Unlocking the Power House:

Policy and system change for domestic micro-generation in the UK

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Executive summary

This report is the product of a two-year interdisciplinary research project: *Unlocking the Power House*. Its aim is to understand how micro-generation might be deployed, and to explore policies to support investment by consumers and energy companies. The research presented in the report was undertaken in parallel with significant policy developments, notably the government Microgeneration Strategy, the Climate Change and Sustainable Energy Act and the wider Energy Review. Despite these developments, there are significant shortcomings in current policies for micro-generation, and in the government's broader strategies to help consumers reduce their energy demand.

This report argues that it is essential that policy makers support a diversity of routes to micro-generation deployment, with incentives for both householders and energy companies. Micro-generation could be deployed in a variety of ways – by individual consumers wishing to assert their independence from established energy systems; by incumbent energy companies that shift their focus towards the delivery of energy services rather than energy supply; or by local developments that implement decentralised microgrids.

The analysis considers three micro-generation technologies: solar photovoltaics (PV), micro-wind and micro-combined heat and power (micro-CHP). It shows that the performance of these technologies is subject to wide variations. It is well known that solar PV's output varies with orientation – with south facing arrays performing best. Stirling engine micro-CHP units are more economic in large and/or inefficient houses that have high heat demand. Our calculations show that micro-wind is likely to be most economic in areas with an excellent wind resource such as rural or seaside locations – if installed in many urban areas, its performance will be poor. They also show that all of these technologies are likely to reduce CO_2 emissions significantly. However, uncertainties remain about the extent of these reductions for micro-wind and micro-CHP due to a lack of operational experience.

This report's economic analysis shows that micro-generation is not particularly attractive for consumers or energy companies under current conditions. Whilst economics are not the only driver for investment in micro-generation technologies, many consumers are put off by high up-front costs and the long payback times involved. Other factors that may discourage consumers from investing at present include the perceived risks of new technology, regulatory barriers such as the need for planning permission, and a lack of information.

Although many of these barriers are now being addressed, we believe that current policy is too focused on incremental changes. It misses opportunities to support micro-generation as part of a broader shift towards demand reduction and consumer behaviour change. The report focuses on two areas in which micro-generation and household energy saving investments suffer from an uneven playing field – the fiscal system and the market settlement system for electricity. The rationale for this is that removing anomalies might partly obviate the need for specific subsidies such as capital grants from the current Low Carbon Buildings Programme.

Levelling the playing field for micro-generation in these two areas can significantly reduce payback times. Crucially, they combine lower up-front costs and financial rewards for exported power. This is achieved by allowing consumers and energy companies to offset investment costs against their tax bill, and by extending the settlement system so that exported electricity can be sold for the real-time market price. Whilst both reforms come with significant costs attached, we believe that they are more accurate and durable than the alternatives. Furthermore, they also open up possibilities for wider engagement with consumers. These could provide direct incentives for consumers to change their patterns of energy consumption and reduce demand.

The potential for a transition from energy supply to the provision of energy services has been discussed for many years. But a market for these services has yet to emerge in the domestic sector. Whilst Ministers trailed the Energy Review with promises to reform energy regulation to encourage this market, there is no detail on how this will be achieved in the Review itself. This report argues that the next phase of the Energy Efficiency Commitment (EEC) provides an ideal opportunity to assess the feasibility of such reforms. Instead of continuing EEC for a further phase to 2011, the government and regulator should consider early implementation of demand reduction obligation on energy suppliers. This would give them a direct incentive to offer a range of services to consumers – from energy efficient lighting to micro-generation.

Going further still, the advent of micro-generation has implications for the development of energy and related infrastructure. The design of infrastructure such as buildings and energy networks has a direct impact on demand patterns and the scope for policy intervention. One key area for action is metering. Smarter designs of meter are now available that can measure real-time imports and exports and can be linked to display systems for consumer feedback.

Research has shown that such feedback can lead to reductions in demand through behaviour change. Micro-generation presents an ideal opportunity to kick-start the modernisation of the UK's meter stock. Smart meters should be mandatory for new micro-generation installations. The case for a national roll out should urgently be reviewed too. Ofgem and the DTI's recent caution on the case for such a roll out misses the point. Smart meters should not be seen as an optional extra that some consumers might wish to buy, but as an essential element in a reoriented energy market based on services rather than supply.

There are significant opportunities to build micro-generation into new construction developments. The Climate Change and Sustainable Energy Act is important since it encourages local authorities to set targets for this. In addition, it will be desirable to include flexible service areas and space (eg as cellars) in new buildings so that future developments in micro-generation and home energy automation can be accommodated. If sustainable visions for larger developments such as Thames Gateway are to be realised, strong intervention will be required from all levels of government. Otherwise an opportunity for the implementation of more pervasive local energy systems based on micro-grids could be lost. Energy regulation has a role to play here too. The Registered Power Zone scheme developed by the regulator, Ofgem allows electricity network companies to experiment with new concepts. The forthcoming review should relax the restrictive rules governing this scheme, and thereby help rebuild capacity for innovation with the electricity network companies.

1. Introduction

Micro-generation in individual homes has been the subject of increasing policy and industry attention in recent years. According to the Energy Saving Trust, micro-generation could supply 30-40% of UK electricity demand by 2050 (EST, 2005b). If adopted by large numbers of households in this way, micro-generation could bring about fundamental change to our energy system. Many consumers would become energy producers, leading to a breakdown of the traditional distinction between energy supply and demand. Established regulatory frameworks and energy infrastructures would need to change radically to deal with a fundamental decentralisation of power and control.

So far, there is a consensus that micro-generation has a desirable role to play in our energy future. Politicians of all parties have endorsed micro-generation as an important response to challenges such as energy security, climate change and fuel poverty. Major energy companies have added their weight to micro-generation with deals to sell technologies to consumers. The Microgeneration Strategy (DTI, 2006c) published earlier this year shows how the UK government plans to speed up deployment. Further momentum has come from the Climate Change and Sustainable Energy Act. However, the Energy Review (DTI, 2006b) is ambiguous in its commitment to the wider changes to the energy system that could be required.

This report presents the main results of a two-year independent research project: *Unlocking the Power House*. It was carried out by an interdisciplinary team of engineers and social scientists from three universities – Sussex, Southampton and Imperial College London.

The report argues that micro-generation should be understood in the context of broader potential changes in the way we supply and use energy. Section 2 analyses some of these changes by considering different models for micro-generation deployment. These include consumer-led models that are driven by a desire for energy independence, company-led models in which micro-generation is part of energy service packages, and community models that emphasise integrated local micro-grids. This section also examines three of the technologies that are likely to be deployed (solar PV, micro-CHP and micro-wind), and shows how their technical and environmental performance was evaluated by the project.

Section 3 of this report considers the current economics of micro-generation investment from the point of view of consumers and energy companies. It shows that in many cases the payback times for micro-generation are long. Whilst the analysis recognises the importance of other factors that influence such investments, it maintains that current incentives might be insufficient to provide micro-generation with the best chance of success.

Section 4 of the report explores measures to level the playing field between energy investments by households such as micro-generation and energy investments outside the home. The rationale is to understand the impact of these inconsistencies, and whether removing them could obviate the need for special treatment or subsidies. In this vein, the section considers changes to fiscal incentives and the operation of energy markets.

The report's final section – Section 5 considers a wider agenda of reforms that could ensure a much greater role for consumers and demand-side action to meet policy goals. It focuses in particular on regulatory reforms that could lead to a domestic energy services market in the UK. It also discusses some critical changes to energy infrastructure that might be necessary for micro-generation and energy-saving measures to realise their potential.

2. Micro-generation: Visions and Technologies

Modelling visions

A wide variety of visions for micro-generation have been put forward in the recent debate. Some of these focus on the potential of these technologies to fundamentally change the energy system, shifting its centre of gravity away from large-scale 'top-down' infrastructure towards more local 'bottom-up' micro-grids:

'In time, micropower may also change the way electricity grids themselves operate—turning them from dictatorial monopolies into democratic marketplaces. Add a bit of information technology to a microgenerator and it will be able both to monitor itself and to talk to other plants on the grid.' (*The Economist*, 2000)

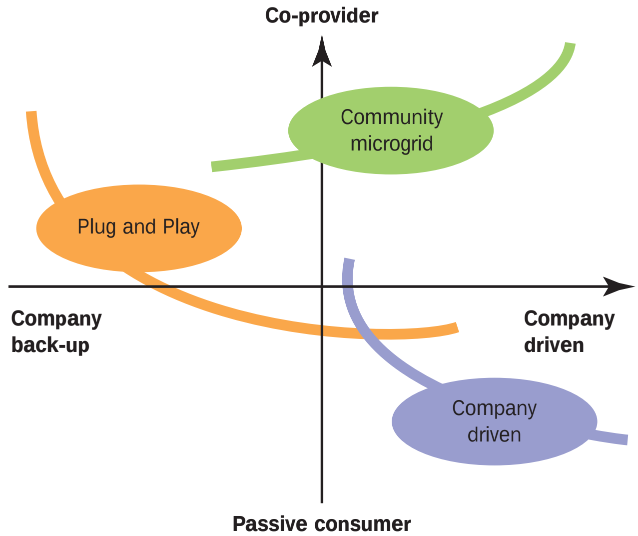
Politicians and environmentalists have emphasised the potential contribution of micro-generation to meeting the UK's environmental goals. The Green Alliance's *Micro-generation Manifesto* argues that the small-scale nature of micro-generation means that individuals can play a part in attaining these goals:

'Micro-generation will make the public co-producers of climate change solutions rather than passive consumers of energy, helping to combat the 'what can I do?' apathy that undermines so many well-meaning public education campaigns' (*Collins*, 2004)

How can these visions aid an economic and policy analysis of micro-generation? In our project, visions like these have been used as the inspiration of a set of three micro-generation deployment models (Watson, 2004). These models do not aim to capture all possible scenarios for deployment. They have been designed to reflect different roles for consumers and for energy companies, and a range of technical and institutional possibilities. The three alternative deployment models are: 'Plug and Play', 'Company Driven' and 'Community Microgrid' (*see Figure 1*).

The different role consumers could take within each deployment model is of particular interest. Consumer involvement ranges from a passive role to a more active role in micro-generation investment and operation. The former role does not imply substantial changes from the current situation. The latter sees consumers as becoming more active participants in the energy system as financial investors in infrastructure and as contributors to policy goals through behavioural change. The anecdotal evidence suggests that owners of micro-generation technologies are likely to modify their pattern and level of energy consumption (Dobbyn and Thomas, 2005).

Figure 1



The more active mode of consumer engagement is associated with 'co-provision' (van Vliet, 2004) – the provision of energy services by a partnership of individuals, communities, the private sector and the State. The philosophy of co-provision has been widely discussed within government under Labour (Halpern, 2004; Willis, 2006). It is seen as a response to the failures of technocratic public service delivery in areas such as health and education. Advocates of co-provision cite the need to engage citizens so that they share the responsibility for these services. Although energy is supplied by private firms, the rationale for co-provision is similar. Micro-generation offers one potential route to make this shift real.

The 'Plug and Play' model is inspired by the idea that micro-generation might allow consumers to become partly independent of conventional energy suppliers. The installed micro-generation unit will contribute to the on site demand and reduce electricity imports from the grid and consequently reduce the household's electricity bill. Under 'Plug and Play' the micro-generation unit is owned, financed and controlled by the homeowner.

The 'Company Driven' model is based on the notion that in the long term companies might use fleets of micro-generators as a substitute for central power generation – ie as a virtual power plant[1]. This model involves a more traditional passive consumer who only provides the site for the micro-generation unit, but it is owned by an energy service company (ESCo) or traditional energy utility. Ultimately, the micro-generation unit could be controlled remotely and

1. For more information about an example of a 'virtual power plant' visit the homepage of the EU-funded project 'The Virtual Fuel Cell Power Plant' at: **www.cogen.org/projects/vfcpp.htm**

operated according to the company's needs. This could help balance supply and demand, and to avoid buying electricity from the wholesale market[2]. For the purposes of this report, remote control has not been assumed within a company driven model. It is more likely in the short to medium term to involve the provision of domestic energy service packages based on micro-generation technologies.

In the third model consumers and institutions in a particular geographical area decide to pool their resources to develop a 'Community Microgrid'. The micro-generation units are connected to the microgrid which implies a high level of consumer involvement at two different levels. They have primary control over their unit, but also will help to guarantee the supply-demand balance within the microgrid. Their incentive to do this stems partly from the fact that they may own shares of the community energy company. If the micro-generated power output is supplied directly via private networks it would avoid system charges and network losses. This would increase its economic viability[3]. At the community level it might however be more efficient (in economic and technical terms) to use technologies at a larger scale instead of in individual houses (eg CHP with community heating).

Each of these deployment models has different technical and institutional implications for the energy system (Sauter and Watson, 2006a). Socially the deployment models will be different with respect to the motivation for the installation, ownership of the unit and behavioural implications. Economically, the upfront financing and income flows will be different. Technically, the operational modes as well as the metering and communication technologies required are different.
In some cases, the impacts of micro-generation deployment are likely to go beyond the boundaries of the existing electricity system. They may have knock-on effects on the housing stock (*see section 5 of this report*) and on telecommunications systems. Policy interventions to support micro-generation will need to take these wider impacts into account.

Models and market uptake

The eventual role of these and other models in the market for micro-generation will depend on customers' motivations and the policies that are put in place to overcome barriers that currently exist. These will differ between consumer types or segments[4]. Studies of the diffusion of innovations distinguish between different consumer groups: 'innovators' are the first group to purchase a new product in its introduction phase, followed by 'early adopters' in the early growth phase and finally by the '(early) majority' in the market 'take-off' phase (Rogers, 1995; Villiger, Wüstenhagen et al, 2000).

Since the market for micro-generation technologies is still at an early stage, studies looking at motivations of homeowners who have installed a micro-generation unit cover predominantly 'innovators' or 'early adopters' (Pehnt, Cames et al, 2006). These consumer segments are generally characterised by an interest in new technologies, understanding of these technologies and sufficient capital available. They will therefore tend towards the more independent Plug and Play model. Another motivation is to show that they are 'being green' to the outside world through the installation of a PV system or micro wind turbine. Consumers in the early growth segment are likely to be less well informed about the technologies available and may not have access to sufficient capital. They are more interested in avoiding hassle and prioritise value for money[5]. Company Driven energy service contracts for micro-generation will therefore play an important early role alongside Plug and Play approaches.

From a customer perspective, Table 1 summarises advantages and disadvantages of each deployment model, how they match potential consumer motivations and to what extent they might help to overcome barriers for the acceptance of micro-generation technologies.

Technology specific features will also influence market uptake. The investment in additional technologies such as micro-wind and PV constitute a discretionary investment decision that may be traded off against others (eg a new plasma TV or a holiday). By contrast, the purchase of a micro-CHP unit is in competition with an alternative new boiler since the domestic heat supply and comfort level will have to be maintained. Upfront and operating costs are also different for the three technologies: upfront costs are rather low – in particular under a cost differential approach – for micro-CHP but high in the case of PV. As this report will show, high up front costs can be particularly discouraging for many consumers.

2. The scope for remote dispatch (start-stop) of the micro-generator depends on the technology: while micro CHP with hot water storage has a certain operational flexibility, PV and micro-wind are less amenable to control.

3. This is the approach taken in Woking – for more information see (Jones, 2005).

4. The Energy Saving Trust has worked on consumer segmentation of the UK for a marketing / communication plan for micro-generation technologies (EST submission to the DTI micro-generation consultation).

5. For a review of various studies on this issue see (Sauter and Watson, 2006b).

Table 1: Different deployment models from a customer perspective

Customer perspective	Deployment model: Plug and Play	Company Driven	Community Microgrid
Motivations			
Independence	+	-	+/-
Technological interest	+	+/-	+/-
Being green	+	+	+
Hassle free provision	-	+	+/-
Reduced energy bill	+	*	*
Barriers			
Lack of access to capital	+/-	+	+/-
Risk aversion	+/-	+	+/-
Scepticism of new technologies	-	+	+
Lack of information and knowledge	-	+	+

*Depends on the contractual arrangement.

Micro-generation deployment using any of the three models could trigger behavioural changes due to the consequent increase in awareness about energy consumption. However, impacts on patterns of consumption may depend on the underlying institutional and contractual arrangement. Under Plug and Play, homeowners might choose to use as much of their micro-generation output on site as possible, particularly if they cannot earn significant income from exports. Within some Company Driven and Community Microgrid models, it might make little economic difference to consumers whether they use micro-generated output on-site or export it. However, more innovative tariff structures or better information about consumption through smart meters could also result in energy savings through behaviour change (Darby, 2006).

At this early stage of micro-generation deployment, it is too early to determine what kind of micro-generation investment will be the most attractive to householders. Variants of all three of the models that we have analysed here have been put into practice either in the UK or abroad. **As policies micro-generation are developed and implemented, it will be important to support a diversity of routes to deployment including individual action, energy service companies and independent microgrids.**

Micro-generation technologies

Micro-generation includes a wide range of technologies for the generation of electricity and heat within households (DTI, 2006c). We made a decision early on to prioritise work on three of these technologies – solar PV, micro-CHP and micro-wind. Each of these is either commercially available or due to be introduced to the market very soon.

Householders have been able to purchase solar PV systems for many years from specialised installers. Recently, there have been moves towards a more mass-market approach. High street electrical retailer Currys has announced it will sell PV panels. By contrast, micro-CHP and micro-wind are at an early stage of commercialisation. A number of micro-CHP

Wall-mounted Microgen Appliance installed in kitchen

products have been announced so far. Both of the leading companies working to commercialise this technology – Powergen with its Whispergen unit and British Gas with its Microgen unit – have delayed the mass market roll out of their units. Powergen has put all new orders on hold until 2007 and Microgen has announced it will introduce its unit to the residential market in 2008. Several micro-wind turbine designs are being developed. Windsave announced that its 1kW turbine would be marketed via the internet and B&Q stores from autumn 2006. Renewable Devices is expected to install 400 to 500 of its 1.5kW Swift turbines in 2006 (Slavin, 2006).

To carry out an economic analysis of these technologies, we used half-hourly output data for these technologies under a variety of conditions. These data were then combined with electricity demand data to get information on import, export and on-site consumption. For solar PV, generation data was used from an existing field trial in a social housing scheme in Havant near Portsmouth.[6] Electricity demand data was also taken from a number of households in this trial. For micro-wind and micro-CHP, the lack of comprehensive output data meant that output of these technologies was derived from models. Micro-wind was explored in more detail than the other two technologies due to the attention it has attracted in the recent debate and the lack of previous analysis of its potential.

The PV field trial includes 9 houses each of which has identical PV systems. The monitoring scheme looks at the electricity consumption of each house combined with environmental parameters (irradiance, temperature) and the performance of the PV system (Bahaj and James, 2004; Bahaj and James, 2006). PV output data are based on the performance of two south-facing 1.5kW arrays (on units 5 and 6) and one similar west-facing array (on unit 7). The annual output is around 1300 kWh/year for south-facing arrays and 850 kWh/year for the west-facing array. Total installation costs for a 1.5kW PV array were assumed to be £9,030 if purchased by a homeowner.

Domestic electricity consumption data was obtained from this field trial from 4 different households or ‘units’. These have an annual consumption of 7140 kWh (unit 4), 6050 kWh (unit 5), 3670 kWh (unit 6) and 2780 kWh (unit 7). This compares to an average UK domestic consumption of 3300 kWh per year (DTI, 2006d). These consumption data reflect different occupancies and usage patterns: unit 4 is home to a young couple with two children and is very peaky, unit 5 (a family with one child) shows strong demand during the day, unit 6 (a single retired person) also has significant daytime demand, and unit 7 (a young professional couple) has lower peaks.

The micro-CHP modelling (*see Box 1*) produced 13 unit arrangements. The highest heat demand was 39,300 kWh for a poorly insulated 4 bedroom detached house where the micro-CHP electrical output is 4,400 kWh. The lowest heat demand of 7,200 kWh occurs in a 2 bedroom bungalow that complies with Part L of the building regulations, and includes an electricity generation of 900 kWh. The average heat demand was 21,100 kWh with an average electrical generation of 2,500 kWh. In most cases more than half of the electricity generated is consumed on-site. The cost of a micro-CHP unit for homeowners is assumed to be £3,000. Since micro-CHP will usually be a replacement investment due to a boiler breakdown, the economic analysis uses a price differential approach. It considers the additional costs of buying a micro-CHP system instead of a new condensing boiler. Two differentials were used that reflect the range of costs for condensing boilers: £500 and £1,500.

Box 1: Micro-CHP

The micro-CHP modelling is based on a nominal electrical capacity of 0.85kW (and a nominal thermal capacity of 6kW) and a maximum electrical capacity of 1.2kW (and 8kW thermal). This does not describe the performance of any of the commercial products that are currently available, though it is similar in size and heat to power ratio to the Whispergen unit being marketed by Powergen. Heat generation between 0 and 6kW generates a scaled electric output of up to 0.85kW, heat generation between 6 and 8kW generates a scaled electrical output of up to 1.2kW, and heat generation between 8kW and 12kW generates en electrical output of 1.2kW. The thermal efficiency is 85% as compared to a condensing boiler of 92%. The heat to electrical power ratio was seven in the normal operating mode (< 6kW thermal).

Since heat demand is the driver for the power output of micro-CHP, two different building types and three different building standards were used to model this technology. As building types a 2 bed bungalow and 4 bed detached house were used. The three building standards considered were: a) poor building with single glazing (wall U-value of 1.8 W/m^{2}K, glazing U-value of 6.3 W/m^{2}K), b) poor building, poor double glazing (wall U-value of 1.8 W/m^{2}K, glazing U-value of 2.8 W/m^{2}K) and c) Part L 2002 building, Part L 2002 glazing[7] (wall U-value of 0.4 W/m^{2}K, glazing U-value of 1.8 W/m^{2}K). Additionally, the modelling distinguished whether occupants were at home or at work during the day and included two options for the building’s location (London and Aberdeen). Electricity consumption data from Havant units 5, 6 and 7 were used.

Transient building simulation using TRNSYS software was used to predict thermal demand for each of these generic building types. Whilst it is possible to associate the thermal demand of a dwelling to its construction, age and size, relating these parameters to electricity demand is far more difficult since user behaviour is the primary driver of the latter demand. This is borne out with analysis of the Havant homes where high variations in annual electrical demand were observed. UK energy statistics show very small regional variations in per capita domestic electricity demand, despite demographic variation in housing quality (SAP rating) and household income.

6. This PV field trial was funded and monitored as part of the DTI’s domestic programme (DFT2 S/P2/00434/00/00). The data was recorded in 5 minute intervals, though 30-minute averages were used for the analyses undertaken for this report.

7. Approved Document Part L1 Conservation of Fuel & Power 2002.

For micro-wind the calculations in this report used a 1.5kW micro-turbine (*see Box 2*) assumed to be installed at 7m height above ground level, and included 6 wind sites with the following annual output: Aberdeen (rural): 1680 kWh generated per year, Calshot 1 (rural): 1490 kWh, Calshot 2 (suburban): 560 kWh, Coombe 1 (rural): 1290 kWh, Heathrow (suburban): 720 kWh and Manchester (suburban): 590 kWh. Sites with an annual output of above 500 kWh were chosen to achieve the threshold for earning at least one Renewables Obligation Certificate (ROC)[8]. It was assumed that a homeowner would have to pay £2,230 for a 1.5kW micro-wind turbine.

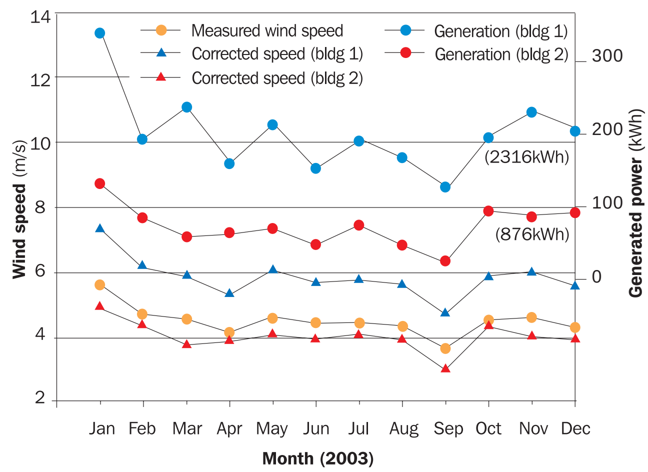
Box 2: Micro-wind

The UK has the best wind energy resource in Europe. However, micro-wind turbines will not benefit as much from this as large-scale devices since they will be sited at low altitude and in built up areas. Baseline wind data for this report was gathered for 6 locations around the UK (Bahaj, Myers et al, in press). All site measured data represents wind speeds recorded 10m above ground level (AGL) over the course of a year. The 30-minute interval data used in the model gives a much more accurate representation of the wind resource than annual average values that are often applied (incorrectly) to estimate annual energy yields. All sites used in this study show a similar trend of increasing wind speed peaking in the late afternoon. Therefore, despite the relatively low wind intensity in urban terrain, the wind resource matches domestic electricity demand to some extent. A good match also occurs when studying the monthly mean wind speeds throughout the year. Stronger winds occur during winter months and there are calmer conditions during the summer. Again, domestic electricity use follows a similar trend, with reduced demand in the summer from lighting and some high-energy appliances such as tumble dryers.

Forecasting wind speeds in areas of rough terrain or urban areas is difficult. At low altitudes, local effects dominate the wind speed. Wind can be channelled between or deflected around buildings depending upon the wind direction. This means it is unrealistic to be able to forecast annual energy yields from a turbine in these areas accurately. However empirical relationships can be used that account for varying terrain roughness and height above ground level. These were applied to our wind model to the wind speed data. The results show that the wind resource close to ground level is relatively poor. As the power generated is proportional to the cube of the wind speed, positioning of micro-wind turbines has a critical impact on their output.

The following example illustrates the method used in this project to generate electricity output curves from a 1.5kW wind turbine. *Figure 2* shows the monthly power output of such a turbine on 2 different buildings in Aberdeen. This uses a generic power curve generated for this report that is not based on any particular micro-wind product. The electricity generated was calculated by combining the power performance curve with the wind speed measured every hour during 2003. Building 1 roof level is 20m AGL in suburban terrain, building 2 is 10m AGL in suburban terrain with 50% wind speed reduction within an arc of 180°-240°. This simulates the effect of a structure that creates a wind shadowing effect. The effect of elevating the turbine height by 10m almost triples the annual energy yield. Despite Aberdeen being one of the windiest UK locations the wind resource close to ground level in these cases is still poor. Generation for Building 2 (876kWh/yr) represents approximately 25% of the typical UK domestic electricity demand (around 3300kWh/yr). However, 1.5kW is expected to be the maximum size for a domestic roof-mounted turbine with most other devices producing less electricity than this.

Figure 2 Wind speed and simulated power output for a 1.5kW turbine on two building types in Aberdeen 2003



Operation and maintenance (O&M) costs for these three technologies are rather uncertain which was a challenge for their economic appraisal. For micro-CHP, it has been claimed that maintenance costs will be similar to those for current boiler service contracts. However, it is too early to tell whether this will be the case. It was suggested that O&M costs for PV are likely to be 1% of the capital costs, and costs for micro-wind are likely to be slightly higher at 1.8% (Energy Saving Trust, 2005b). Applying these O&M costs would at least cancel out any income from ROCs.

Some of our interviewees did not accept these figures. For example, some expected very low O&M costs if a sealed micro-wind turbine unit is used. Also of importance are the costs of DC/AC inverter replacement. If required, this would seriously impact the economics of micro-wind and PV systems. It is likely that these costs could fall over time. Additionally, changes in building designs and appliances could make the use of inverters unnecessary if homes had not only AC, but also DC wires (Patterson, 2006).

Due to these uncertainties and a lack of hard evidence, O&M costs were only included in the calculations for energy service contracts for micro-CHP units. This means that the economic results in this report should be viewed with care – **maintenance costs cannot be ignored and need to be considered as an additional factor in decision making.**

Another set of costs that were not included in the calculations are network reinforcement costs. It could be argued that the expansion of micro-generation will lead to significant expenditure to upgrade electricity networks. However, two studies of the UK have been carried out. Both conclude that there are no major network problems or costs expected at this stage in the micro-generation market (Mott MacDonald,

8. ROCs are available for renewable electricity but not for electricity from micro-CHP. The minimum generation to qualify is 500 kWh per year. The amount generated is then rounded up or down to the next full MWh.

2004; Econnect, 2005). This is expected to remain the case for some time even if deployment increases quickly. Some low voltage network modifications might be necessary if many micro-generation units are concentrated in a particular geographical area. By contrast, economic benefits are expected at higher voltage levels since micro-generation would partly cancel out load growth.

Carbon savings from micro-generation

Whilst we did not carry out detailed modelling of potential carbon emissions savings, it was important to test one of the key rationales for government support for micro-generation technologies. CO_2 savings from micro-generation technologies depend on assumptions about CO_2 emissions for displaced electricity from the UK grid. For micro-CHP, the displacement of electricity from very efficient CCGT plants and less efficient coal plants was considered. Thus, a range of potential CO_2 savings were calculated comparing three assumptions about the emission factors for the displaced electricity: first, 0.568 kg/kWh for the average unit of the UK grid is used. This is taken from the guidance document that accompanies Part L of the Building Regulations for the calculation of CO_2 savings from micro-generation (ODPM, 2006)[9]. Second, 0.32 kg/kWh for very efficient CCGT plants (58% efficiency) and finally, 0.85 kg/kWh for a coal plant.

Early results of CO_2 savings from micro-CHP field trials run by the Carbon Trust showed ambiguous results (The Carbon Trust, 2005). They indicate that carbon emissions from micro-CHP depend on the operating environment. A more continuous thermal load reduces emissions from micro-CHP. This effect played a marginal role in our thermal modelling since start-up times were considered to be very short. Therefore the projected carbon savings are rough estimates and higher than those reported by the Carbon Trust. Our analysis compares the CO_2 emissions from a micro-CHP unit with a thermal efficiency of 85% to a new condensing boiler with an efficiency of 92%, assuming CO_2 emissions of 0.19 kg/kWh of gas. If micro-CHP replaces electricity from CCGTs, CO_2 emissions are around 10% lower. For the UK grid supply mix the savings are around 20%, and for coal they up to 30%. As an example this means for a 2 bedroom bungalow with an annual heat demand of around 17,750 kWh yearly savings of 460 kg of CO_2 (compared to CCGT), 1,051 kg of CO_2 (average UK grid), or 1,722 kg of CO_2 (compared to a coal plant).

Annual CO_2 savings for micro-wind and PV are calculated only on the basis of the carbon dioxide factor for grid-displaced electricity that is suggested in guidance to support the Building Regulations – 0.568 kg/kWh (ODPM, 2006). For a good micro-wind site (1.5kW turbine, load factor 0.13) with an annual output of 1680 kWh this leads to annual CO_2 savings of 956 kg of CO2 and for a south facing 1.5kW PV array, the saving is 726 kg of CO_2.

Overall, these calculations show that the three micro-generation technologies analysed in this report are likely to reduce CO_2 emissions significantly. Whilst this conclusion is robust for solar PV and micro-wind, the Carbon Trust trials indicate that some uncertainty remains in the case of micro-CHP.

9. This number is higher than 0.43kg/kWh of the projected UK fuel mix as used by Defra for the reporting on greenhouse gas emissions within the emissions trading scheme (Defra, 2005). It is more accurate for domestic micro-generation since it includes line losses for example.

3. Micro-generation investment today

How do the different ways to deploy micro-generation technologies compare in economic terms today? The quantitative analysis compares payback times for two deployment models: Plug & Play and Company Driven. The Community Microgrid model has not been analysed in this way since it is subject to much greater uncertainty and is more difficult to quantify.

In carrying out this analysis, we recognise that economic payback is not the only factor that influences micro-generation investment decisions. In common with other investments on the demand side of the energy system, a short payback for micro-generation does not automatically mean that consumers or companies will take up this option. For individual consumers in particular, high upfront costs discourage investment even if payback times are short (Sustainable Development Commission, 2006). Investment decisions are affected by a range of other factors including risks, imperfect information, bounded rationality and a lack of access to capital (Sorrell, 2004). Consequently, the numbers have to be interpreted carefully and policy as well as regulatory implications must take into account the broader context of households' energy related investment decision making.

Payback times for a homeowner's investment in micro-generation in this report do not consider a discount rate. Company investments in micro-generation are calculated using a discounted cash flow analysis with a discount rate of 8%. Research shows that it is difficult to identify an accurate discount rate for such consumer investment decisions. It also shows that rates for individuals are much higher than those for firms (Hausman, 1979; Train, 1985). Furthermore, it is unlikely that individuals will use a discounted cash flow analysis as a basis for their purchase decisions. Alternative, or competing, domestic investments (eg in fitted kitchens, conservatories or loft conversions) are good examples, though these are sometimes made to increase the value of a house.

Plug and Play: Current economics for consumers

Under current conditions homeowners investing in an energy-generating device in their home have a number of income streams available (*see Table 2*)

For micro-CHP payback times under current conditions depend on the price differential in comparison with the purchase of a new condensing boiler. For a £500 price differential, payback time ranges between 2 years (for a very high heat demand of almost 40,000 kWh per year) and 9 years (for a low heat demand of around 7,200 kWh per year). For a £1,500 price differential, payback time varies from 6 years and around 20 years (*see Figure 3*).

For micro-wind payback times are between 7 and 19 years depending on location (*see Figure. 3*). For the two south-facing 1.5kW PV arrays, payback times vary from 35 to 48 years depending on how much of the micro-generated output is consumed on site.

Figure 3: Payback times under current conditions

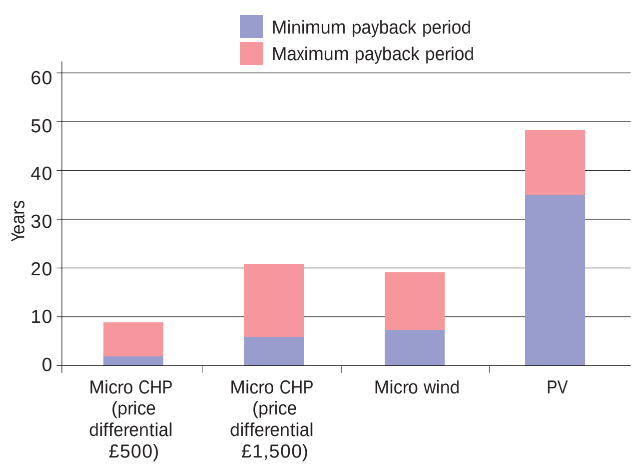


Table 2: Income streams analysed for 'Plug and Play' under current conditions

Income stream	Micro-CHP	Technology PV	Micro-wind
Low Carbon Buildings Programme capital grants	No	Maximum £3,000 / kWp installed, up to a maximum of £15,000. Overall limit: 50% of the installed cost cost (excluding VAT)	Maximum £1,000 / kW installed, up to a maximum of £5,000. Overall limit: 30% of the installed cost cost (excluding VAT)
Reduced electricity bill	Electricity price of 10p/kWh		
Renewables Obligation Certificates	No	ROC price of £39/MWh[10]	
Export / generation rewards	Other export / generation rewards were not considered since they are only available on a discretionary basis from some suppliers.		

10. The ROC auction price from the Non-Fossil Purchasing Agency in October 2005. The third annual report on the RO by Ofgem gives an annual ROC value of £45/MWh for 2004/05.

The range of payback times is quite large for all three technologies and shows the influence of varying electricity outputs and different levels and patterns of consumption. In the case of micro-CHP domestic heat demand in the home is the major influence on payback period. Homes with lower heat demand such as those with high levels of insulation are less suitable. For the modelled Stirling engine the data suggest a minimum heat demand of 15,000 kWh is required to reach a payback period of around 15 years if the price differential is £1,500. This is the expected lifetime of the unit. This illustrates a general result: **Stirling engine micro-CHP units are more economic in large and/or inefficient houses that have high heat demand.** This heat demand limitation for micro-CHP could be overcome with the help of more flexible Stirling unit designs with an additional burner (which would allow a higher power output) or by using fuel cell based micro-CHP (which has a lower heat to electrical power ratio).

Our calculations show that micro-wind output is heavily dependant on the installation site, turbine height above ground level and the extent of any wind shadowing. This technology is likely to be most economic in areas with an excellent wind resource such as rural or seaside locations. In many urban environments, the performance of micro-wind turbines could be poor. This is particularly the case if there are obstructions to the south west of the turbine, the prevailing wind direction in the UK.

Identically oriented PV systems at the New Lane test site produced, as would be expected, very similar electrical outputs. However one homeowner consumed less than 50% of the PV generation on-site and would therefore need 13 years more for the investment to pay back as compared to his neighbour consuming 75% of the generation in his home. The same applies for micro-CHP: despite similar heat demand and electricity generation, payback time can differ by several years. This behavioural aspect is less of an issue for micro-wind where on average 80% of the output is consumed within the house where it is sited. This is because the turbine rarely produces high instantaneous power where electricity export is likely. Periods of strong wind (> 12 m/s) do not occur very frequently at low altitude in the UK.

Company Driven: Current economics for energy companies

The economic analysis for Company Driven investments in micro-generation technologies compares three different energy service contract arrangements. Energy service contracts can take a variety of forms related to their scope and depth (what and how it is included), investment and finance as well as ownership and risk (Sorrell, 2005). Furthermore they can refer to different energy flows: delivered energy (such as gas and electricity), useful energy (such as hot water) and the actual energy services (such as space heating and lighting). Depending on which energy flows are covered supply contracts and performance contracts can be distinguished. Whilst the former does not cover final energy services but focuses instead on delivered energy and its (efficient) conversion into useful energy, the latter one includes some control over the demand for final energy (eg space heating).

Both supply and performance contracts are possible for micro-generation technologies. Supply contracts can be applied to all three technologies in that they reduce the electricity supply from the grid. It is assumed that currently performance contracts are most likely for micro-CHP units where space heating can be part of the energy service contract.

With this in mind, three types of energy service contract have been analysed within the Company Driven model (*see Table 3*):

- First, a standard supply contract with an upfront payment by the consumer.
- Second, a lease contract with a regular lease payment and an upfront payment.
- Third, a contracting arrangement where the customer pays for the heat consumed instead of the gas delivered, but continues to pay for the electricity consumed[11].

Table 3: Summary of company income from different micro-generation contracts

<table>
<tr><th>Supply contract</th><th>Lease contract</th><th>Contracting</th></tr>
<tr><td>Upfront payment</td><td>Upfront payment</td><td>Heat purchase</td></tr>
<tr><td></td><td>Lease payment</td><td></td></tr>
<tr><td colspan="3">ROCs, LECs</td></tr>
<tr><td colspan="3">Output at SBP / Embedded benefits</td></tr>
<tr><td colspan="3">Upfront incentives
(eg bulk purchase discount of 30%)</td></tr>
</table>

11. It was not possible to include tax on the profits from micro-generation contracts within Company Driven models because this would partly depend on the energy (service) company's overall cost structure.

Under all arrangements the company will have access to ROCs (for PV and micro-wind), Levy Exemption Certificates (LECs)[12] and is assumed to value the power output at the system buy price (SBP)[13]. Upfront payment and/or lease payment under current conditions depend on the capital costs for each technology. The payment amounts used in the models are designed to be illustrative.

A 'supply contract' with an upfront payment is only economically viable for micro-CHP and micro-wind under certain scenarios; for micro-CHP customers may be prepared to pay upfront a similar amount to the price differential between a micro-CHP unit and a new condensing boiler. For lease contracts upfront payments of £100 are considered for micro-CHP and micro-wind, and of £1,000 for PV (*see Table 4*). Annual lease payments are assumed to be £150 for micro-CHP, £100 for micro-wind and £500 for PV. Annual operation and maintenance costs were assumed to be £50 in the case of micro-CHP and negligible for PV and micro-wind (*see discussion in section 2*).

For company investment in micro-CHP two cases are compared: first, a 2 bedroom bungalow with an annual heat demand of 17,750 kWh and annual electrical power output of 2,380 kWh and second, a 4-bed detached house with annual heat demand of 31,440 kWh and an annual electricity generation of 3,760 kWh. Under our assumptions, a standard contract is not viable for the 2-bed bungalow. It would achieve a profit (or positive net present value, NPV) in year 10 for the 4-bed detached house. The lease contract would achieve a positive NPV after 11 years for the 2-bed bungalow and after 7 years for the 4 bed detached house. Micro-CHP contracting would take 20 years for the 2-bed bungalow and 8 years for the 4-bed detached house to reach a positive NPV (*see Figure 7 and 8 in section 4*).

For PV and micro-wind, only lease contracts were tested – in the case of micro-wind for 2 different wind sites. This shows that under current conditions a contract for micro-wind would reach a positive NPV after between 7 and 13 years. A 1.5kW south facing PV installation would achieve a positive NPV in year 14 under our assumptions.

Barriers to deployment and uptake

These results suggest that investments in micro-generation under current conditions are unlikely to be attractive for many companies or households. Based on our interviews, payback times should be well below 10 years and probably be less than 5 years for consumers to invest. Of course, some consumers will continue to invest despite this cost barrier whilst others would not do so even if payback times were much shorter. This and other barriers to the uptake of domestic micro-generation technologies have been discussed extensively (eg DTI, 2006c). Five main areas can be distinguished: costs, technology, regulation, information and 'bounded rationality'.

Costs. Some micro-generation technologies are still rather expensive. This is particularly true for PV with upfront costs of around £9,000 for a 1.5kW array. It can however be expected that prices will fall for all these technologies with an increased market share of these technologies as a consequence of economies of scale (Energy Saving Trust, 2005b). A further economic barrier exists since there is currently no obligation for suppliers to pay an 'export reward' for micro-generated electricity exported to the grid. While some suppliers pay a relatively good price for exports, they do so on a voluntary basis.

Technology. Since many micro-generation technologies are new – at least to the household market in the UK – consumers may be discouraged by the potential risks of investment. Despite its high costs, solar PV is an established technology that has a track record. The other two technologies considered in this report are more novel and their long-term technical performance has not yet been proven. Poor performance would negatively impact their economics and their contribution to carbon emissions reduction.

Table 4: Basic assumptions for each technology for company driven arrangements

	Micro-CHP	PV	Micro-wind
Capacity (kW_{el})	1.2	1.5	1.5
Costs			
Total upfront costs *	£1,910	£5,935	£1,399
Annual O&M	£50	£0***	£0***
Income			
Upfront payment			
Supply contract	£600	na	na
Lease contract	£100	£1,000	£100
Contracting	£0	na	na
Annual lease payment	£150	£500	£100
Contracting heat price **	£0.02/kWh		

*including 30% bulk purchase discount and meter installation costs of £50

**Gas price for contractor: £0.01262/kWh as payable by major UK power producers and of gas at UK delivery points 4th quarter 2005 (DTI, 2006a)

***Due to uncertainties and a lack of hard evidence, O&M costs were not included in the calculations for PV and micro-wind (see discussion above).

12. Generators of electricity from renewable energy sources and Good Quality CHP that are exempted from the climate change levy (CCL) receive Levy Exemption Certificates (LECs) for each MWh of power exported.

13. The average half-hourly SBP in 2005 was 4.2p/kWh. SBP is usually higher than the wholesale price. The average wholesale price between June 2005 and May 2006 was however 4.5p/kWh (The Carbon Trust, 2006).

Regulation. Various regulatory barriers significantly inhibit the diffusion of micro-generation technologies in the UK. Examples include planning regulations, the rules governing the Renewables Obligation (RO) and the distribution network regulations. Homeowners who want to install a micro-wind turbine need a planning permission from their local council which adds hassle and cost. Access to ROCs for micro-generators is complex since the system is primarily designed to benefit large renewable energy schemes. Distribution network regulations mean that the income of Distribution Network Operators (DNOs) is based on the throughput of electricity in their network. A significant expansion of micro-generation might reduce this income and therefore be discouraged by these companies.

Information and bounded rationality. The lack of sufficient information and knowledge can prevent people from considering micro-generation as an option. There is a general lack of reliable advice that takes into account the individual, site-specific circumstances of homeowners. The importance of advice is illustrated by successful experience. A recent survey of consumers with solar hot water systems conducted at SPRU showed that the advice and support of a local energy agency was the single most important factor in their decisions (Schulz, 2006). A related issue is the bounded rationality of consumers. Human decision-making is subject to constraints on people's time, attention, resources and ability to process information. Consequently many decisions are unlikely to be made based on exhaustive economic and technical appraisals, but are embedded in routines and rules of thumb.

As a result of recent policy interest in micro-generation, many of these barriers are now being addressed – either through the government's Micro-generation Strategy and wider Energy Review, or though the Climate Change and Sustainable Energy Act[14] that completed its passage through Parliament in June 2006. These include a number of measures:

- Work to simplify the process required to receive ROCs for micro-generated electricity;
- A review of the planning regulations. The objective is to give micro-generation permitted development status that is similar to that granted to satellite dishes;
- Suppliers are expected to develop and implement a reward scheme for micro-generated electricity exported to the grid within a year of the passage of the Climate Change and Sustainable Energy Act. If they do not, the government can impose a scheme;
- An accreditation scheme that will include products, installers and manufacturers. This aims to provide consumers with trustworthy information on micro-generation;

- Consideration of national targets by the government (but no obligation to implement these). This is accompanied by guidance for local authorities to integrate targets for micro-generation in new developments where appropriate;
- A DTI sponsored field trial on smart metering;
- Promotion of community energy projects;
- A review of incentives and barriers for decentralised energy generation carried out by the government and Ofgem; and
- The extension of the Energy Efficiency Commitment to all micro-generation technologies, and modifications to it so that it is based on carbon savings instead of energy savings.

Whilst current policy initiatives will improve the attractiveness of micro-generation for consumers and energy companies, they do not go far enough. There are at least three grounds for this view. First, some of the initiatives are over-cautious and incremental. In areas such as export rewards and smart metering, there will be delays in implementation while further trials and discussions take place. This is in stark contrast to the quicker actions in other countries with respect to similar measures. Second, this agenda misses out important reforms that could begin to level the playing field between micro-generation and other forms of energy investment outside the home. Section 4 of this report analyses just two of these in detail – changes to fiscal rules and the extension of the market settlement system for electricity. Third, these measures take the current regulatory framework for energy as given. The potential for more wide-ranging reforms that recognise the need for a different approach to energy provision and the requirement for new infrastructures has not yet been fully recognised. This wider agenda is discussed in more detail in section 5 of this report.

14. **www.opsi.gov.uk/ACTS/acts2006/ukpga_20060019_en.pdf**

4. Levelling the playing field

Economic incentives for the uptake of micro-generation technologies usually take two forms. Either they subsidise capital costs as is the case with the Low Carbon Buildings Programme. This has the advantage of tackling what many consumers see as the most important economic barrier. Or they provide an economic incentive related to the output of a micro-generation unit. This is the rationale for the current obligation on energy suppliers to develop an export reward scheme. Policy makers and the micro-generation industry argue that measures in both categories are necessary to kick start the micro-generation market.

But are we missing an opportunity here? What if the same incentive effect could be achieved by levelling the playing field for energy investments. Instead of introducing new subsidies, why not use this opportunity to remove anomalies in the treatment of micro-generation? This would provide micro-generators with the same benefits enjoyed by investors elsewhere in the energy system. This section examines two of these anomalies – unequal fiscal treatment for energy investment and the lack of access to the settlement system for micro-generation.

The same fiscal treatment

Fiscal incentives for micro-generation investment have hitherto been widely neglected. Notable exceptions are the Energy Saving Trust's study on fiscal incentives for domestic energy efficiency and the Association for the Conservation of Energy's work on fiscal instruments for the support of energy efficiency and micro-generation (ACE, 2005; Energy Saving Trust, 2005a).

The fiscal treatment of investments in energy supply infrastructure is biased towards business investment in central power stations. While corporate investors can generally offset their upfront costs against their tax liability in the year of investment and can pass through VAT, individual taxpayers do not have access to tax allowances or tax credits and have to pay (reduced) VAT (Chesshire, 2003) (*see Table 5*). This has significant consequences for the economics of micro-generation technologies and other demand side measures.

Businesses investing in new plants or machinery can offset their investments against their tax bill in the form of capital allowances and consequently reduce their upfront costs. The standard capital allowance is 25% on a reducing balance basis over several years. Small and medium sized businesses can claim a larger 40% allowance in the first year, whilst investment in plant and machinery by oil and gas companies attracts a 100% first year allowance[15].

On the demand side businesses have access to Enhanced Capital Allowances (ECA) under which they can offset 100% of the investment costs for energy saving or low carbon technologies[16] in the year of investment[17]. For an average company, this means that the actual investment costs are reduced by 30% in the year of investment. The same treatment applies to expenditures under energy service contracts for businesses. While some CHP technologies are ECA approved, micro-generation technologies such as PV or micro-wind are not.

As a result, householders are disadvantaged in two ways. Private individuals purchasing a micro-generation unit or investing in energy saving measures do not have access to capital allowances. In addition, companies offering energy service contracts to domestic customers do not have access to these allowances either[18].

Recent policy recognises that the fiscal system must change to attract more investment in energy efficient technologies. The Budget 2006 identifies as one long-term policy goal to address 'environmental challenges, such as climate change and the need for energy efficiency in response to rising oil prices'

Table 5: Tax treatment of capital expenditure

		Business				Private
			ECA approved	Energy Service Agreement for *business*	Energy Services Agreement for *domestic*	
Capital allowance	*Supply*	Standard	**No**	Standard / enhanced	**No**	**No**
	Demand	Standard	Enhanced	Standard / enhanced	**No**	**No**
VAT	*Supply*	Pass-through	Pass-through	Pass-through	Pass-through	**VAT payable**
	Demand	Pass-through	Pass-through	Pass-through	Pass-through	**VAT payable**

Source: Based on Chesshire (2003)

15. Long life assets that are expected to last over 25 years attract lower levels of allowance.

16. Energy saving or low carbon technologies must meet the eligibility criteria as outlined in the Energy Technology List to qualify for Enhanced Capital Allowances (ECA).

17. ECAs were introduced in 2001 as part of the climate change levy package to support businesses investment in energy saving and low carbon technologies.

18. Under current regulations capital expenditure on plant or machinery for use in a house does not qualify for capital allowances: **www.hmrc.gov.uk/manuals/camanual/CA23060.htm** 21/07/2006.

(HM Treasury, 2006: 3). It acknowledges that short-term considerations and market failures can prevent businesses and households from investing in cost-effective sustainable measures. Similarly the Energy Review pointed out that: 'the principle that fiscal measures can play a part in achieving our environmental goals has been established' (DTI, 2006b: 131).

To put these goals into practice, the fiscal regime therefore needs to reflect a fundamental change in the energy system that stems from micro-generation. Micro-generation is a supply technology contributing to production of energy, but it is installed on the demand side of the energy system. The Keynesian distinction between the production sector (firms) and the consumption sector (households) that shapes taxation policy is therefore open to challenge. Capital expenditure in the energy system – on electricity generation or energy saving measures – will increasingly be made by individuals as well as the private sector.

Therefore, all investors should have access to the same tax benefits. A 'level playing field' in tax treatment would include the following changes:

- Individuals investing in micro-generation technologies will have access to the same capital allowances as companies have;
- Enhanced capital allowances will be available for all micro-generation technologies;
- Capital expenditure within domestic energy service contracts will qualify for capital allowances.

There are precedents for such changes. For example, there are already policies in place that provide tax incentives for landlords to invest in energy saving in rented housing (HMRC, 2005). There are also provisions within the 'Affordable Warmth Programme' to provide capital allowances for the lessor of heating systems for fuel poor households (HM Treasury, 2000). In addition, non-energy related tax breaks in the domestic sector have been available for various domestic goods and services for a number of years. These include tax allowances for home computers (abolished in the Budget 2006), mobile phones, cycles and childcare. These policies are (or were) based on wider policy objectives such as the transition to the 'digital society', better health and the reduction of environmental pollution.

Current energy policy priorities such as reducing carbon emissions, improving energy security and widening competition are equally important rationales for tax breaks – in this case for micro-generation and demand-side energy investments. If individual taxpayers were given access to enhanced tax allowances in the year of investment, this would reduce installation costs by 22% or 40% depending on their marginal tax rate. Nearly 10 million people fill in a tax return each year and could claim this allowance with little additional bureaucracy (National Audit Office, 2005b). Alternatively a new 'salary sacrifice' scheme[19] could be set up for micro-generation and energy saving investments. Employees would be able to use part of their salary to build up a fund (or repay a loan) that they must use for these investments.

These additional tax allowances could be financed by the Environmental Transformation Fund (DTI, 2006b: 15) or the Non-Fossil Fuel Obligation fund[20]. Over the period to 2010 this latter fund is expected to be between £550 million and £1 billion, while only £60 million is so far earmarked for the promotion of renewable energy (National Audit Office, 2005a: 5).

Equal access to the settlement system

The settlement system is another important area in which the treatment of centralised power plants and micro-generators is different. Whilst the power output from central power plants can be sold into this system for the half-hourly wholesale price, exports from micro-generation cannot be settled in this way. This is a major barrier for micro-generators since their exports to the grid are not valued correctly – in many cases they are undervalued.

With the recent introduction of new profiles (approximations of a micro-generator's output), it is possible for suppliers to consider exports from micro-generators in the settlement system (Elexon, 2002). However, these profiles are not often used due to a lack of accuracy. Instead, suppliers tend to offer discretionary, nominal payments for exports that are not related to their value. All suppliers within a given geographical area benefit from micro-generation exports. The value of these is subtracted from their bill in relation to their supply share within this area.

The need for settlement system reform to allow the inclusion of micro-generation is a classic 'chicken and egg' dilemma. Whilst only high volumes of exports make changes economically worthwhile, modifications to the settlement system could significantly contribute to the uptake of micro-generation technologies.

So how could this be achieved? Two routes are possible: more new profiles or half-hourly metering. It has been claimed that the value of data volumes generated by domestic customers are too low for half-hourly metering to be economic. The high costs of half-hourly metering are largely related to the costs for data collection and aggregation rather than the metering hardware. These stem from the need to upgrade IT systems operated by suppliers, data aggregators and data collectors.

19. The employee gives up the right to receive part of the cash pay due under their employment contract. Usually the sacrifice is made in return for some form of non-cash benefit' (See guidance at: **www.hmrc.gov.uk/specialist/salary_sacrifice.pdf**).

20. When the Renewables Obligation (RO) was introduced in 2001, existing projects built under the NFFO were included in the RO. The surplus benefits generated went into the NFFO fund administered by Ofgem.

This explains why profiles are currently favoured, though this approach is not without problems. The research for this report shows that profiles would only be useful if a large number were generated to reflect variations in performance. In particular, micro-wind and micro-CHP output is heavily dependent on the installation site. The costs for the establishment and maintenance of enough profiles might therefore be very high. Estimates show that the establishment of new generation profiles for each micro-generation technology could cost £100,000. An additional annual maintenance cost of £250,000 would also arise.

This can be contrasted with the estimated costs of £15 per unit per year for half-hourly meters (ILEX Energy Consulting, 2005: 27). It is difficult to get any transparent cost estimates for data collection and aggregation from half-hourly meters for use in the settlement system. However, one advantage of using this route would be that it would also enable a range of possibilities for demand management and consumer engagement. Smart half-hourly meters could collect data for the settlement system but could also be combined with other services to stimulate behavioural change such as prominent displays that provide real time information on usage and pricing. This report will return to these wider potential benefits of smart metering in section 5.

The Economics of a Level Playing Field

Plug and Play

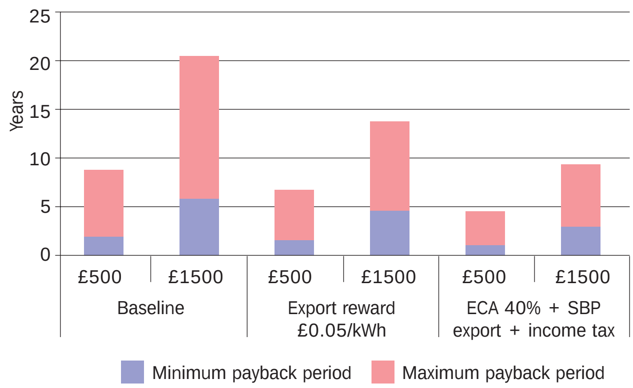
From a homeowner's perspective the analysis shows how a 'level playing field' compares to the current ('baseline') situation outlined in section 3. This means the that householders have access to ECAs, pay income tax on earnings from power sales and ROCs[21] and get paid the real time system buy price for exports. For comparison an export reward of 5p/kWh for all technologies is used in order to test the aim of the Microgeneration Strategy for a 'fairer reflection of the value of the exported energy' (DTI, 2006c: 25). Our calculations suggest that average 'fair' export rewards should be at least: 5p/kWh for micro-CHP and PV, 4p/kWh for micro-wind[22].

For micro-CHP, the analysis compares a £500 and a £1,500 price differential and provides a range of payback times for low heat demand (and low power output) and high heat demand (and high power output). Assuming a price differential of £1,500, Figure 4 shows that a level playing field provides the most attractive framework for homeowners to invest in micro-CHP. It more than halves payback times for the low heat demand from 21 years to 9 years for a 40% marginal tax rate payer. At a £1,500 price differential an export reward of 5p/kWh the maximum payback time would be reduced to 14 years.

21. Income tax payment is considered for the sale of ROCs and exports. Currently consumers do not pay income tax on these. To level the playing field, it might be argued that such an income tax payment has to be applied.

22. For the calculation of a 'fair' export reward for each technology the annual value of exports based on half hourly SBP prices for 2005 were divided by the total amount of annual electricity exports.

Figure 4: 'Plug & Play': A level playing field for micro-CHP



For micro-wind a 'level playing field' would create the same investment conditions for a homeowner as under current conditions with access to LCBP grants. The payback would be considerably more attractive than with an export reward of 5p/kWh without LCBP grants (*see Figure 5*). In the case of PV, a 'level playing field' does not improve payback time compared to current investment conditions if the LCBP is included. Export rewards of 5p/kWh are only a viable option for PV if they are on top of upfront incentives like LCBP. In this case export rewards can reduce payback time by more than 10 years (*see Figure 6*).

Figure 5: 'Plug & Play': A level playing field for micro-wind

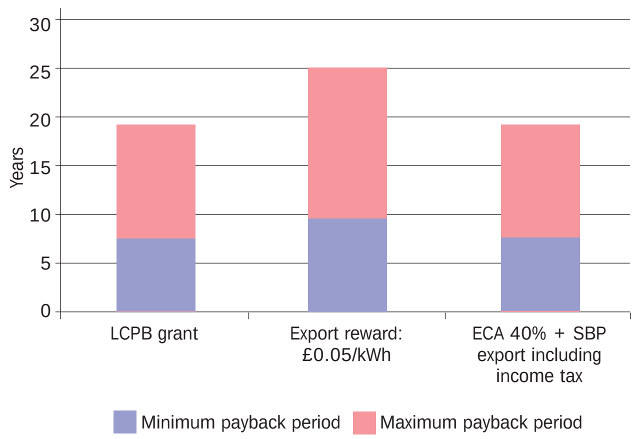
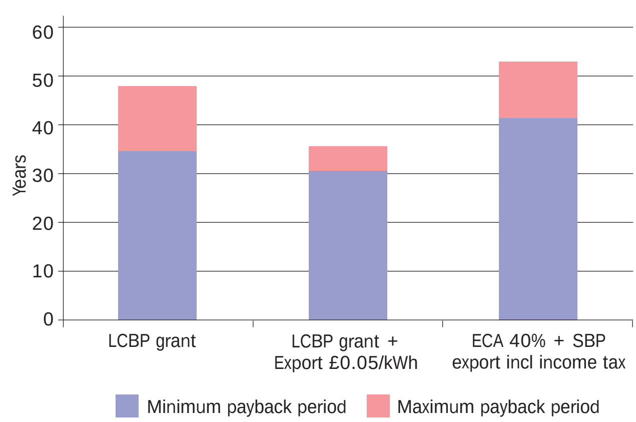


Figure 6: 'Plug and Play': A level playing field for PV (south-facing)



A system of 'fair' export rewards can improve the economic attractiveness, particularly of micro-CHP and PV but should only be used as short-term solution for the transition towards a 'level playing field' in the fiscal treatment and settlement system. Tax allowances would provide a longer-term framework for investors and industry. Furthermore, upfront incentives such as tax allowances are more attractive for individuals since they value upfront income considerably more than future income.

One further mechanism for shortening payback times is expected to be falls in installation costs as a result of increasing production volumes and learning. We tested this by applying the learning curves used by the Energy Saving Trust to produce possible costs for 2016 (Energy Saving Trust, 2005b[23]). Using our level playing field assumptions, investments in PV and micro-wind could just pay back within the unit's lifetime without any additional support. PV would payback in 18-23 years and micro-wind would pay back in 5-14 years. Micro-CHP's payback times would improve marginally since the cost reduction potential is assumed to be lower.

Company Driven

For Company Driven investments the analysis shows how company access to capital allowances for expenditure as part of energy service contracts would increase the economic viability for each technology. It compares access to standard capital allowances (SCA) and enhanced capital allowances (ECA). Furthermore it tests the influence of a 10% electricity price increase per year and reduced installation costs in 2016 using the Energy Saving Trust experience curves.

For a 2 bed bungalow, access to SCAs and ECAs can reduce payback times for micro-CHP from above 20 years to 11-14 years respectively under a standard contract. Times are reduced from 11 to 7-8 years respectively under a lease contract, and from 20 to 11-12 years respectively under a contracting arrangement. Similarly for a 4 bed detached home a positive NPV would be reached in year 5 or 6 instead of in year 10 under a standard contract, in year 5 under a lease contract, and year 5 or 6 instead of in year 8 with contracting. Figures 7 and 8 summarise these results.

23. In our analysis, we applied the EST learning rates to derive capital costs for micro-CHP and PV in 2016. Since our current cost assumption for micro-wind is much lower than EST's, we have assumed a more modest cost reduction than that in their study following advice from several of our interviewees.

Figure 7: Company Driven: A level playing field for micro-CHP in 2 bed bungalow (annual electricity output: 2380 kWh)

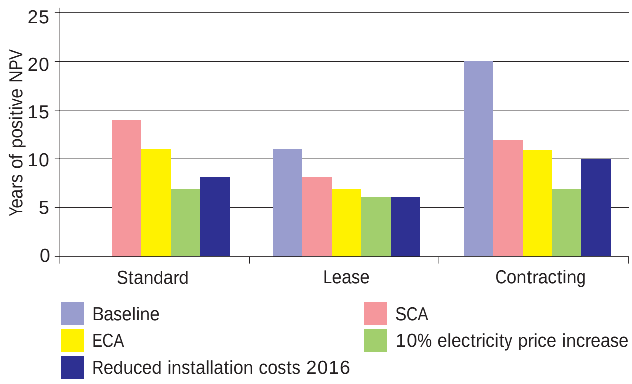
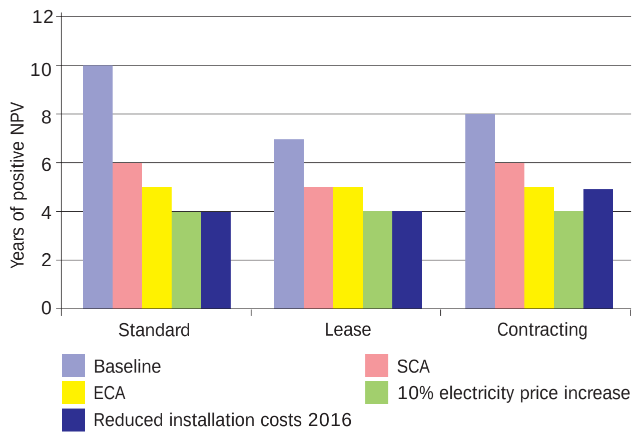


Figure 8: Company Driven: A level playing field for micro-CHP for 4 bed detached (annual electricity output: 3760 kWh)



At a good rural wind-site, investment in a micro-wind turbine would reach a positive NPV after 4 years (with ECA) or 5 years (with SCA) instead of 7 years (*see Figure 9*). For solar PV, a positive NPV would be reached in year 8 (with ECA) or 9 (with SCA) instead of year 14 (*see Figure 10*).

Figure 9: Company Driven: A level playing field for micro-wind with lease contract

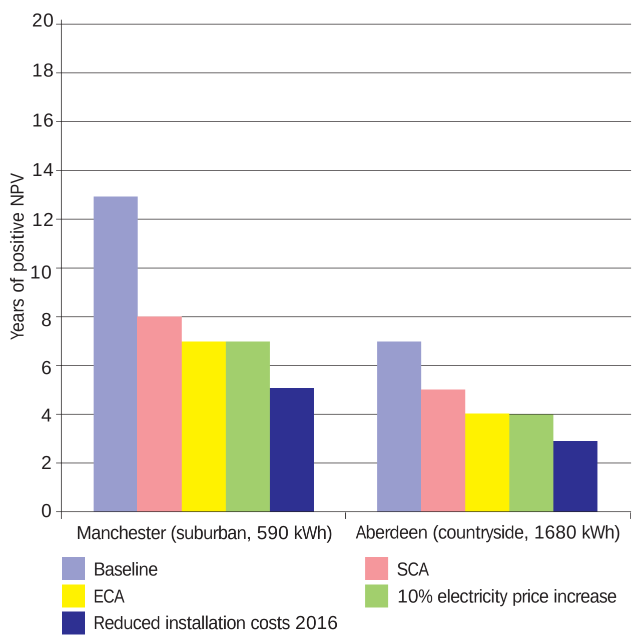
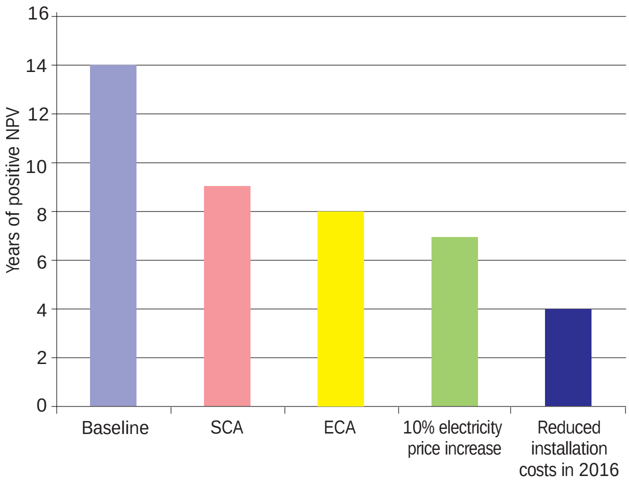


Figure 10: Company Driven: A level playing field for PV (south facing) (annual electricity output: 1300 kWh)



The two other scenarios – increasing electricity prices and reduced installation costs in 2016 in addition to the ‘level playing field’ assumptions – would further improve investment conditions for domestic micro-generation. Reduced installation costs have the greatest impact for PV (even without up-front payment by customers) and micro-wind (*see Figures 7-10*).

Overall, results for both Plug and Play and Company Driven models show that levelling the playing field for energy investment can significantly improve the economics of micro-generation. For Plug and Play investment, micro-CHP payback times are less than a decade – less than half that in many cases. A level playing field produces similar economic results to the Low Carbon Building Programme for micro-wind and solar PV. Under the illustrative assumptions chosen for our Company Driven examples, many energy service contracts for micro-generation pay back well within 10 years.

These results support the need for reforms in the two key areas we have analysed – the fiscal regime and the settlement system. Such reforms are not only required to remove bias against micro-generation. They will also provide strong incentives for deployment which – if all goes well – will lead to economies of mass production and therefore to reductions in unit cost.

The first of these is the most important since reductions in up-front costs tend to be valued more highly by consumers than financial benefits over time. **Consumers who invest in micro-generation and other energy saving investments should be able to claim Enhanced Capital Allowances – so should companies that make these investments as part of domestic energy service contracts.** For householders, this could be implemented either through the tax return system or a salary sacrifice initiative managed by employers.

The government, Ofgem and the industry should also consider early action to allow micro-generation exports to be sold accurately into the settlement system. In common with previous developments in the electricity market such as the New Electricity Trading Arrangements, the costs of implementation will be significant. Therefore it could be argued that this should wait until there is a critical mass of micro-generation installed. However, without this extension, micro-generators will not be able to benefit from the full value of the power they export. It is hard to see how alternative solutions such as profiles can achieve this.

5. Towards System Change

Removing inconsistencies in fiscal and regulatory frameworks can do much to increase the attractiveness of micro-generation for consumers and energy suppliers. Such measures would not only assist micro-generation deployment since they could also provide an incentive for a range of energy saving measures. Going one step further, they should be seen as part of a much wider agenda of reforms that could ensure a much greater role for consumers and the demand side of the energy system. This agenda also includes a more integrated approach to the development of energy infrastructure (Patterson, 2003): from metering systems through to new housing developments.

Energy services

In the discussions surrounding the Energy Review, this wider agenda gained some prominence. Despite the focus of the review on nuclear new build, a number of Ministers went out of their way to make radical proposals for the demand side. Fundamental regulatory reforms were mooted that would shift the relationship between energy supplier and consumer. Particular emphasis was placed on new modes of energy service provision. In a speech to the Fabian Society in June, Trade and Industry Secretary Alistair Darling said that:

'we are looking at how to create a shared incentive between consumers and energy suppliers to reduce energy use. We must look at how [energy suppliers] can change from just selling units of electricity to providing energy services – heating and lighting homes – making it their business to increase energy efficiency and cut demand.' (Darling, 2006)

Despite this, the Energy Review says very little about energy services or how the regulatory system might be changed. There is evidently some interest in these changes within government, but the political will to implement them has not yet been demonstrated.

Any reforms that are proposed will need to take into account barriers as well as some of the new opportunities that are coming to light. Whilst this report has already explored in some detail how energy service contracts could be used to deploy micro-generation, it has not yet discussed the conditions under which energy companies might pursue this approach.

What could drive energy services?

The prospects for a household energy service market have been discussed for many years, but there has been little sign of this market in practice. To explain this lack of activity, numerous studies have pointed to a range of barriers (Chesshire, 2000: 12; Energy Services Working Group, 2003; Cragg Ross Dawson, 2004; HM Treasury, The Carbon Trust et al, 2005; SDC/UKERC, 2006). These can be summarised as follows.

- The 28-day rule under which consumers can change their supplier every four weeks prevents companies from offering long-term contracts;
- The costs of marketing energy services packages would initially be high;
- Energy service contracts could be expensive to set up in relation to the savings made;
- Various risks to profitability (eg that consumers move house during the contract);
- Consumers' mistrust of companies' motives for investing in energy saving; and
- Aversion to a long-term commitment to a particular supplier.

Despite these barriers, it has been argued that domestic energy service contracts are becoming more attractive for both companies and homeowners. An important driver for this is increasing energy prices. For an average UK household electricity bills increased by 37% and gas bills by 57% between 2003 and the beginning of this year[24]. Further increases have been introduced at regular intervals since then.

Against this background, several newspaper articles[25] have identified micro-generation technologies and demand reduction measures as ways of reducing domestic energy bills. As a result of this media interest one supplier reported that 2,500 people have contacted them for more information about micro-generation without any additional marketing efforts.

Therefore, instead of leaving homeowners to go for the independent 'Plug and Play' model, suppliers might prefer to offer energy service packages for micro-generation technologies. One change has already been agreed that might help to open up this possibility – the removal of the 28-day rule (Ofgem,

24. According to unpublished calculations by Energywatch.

25. Eg 'How to make home a powerhouse' *The Observer* 23/10/2005, p11.

2006b: 10). In interviews for our research, suppliers referred to this rule as one reason why they have not offered energy service packages. **Whilst the trial suspension of the 28-day rule has not led to significant energy service activities, Ofgem is right to propose the removal of this rule.**

Energy service contracts could allow these companies to retain customers who would otherwise switch supplier – a trend that has intensified as prices have risen. For example, in March 2006, 900,000 domestic customers switched their gas and/or electricity supplier. This is the highest rate for four years (Ofgem, 2006a). A long-term relationship is economically attractive for energy companies since it is much more costly to gain a new customer than retain an existing one. Furthermore, such a relationship would compensate for the low profit margins these companies make in their core retail business. As one supplier told us:

'the ability to build up a portfolio of other transactions with that customer is a big part of the equation. There's still an ongoing supply relationship but you could almost ignore that in terms of assessing the benefits of a long-term relationship and the opportunity of other products'.

Another approach is possible. Due to the risks that a consumer would move house part-way through a service contract, Scottish and Southern Energy have proposed that the additional costs for the energy service contract should be recovered by an increased network charge for the meter (Environmental Audit Committee, 2006). This charge would have to be paid irrespective of who occupies the home.

The role of regulation

Despite this optimism that domestic energy services will soon become more attractive, a widespread market is unlikely without the more fundamental reforms hinted at recently by Ministers. These reforms will not only require policy developments by DTI and Defra, they also imply a significant change of emphasis within the energy regulator, Ofgem. At present, Ofgem's remit is primarily to protect current consumers – social and environmental concerns have a lower status by comparison. The increasing importance of energy services, micro-generation and smart meters mean that this lower status should be questioned. Just as micro-generators challenge fiscal rules by producing energy on the demand side of the meter, they also require the regulatory system to take a broader view of consumers (Willis, 2006).

At present, energy companies are required to implement a specified amount of energy saving across their customer base under the Energy Efficiency Commitment (EEC). The Energy Review has proposed that the third phase of EEC which is due to run from 2008-2011 should be 50-100% larger than the current phase (DTI, 2006b: 59). It also said a scheme would be in place until 2020. The Sustainable Development Commission (2006)

has called for EEC to be expanded more rapidly, with early implementation of a third phase target that is three times larger than that for the first phase.

The Energy Review concedes that 'EEC has been very successful at delivering … measures such as loft and cavity wall insulation, but does not address the important issue of consumer behaviour … or think about the energy efficiency of appliances' (DTI, 2006b: 59). Micro-generation deployment has been unaffected by EEC so far even though micro-CHP is eligible as an 'innovative action' within EEC's current second phase. In recognition of these drawbacks, it is proposed that the third phase would allow suppliers to include additional innovative actions to meet their target including behavioural measures. It will also include all micro-generation technologies within its remit (Defra, 2006).

More fundamentally, the review proposes that EEC should be replaced in 2011 by a new obligation on suppliers to reduce absolute energy demand or carbon emissions coupled with a scheme of 'white certificates'. These certificates would be generated by energy savings and could be traded between suppliers to encourage the least cost measures to be taken first. This leads to a question: if EEC has a limited shelf life and Ministers wish energy suppliers to implement energy saving as a core activity, why not bring forward this transition?

Waiting until 2011 for a supplier obligation could delay progress unnecessarily. If it includes ambitious targets, an obligation to reduce demand is likely to be much more powerful than EEC – and would lead to an integrated approach by suppliers to energy saving measures including micro-generation. **Therefore, the DTI, Defra and Ofgem should consider an earlier transition from EEC to a demand reduction obligation on suppliers and a system of white certificates in 2008.**

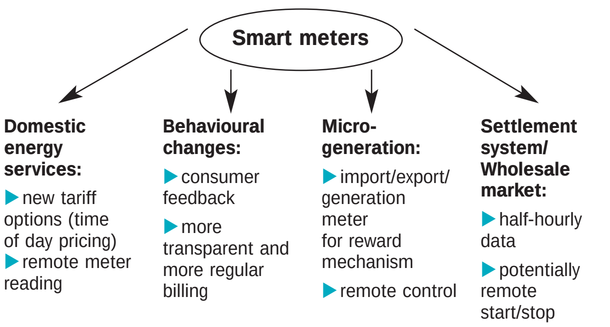
Changing energy infrastructures

Reforms to regulatory frameworks are only part of system change. The advent of micro-generation and the need to engage consumers more directly in energy saving also requires changes to energy infrastructures.

Smarter meters

It is now widely believed that the UK's stock of domestic meters is outdated. There is increasing interest in smart meter designs with enhanced capabilities (DTI, 2006b; Owen and Ward, 2006). For example, they can measure half-hourly demand, they can be linked to display systems that show current and historical consumption data, and they can measure imports and exports for consumers with micro-generation (*see Figure 11*).

Figure 11: The potential impact of smart metering



As a result, smart meters should be seen as an essential addition to the UK's energy infrastructure that facilitates micro-generation and provides consumers with information that could catalyse behaviour change. Just as the current energy market could not operate without infrastructures such as wholesale markets and billing systems, future markets will need smarter meters if consumers are to play a full role in meeting policy goals.

A number of studies have discussed international experience of smart meters and the extent to which their presence leads to consumer behaviour change (eg Darby, 2006). There is some evidence that the information provided to consumers from these meters leads to significant reductions. The response of the UK government and of Ofgem has been enthusiastic about their potential but cautious on implementation (Ofgem, 2006b; DTI, 2006b). Funding for field trials of smart meters together with other innovations such as real-time displays was announced in the 2006 budget, with results due to be available in 2008.

Our research suggests that smarter meters are an essential element of micro-generation systems. As a minimum, micro-generation requires the measurement of both export and import of power from the home. Some firms sell micro-generation systems that also include a display system that shows how much electricity is being produced. If micro-generated electricity is to be sold into the settlement system, meters will need to collect half-hourly data. **This leads to the conclusion that a policy of future-proofing is required: smart meters should be mandatory when micro-generation technologies are installed.**

Going further, there is no reason why the installation of smart meters should be restricted to micro-generators. The benefits to society are likely to outweigh the costs, but regulatory intervention is necessary for it to happen (Owen and Ward, 2006). National roll-outs are underway in other countries, notably Italy and Sweden. Recent consultations in the UK have also considered this (Ofgem, 2006b). However, a range of options to deliver UK roll-out have been rejected including supplier obligations and re-bundling meters into distribution businesses. Ofgem argues that there are too many uncertainties: about the best metering technology, the costs involved and the impact on consumer choice. This latter argument in particular misses the point. Smarter meters should be regarded as facilitators of choice in a future energy service market rather than an optional extra that consumers might wish to buy. **Ofgem and the DTI should therefore reconsider their wait and see policy, and develop plans with the energy industry for a national smart meter programme.**

The built environment[26]

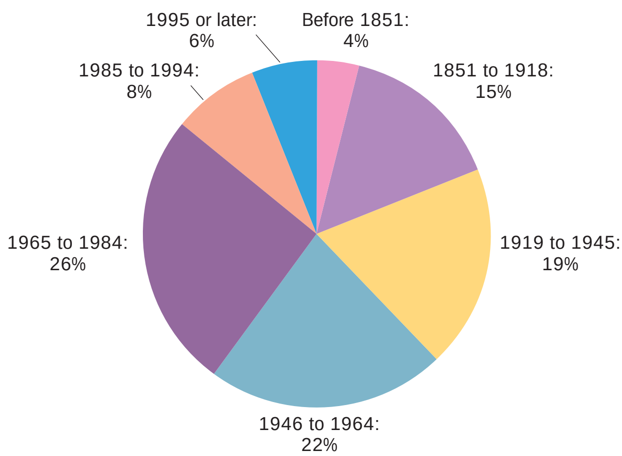
The UK's building infrastructure will have an important influence on the extent of micro-generation deployment. Characteristics such as building age and type influence the choice of suitable micro-generation technologies used at particular sites. Major refurbishment and new build developments present an opportunity for fuller integration of micro-generation in combination with energy saving innovations.

A number of high-profile studies have shown that carbon emissions from buildings can be cut considerably (eg Boardman, Darby et al, 2005). Within these studies, micro-generation has a substantial role to play in reducing emissions – both in existing housing and in new developments. Whilst the latter could provide the most cost effective opportunities for micro-generation, the improvement of existing buildings is a much larger task.

The turnover of the building stock is slow (*see Figure 12*). Even under optimistic assumptions, 70% of the housing stock that will be here in 2050 already exists today (Sustainable Development Commission, 2006: 11).

26. Some of the material in this section and the next is based on discussions at a project workshop for the housing and construction industry held at the Tanaka Business School, Imperial College London in May 2006.

Figure 12: Dwelling stock in England by year of construction (2004/05 Survey of English Housing)



As this report has already demonstrated, some micro-generation technologies are particularly suitable for older, less efficient homes. Micro-CHP units that use Stirling engines are more economic in these homes than in more modern houses that comply with the latest Building Regulations. Nevertheless, there is still considerable scope for reducing the energy demand of older homes – through solid wall insulation for example. If these measures were implemented more widely, this kind of micro-CHP would become less attractive.

This potential lends weight to policy incentives that benefit both household micro-generation and energy saving investments. **Whilst some micro-generation specific policies are required, a more general approach would steer (but not mandate) consumers and energy companies towards implementing the most cost effective demand side measures first.** We have already suggested that enhanced capital allowances for households should be available for a range of demand side investments. Reforms to energy regulation such as a demand reduction obligation on suppliers would have a similarly broad remit.

Another set of relevant regulations have only been mentioned in passing so far in this report. The Building Regulations have a significant influence on changes to existing properties as well as new construction. Recent modifications to the regulations have, for example, had a major effect on the market for condensing boilers. Condensing boilers now account for 85% of the boiler market (Sustainable Development Commission, 2006). Before the regulations took effect, the share was 20%. This example shows that the Building Regulations may have a role to play in providing incentives for micro-generation technologies in the future. However, there may be limits to this because the suitability of a particular technology is likely to vary from building to building. It is difficult to imagine future regulations mandating micro-generation when boilers are replaced or when major refurbishment work is undertaken.

New housing and communities

With an increasing demand for housing, new construction constitutes a major opportunity for the market uptake of domestic micro-generation in the UK. For example, 140,000 new homes were built in 2001 in England (ODPM, 2003: 9). The upfront integration of micro-generation could result in direct savings through the replacement of other building materials (eg roof tiles in the case of PV). Additionally cost reductions could be achieved due to economies of scale. Integrating micro-generation in the housing design could also increase the annual output from the technologies (eg by designing in south-facing PV panels).

Innovations in IT and telecommunications will enable the integration of micro-generation technologies while improving the general performance of the buildings. For example, 'Smart Homes' initiatives represent the rapidly expanding market for home entertainment control systems, providing remote/wireless operation of audio and video systems. Few of these systems address detailed home energy control issues. The development of affordable home automation systems based on networked devices will eventually help to maximise the efficiency of energy usage in the home and integrate micro-generation fully.

Adaptable buildings are essential for current and future micro-generation systems. It is desirable to include additional space and flexible services in new designs. Future heating and power plant together with their infrastructure could require more space than the compact boilers now in common use. One potential solution is the cellar. These have not been provided in UK housing in recent decades to keep overall costs down. Re-introducing them would give adequate additional space for the plant, fuel storage, battery storage, or whatever might be required. Some architects told us that UK housing misses an opportunity by not providing cellars for general storage, while they are the norm in continental Europe.

In addition to thinking about possible space requirements, new buildings can be future-proofed by ensuring that additional cabling and piping can be run through the service ducts without requirement for building modification. The European project 'FutureHome' has explored the concept of service modules to achieve this (Atkin and Wing, 2002). These consist of factory assemblages of piping, wiring and ducting to be assembled on-site units compatible with the wall and other pre-assembled components.

There are, however, challenges to overcome before this kind of thinking is mainstream. Innovation processes in the construction industry are different to those in other markets. In other industries there is usually a means of measuring innovation, eg from the rate of introduction of new products, or the number of patents. No such simple yardstick may be found in construction however, as the innovation comes from many directions, eg novel design concepts, use of new materials, different approaches to the setting of buildings in their environment (Atkin, 1999). Leading designers and construction firms gain reputations for applying imagination and bringing ideas from other sectors into their work in order to meet the challenges of a particular project. Such innovations are not reflected in new products, patents or licence fee income, but have a more diffuse impact.

Tradition and resistance to change in the construction industry represent further barriers. The onus is largely placed on the customer to require innovations in new buildings. In manufacturing industry the customer leads the innovation process in this way by demanding the latest technologies in their car or mobile phone. In construction, the client needs to be well informed, even expert, to fulfil this role. The client meets the cost and takes the risks. It is therefore not surprising that developers identify high costs and a lack of demand as the main barriers to low carbon buildings (Energy Saving Trust, 2005b: 12). Policy intervention is required to help steer innovation in this direction. As with existing buildings, the Building Regulations have recently been updated to specify higher standards of energy efficiency. These revisions have had little impact on the demand for micro-generation so far. Whilst guidance is given on these technologies, there are no requirements that they should be used.

By contrast, developments in planning policy have started to have an effect. The London Borough of Merton pioneered a policy (now known as the Merton rule) that 10% of energy requirements in new developments should be provided by onsite renewable energy production. A number of other local authorities have started to develop similar policies in conjunction with the Town and Country Planning Association. **The provision in the Climate Change and Sustainable Energy Act that encourages local authorities to do so is welcome. This provides an important but flexible signal that micro-generation should be built in to new developments.**

New construction could improve the prospects for Community Microgrid models of micro-generation deployment in which whole developments are designed to maximise local energy generation and use. The Energy Review has raised this possibility with respect to the Thames Gateway development in London (DTI, 2003b). There have been discussions about making Thames Gateway a low carbon development for some time. **Given the barriers to innovation in the construction industry and the complexity of the Thames Gateway development, the realisation of this vision will require strong intervention by planners at all levels of government.**

The pioneering example of Woking has demonstrated that this kind of vision can be achieved. Replication on a larger scale will require energy network innovation as well as housing innovation. Distribution Network Operators (DNOs) should be encouraged to develop and manage such networks. Again, the regulatory system has a part to play. Ofgem has introduced a scheme known as Registered Power Zones that allows DNOs to recover some of the costs of innovative network experiments. So far, only three of these zones have been registered so far, two of which do not include generation sources (Woodman, 2006).

Critics maintain that the current rules are too restrictive to make innovation economically viable, particularly for firms that have run down their innovative capacity over the past decade or so. **The forthcoming review of the Registered Power Zone scheme presents an opportunity for Ofgem to relax the rules governing network innovation.** This will be important for the development of new network concepts that could help to integrate large numbers of micro-generators into housing developments – both existing and new.

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