit 50–150kW		20.0/50.0	
New build 150–250kW		20.0/50.0	
Retrofit 150–250kW		20.0/50.0	
New build 250–5000kW		20.0/50.0	
Retrofit 250–5000kW		20.0/50.0	
Stand alone system		100	
Aggregators<4kW		50	
Aggregators>4kW		25/50	

Table C.3: PV Technology Lifetime Years

Size	Low	Medium	High
All PV types	25	35	50

Table C.4: Cumulative PV Installed Capacity, installed by tariff band, kW

Size	2010
<=4kW (new build)	747
<=4kW (retrofit)	55,063
>4-10kW	2,597
>10-50kW	4,209
>50kW-150kW	422
>150-250kW	200
>250-5000kW	0
stand alone	289
aggregators	8,964

Table C.5: Cumulative PV Installed Capacity, installed by tariff band, number

Size	2010
<=4kW (new build)	401
<=4kW (retrofit)	21,280
>4-10kW	402
>10-50kW	224
>50kW-150kW	6
>150-250kW	1
>250-5000kW	0
stand alone	42
aggregators	3,464

Table C.6: Fuel price

Size	Domestic	Commercial building	Developer	Utility
New build domestic (<=4kW)	domestic	commercial	domestic	domestic
Retrofit domestic (<=4kW)	domestic	commercial	domestic	domestic
New build 4–10kW	domestic	commercial	commercial	commercial
Retrofit 4–10kW	domestic	commercial	commercial	commercial
New build 10–50kW	domestic	commercial	commercial	commercial

Size	Domestic	Commercial building	Developer	Utility
Retrofit 10–50kW	domestic	commercial	commercial	commercial
New build 50–150kW	domestic	commercial	industrial	industrial
Retrofit 50–150kW	domestic	commercial	industrial	industrial
New build 150–250kW	domestic	commercial	wholesale	wholesale

Table C.7: PV technology size band[36]

Size	Large or small
New build domestic (<=4kW)	small
Retrofit domestic (<=4kW)	small
New build 4–10kW	small
Retrofit 4–10kW	small
New build 10–50kW	small
Retrofit 10–50kW	small
New build 50–150kW	small
Retrofit 50–150kW	small
New build 150–250kW	small
Retrofit 150–250kW	small
New build 250–5000kW	large
Retrofit 250–5000kW	large
Stand alone system	large
Aggregators<4kW	small
Aggregators>4kW	small

[36] Used in calculation of supply chain constraints

Table C.8: PV, Capital costs (fixed), in £, low case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)	1,000	975	951	928	905
Retrofit domestic (<=4kW)	1,000	975	951	928	905
New build 4–10kW					
Retrofit 4–10kW					
New build 10–50kW					
Retrofit 10–50kW					
New build 50–150kW					
Retrofit 50–150kW					
New build 150–250kW					
Retrofit 150–250kW					
New build 250–5000kW					
Retrofit 250–5000kW					
Stand alone system					
Aggregators<4kW	750	731	713	696	678
Aggregators>4kW					

Table C.9: PV, Capital costs (marginal), in £ per kW, low case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)	2,500	1,739	1,210	987	804
Retrofit domestic (<=4kW)	2,500	1,739	1,210	987	804

Size	2010	2015	2020	2025	2030
New build 4–10kW	2,700	1,198	707	547	470
Retrofit 4–10kW	2,700	1,198	707	547	470
New build 10–50kW	2,500	1,109	655	507	435
Retrofit 10–50kW	2,500	1,109	655	507	435
New build 50–150kW	2,300	1,021	603	466	400
Retrofit 50–150kW	2,300	1,021	603	466	400
New build 150–250kW	2,200	976	576	446	383
Retrofit 150–250kW	2,200	976	576	446	383
New build 250–5000kW	1,900	843	498	385	331
Retrofit 250–5000kW	1,900	843	498	385	331
Stand alone system	1,900	843	498	385	331
Aggregators<4kW	1,400	923	608	471	364
Aggregators>4kW	1,600	1,055	695	538	416

Table C.10: PV, Capital costs (fixed), in £, medium case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)	1,500	1,426	1,357	1,290	1,227
Retrofit domestic (<=4kW)	1,500	1,426	1,357	1,290	1,227
New build 4–10kW					
Retrofit 4–10kW					
New build 10–50kW					

Size	2010	2015	2020	2025	2030
Retrofit 10–50kW					
New build 50–150kW					
Retrofit 50–150kW					
New build 150–250kW					
Retrofit 150–250kW					
New build 250–5000kW					
Retrofit 250–5000kW					
Stand alone system					
Aggregators<4kW	1,200	1,141	1,085	1,032	981
Aggregators>4kW					

Table C.11: PV, Capital costs (marginal), in £ per kW, medium case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)	3,250	2,261	1,750	1,502	1,290
Retrofit domestic (<=4kW)	3,250	2,261	1,750	1,502	1,290
New build 4–10kW	3,200	1,890	1,245	1,015	872
Retrofit 4–10kW	3,200	1,890	1,245	1,015	872
New build 10–50kW	3,000	1,771	1,168	952	818
Retrofit 10–50kW	3,000	1,771	1,168	952	818
New build 50–150kW	2,700	1,594	1,051	857	736
Retrofit 50–150kW	2,700	1,594	1,051	857	736

Size	2010	2015	2020	2025	2030
New build 150–250kW	2,700	1,594	1,051	857	736
Retrofit 150–250kW	2,700	1,594	1,051	857	736
New build 250–5000kW	2,500	1,476	973	793	681
Retrofit 250–5000kW	2,500	1,476	973	793	681
Stand alone system	2,500	1,476	973	793	681
Aggregators<4kW	2,000	1,391	968	789	644
Aggregators>4kW	2,250	1,565	1,089	888	724

Table C.12: PV, Capital costs (fixed), in £, high case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)	2,500	2,318	2,149	1,993	1,848
Retrofit domestic (<=4kW)	2,500	2,318	2,149	1,993	1,848
New build 4–10kW					
Retrofit 4–10kW					
New build 10–50kW					
Retrofit 10–50kW					
New build 50–150kW					
Retrofit 50–150kW					
New build 150–250kW					
Retrofit 150–250kW					
New build 250–5000kW					
Retrofit 250–5000kW					

Size	2010	2015	2020	2025	2030
Stand alone system					
Aggregators<4kW	2,150	1,994	1,848	1,714	1,589
Aggregators>4kW					

Table C.13: PV, Capital costs (marginal), in £ per kW, high case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)	4,000	3,435	2,950	2,639	2,386
Retrofit domestic (<=4kW)	4,000	3,435	2,950	2,639	2,386
New build 4–10kW	5,000	4,077	3,324	3,005	2,716
Retrofit 4–10kW	5,000	4,077	3,324	3,005	2,716
New build 10–50kW	4,500	3,669	2,992	2,704	2,444
Retrofit 10–50kW	4,500	3,669	2,992	2,704	2,444
New build 50–150kW	4,200	3,425	2,792	2,524	2,282
Retrofit 50–150kW	4,200	3,425	2,792	2,524	2,282
New build 150–250kW	4,000	3,261	2,659	2,404	2,173
Retrofit 150–250kW	4,000	3,261	2,659	2,404	2,173
New build 250–5000kW	3,200	2,609	2,127	1,923	1,738
Retrofit 250–5000kW	3,200	2,609	2,127	1,923	1,738
Stand alone system	3,700	3,017	2,460	2,224	2,010
Aggregators<4kW	3,250	2,650	2,161	1,953	1,765
Aggregators>4kW	4,500	3,669	2,992	2,704	2,444

Table C.14: PV, Operating costs (fixed), in £/ year, low case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)	50	49	48	46	45
Retrofit domestic (<=4kW)	50	49	48	46	45
New build 4–10kW					
Retrofit 4–10kW					
New build 10–50kW					
Retrofit 10–50kW					
New build 50–150kW					
Retrofit 50–150kW					
New build 150–250kW					
Retrofit 150–250kW					
New build 250–5000kW					
Retrofit 250–5000kW					
Stand alone system					
Aggregators<4kW	45	44	43	42	41
Aggregators>4kW					

Table C.15: PV, Operating costs (marginal), in £ per kW, low case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)					
Retrofit domestic (<=4kW)					
New build 4–10kW	17	17	16	16	15
Retrofit 4–10kW	17	17	16	16	15
New build 10–50kW	17	17	16	16	15
Retrofit 10–50kW	17	17	16	16	15
New build 50–150kW	16	16	15	15	14
Retrofit 50–150kW	16	15	14	14	13
New build 150–250kW	16	15	14	14	13
Retrofit 150–250kW	16	15	14	14	13
New build 250–5000kW	16	15	14	14	13
Retrofit 250–5000kW	16	15	14	14	13
Stand alone system	16	15	14	14	13
Aggregators<4kW					
Aggregators>4kW	16	15	14	14	13

Table C.16: PV, Operating costs (fixed), in £, medium case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)	70	69	69	68	67
Retrofit domestic (<=4kW)	70	69	69	68	67

Size	2010	2015	2020	2025	2030
New build 4–10kW					
Retrofit 4–10kW					
New build 10–50kW					
Retrofit 10–50kW					
New build 50–150kW					
Retrofit 50–150kW					
New build 150–250kW					
Retrofit 150–250kW					
New build 250–5000kW					
Retrofit 250–5000kW					
Stand alone system					
Aggregators<4kW	100	99	98	97	96
Aggregators>4kW					

Table C.17: PV, Operating costs, in £ per kW, medium case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)					
Retrofit domestic (<=4kW)					
New build 4–10kW	23	23	22	22	22
Retrofit 4–10kW	23	23	22	22	22
New build 10–50kW	22	22	21	21	21

Size	2010	2015	2020	2025	2030
Retrofit 10–50kW	22	22	21	21	21
New build 50–150kW	22	21	20	20	19
Retrofit 50–150kW	22	21	20	20	19
New build 150–250kW	20	19	19	18	17
Retrofit 150–250kW	20	19	19	18	17
New build 250–5000kW	20	19	19	18	17
Retrofit 250–5000kW	20	19	19	18	17
Stand alone system	20	19	19	18	17
Aggregators<4kW					
Aggregators>4kW	25	24	23	22	22

Table C.18: PV, Operating costs (fixed), in £, high case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)	110	110	110	110	110
Retrofit domestic (<=4kW)	110	110	110	110	110
New build 4–10kW					
Retrofit 4–10kW					
New build 10–50kW					
Retrofit 10–50kW					
New build 50–150kW					
Retrofit 50–150kW					
New build 150–250kW					

Size	2010	2015	2020	2025	2030
Retrofit 150–250kW					
New build 250–5000kW					
Retrofit 250–5000kW					
Stand alone system					
Aggregators<4kW	150	150	150	150	150
Aggregators>4kW					

Table C.19: PV, Operating costs, in £ per kW, high case

Size	2010	2015	2020	2025	2030
New build domestic (<=4kW)					
Retrofit domestic (<=4kW)					
New build 4–10kW	33	33	33	33	33
Retrofit 4–10kW	33	33	33	33	33
New build 10–50kW	32	32	32	32	32
Retrofit 10–50kW	32	32	32	32	32
New build 50–150kW	30	30	30	30	30
Retrofit 50–150kW	30	30	30	30	30
New build 150–250kW	28	28	28	28	28
Retrofit 150–250kW	28	28	28	28	28
New build 250–5000kW	28	28	28	28	28
Retrofit 250–5000kW	28	28	28	28	28

Size	2010	2015	2020	2025	2030
Stand alone system	28	28	28	28	28
Aggregators<4kW					
Aggregators>4kW	35	35	35	35	35

Table C.20: PV Load Factors

Site Type	Low	Medium	High
Scotland	8.5%	9.0%	9.5%
Midlands	9.0%	9.5%	9.7%
South-east	9.5%	9.7%	10.0%
South-west	9.7%	10.0%	10.3%

Table C.22: PV, Technical Potential, MWh per year per site type, medium

Size	Scotland	Midlands	South-East	South-West
New build domestic (<=4kW)	9,900	38,744	64,298	40,058
Retrofit domestic (<=4kW)	1,230,685	4,783,465	7,907,615	4,863,236
New build 4–10kW	2,200	8,610	14,288	8,902
Retrofit 4–10kW	306,279	1,190,455	1,967,958	1,210,307
New build 10–50kW	4,495	22,014	35,014	24,410
Retrofit 10–50kW	449,525	2,201,401	3,501,351	2,440,974
New build 50–150kW	466	2,281	3,628	2,529
Retrofit 50–150kW	46,572	228,073	362,752	252,894
New build 150–250kW	3,383	19,714	27,005	14,898

Size	Scotland	Midlands	South-East	South-West
Retrofit 150–250kW	333,143	1,941,042	2,658,972	1,466,844
New build 250–5000kW	3,383	19,714	27,005	14,898
Retrofit 250–5000kW	333,143	1,941,042	2,658,972	1,466,844
Stand alone system	2,271,679	1,773,969	2,712,282	1,742,070
Aggregators<4kW	218,927	850,978	1,406,808	865,287
Aggregators>4kW	132,436	596,119	960,690	642,279

Table C.23: PV, % Generation per investor types

Size	Domestic	Commercial Building	Developer	Utility
New build domestic (<=4kW)	95%	5%		
Retrofit domestic (<=4kW)	95%	5%		
New build 4–10kW	25%	75%		
Retrofit 4–10kW	25%	75%		
New build 10–50kW		80%	10%	10%
Retrofit 10–50kW		80%	10%	10%
New build 50–150kW		80%	10%	10%
Retrofit 50–150kW		80%	10%	10%
New build 150–250kW		10%	45%	45%
Retrofit 150–250kW		10%	45%	45%
New build 250–5000kW		10%	45%	45%
Retrofit 250–5000kW		10%	45%	45%

Size	Domestic	Commercial Building	Developer	Utility
Stand alone system		10%	45%	45%
Aggregators<4kW	90%	10%		
Aggregators>4kW	60%	40%		

Table C.24: Summary of proposed input hurdle rates

Investor type	Lower hurdle rate	Upper hurdle rate
Households	1%	12%
Commercial property	5%	8%
Aggregators/ developers/ utilities	5%	8%