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Economic Analysis of Micro-generation Deployment Models

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1 Introduction

Micro-generation - the generation of electricity in individual households - has attracted increasing interest over the past few years in the UK. There are a number of drivers for this interest in domestic energy generation technologies, including concerns about climate change, energy security and fuel poverty[2]. Micro-generation may also help to stimulate competition in energy markets through the development of new energy services for the household sector (e.g. DTI, 2005).

A number of studies have concluded that micro-generation could provide a significant share of the UK's energy (Energy Saving Trust, Econnect et al., 2005). At present, the deployment of micro-generation technologies remains at a very early stage. Domestic micro-generation will have to attract investments from both suppliers and consumers or homeowners to fulfil its potential. Therefore, these investments are likely to require a range of different approaches to deployment.

This paper draws on ongoing work within the ESRC's funded STP project 'Unlocking the Power House' that is investigating three micro-generation technologies: micro combined heat and power production (CHP), micro wind and PV. The paper explores the economics of three deployment models for investments in these technologies (Watson, 2004). These models are 'Plug & Play', 'Company Control' and 'Community Microgrid'. The main difference between them is the roles they assume for householders and energy suppliers.

As well as analysing the economic performance of micro-generation using these models, the paper examines how policy and regulatory changes could improve payback times. Whilst economic payback is not the only factor that influences micro-generation investment decisions, the evidence shows that economic barriers are amongst the most important impediments for consumers and energy suppliers (Energy Saving Trust, Econnect et al., 2005).

While the authors have tried to be as accurate as possible in their analysis, the results depend on the interpretation of a complex set of variables, and on the potential impact of a range of policy and regulatory measures. These results are therefore indicative, and readers should treat them with some care. This working paper presents work in progress and is the basis for a series of interviews with relevant actors from industry, policy and NGOs. The authors welcome feedback on the underlying assumptions behind this analysis and how to further improve the results.

The paper is structured as follows. After an outline of the analytical methods used, the paper will provide an overview of the different deployment models considered in the research project and their underlying rationale. Section 4 will explain the different micro-generation technologies, including their generation, import and export profiles, alongside different domestic load profiles. Section 5 will provide a detailed analysis of the potential value of micro-generated electricity in the existing UK electricity system, possible sales arrangements as well as existing and potential support policies. Section 6 will relate this back to the

[2] In the UK "a household is defined as being in fuel poverty where it would need to spend more than 10 per cent of its income on energy to maintain a satisfactorily warm home" (Ofgem, 2005b). Although fuel-poor households in the UK fell from 5.5 million in 1996 to 2.25 million in 2002 due to improved incomes and falling energy costs, fuel poverty might rise again with recent energy price increases.

deployment models. Section 7 will provide the results of the spreadsheet-based calculations. The paper will then conclude with policy and regulatory implications.

2 Methods

The paper analyses the economics of the different deployment models using a spreadsheet tool. It calculates payback times for investments in micro-generation and tests the impacts of policy and regulatory changes.

The calculations are based on a range of domestic electricity and heat demand profiles and output data for the three technologies of interest. Measured PV output data and electricity demand data from the DTI PV Field Trial in Havant has been used[3]. Due to the novelty of micro wind and micro-CHP, new modelling results were used to simulate half-hourly electricity generation from these technologies. A micro wind model developed within the project using real UK wind data and considering wind conditions in the built environment provides micro wind output data (Myers, Bahaj et al., forthcoming). Furthermore a thermal building model was used to simulate electrical output from a micro-CHP unit every 5 minutes. Different building types and standards and their thermal loads were used to test how these factors might influence micro-CHP performance[4].

Taken together, these model outputs and the measured Havant data provide half-hourly consumption, output, import and export data for each technology. These data are then used in the main economic spreadsheet tool along with assumptions about energy prices, policy incentives and so on to generate payback times. Further details of the data and assumptions used can be found in section 4 of this working paper.

3 Different deployment models for micro-generation

The use of different deployment models for micro-generation technologies may increase the economic (and social) attractiveness of micro-generation, depending on the investors' preferences and the regulatory and institutional framework (Watson, 2004).

Three alternative models for deployment have been developed for this task which suggest a wide range of consumer and energy supplier roles. They represent three rather 'extreme models' in terms of the consumer-supplier relationship, and the role each side might play. Consumer involvement ranges from a passive role to a 'co-provision' role (van Vliet, 2004). The former role does not imply substantial changes in behaviour as a result of having micro-generation installed in the home. The latter sees consumers as becoming more active participants in the electricity system.

The 'Plug and Play' model is inspired by the idea that micro-generation might allow consumers to become partly independent of conventional energy suppliers. Consequently the consumer takes the initiative to purchase, install and operate the unit. The micro-generation unit is owned and financed by the homeowner. Within this model, consumers might change their consumption pattern due to higher awareness on energy issues gained during the purchasing and installation process or for economic reasons in response to the reward mechanism: they might choose to maximise their revenue through exporting as much

[3] For further details see: http://www.energy.soton.ac.uk/research/Havant.html
[4] For the thermal modelling TRNSYS software was used.

electricity as possible into the grid under a scheme of attractive export rewards, or they could choose to maximise their on-site consumption, particularly if export rewards are low (i.e. they reduce their electricity bill through lower consumption of imported electricity). Technically this leads to the requirement of an import-export or additional generation meter – possibly read remotely. This could also include HH data collection linked to time of day pricing.

The 'Company Control' model is based on the notion that companies might use fleets of micro-generators as a substitute for central power generation – i.e. as a virtual power plant[5]. As opposed to 'Plug & Play' under this approach an energy service company (ESCO) or traditional energy utility is the driving force for the micro-generation installation and provides the upfront capital. The micro-generation unit is operated according to the company's needs so as to help balance supply and demand, and to avoid buying electricity from the wholesale market[6]. The needs of the consumer – particularly for hot water and heating in the case of micro-CHP – must also be taken into account to some extent. Technically this model requires real-time remote control over the unit involving a multifunction meter with information about the operation mode (import, export) and a facility to send control signals to the micro-generator to optimise the supply-demand balance.

In the third model, consumers and institutions at the regional or local level in a particular geographical area decide to pool their resources to develop a 'Community Microgrid'. The 'Community Microgrid' model could be set up by the local community and consumers to provide the energy services required as suggested elsewhere (Devine-Wright, 2004). Consumers may buy shares of the (newly established) local supply company that owns or rents the local grid which it uses to directly supply its customers with micro-generated electricity. Consumers are willing to actively support the use of their unit for the supply-demand balance within this microgrid – potentially through lifestyle changes (e.g. accepting lower indoor temperatures if there is oversupply in the grid and micro-CHP output has to be reduced). Their incentive to do this stems partly from the fact that they may own shares of the community energy company. Technically it has similar implications as 'Company Control'. Since the quantification of costs related to this deployment model is very difficult, it is only treated in a qualitative way and inputs for a more detailed analysis of this approach are very welcome.

Table 1 summarises the three deployment models distinguishing between social, economic and technical characteristics. The following sections will explore the economic dimension of these deployment models.

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[5] 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: http://www.cogen.org/projects/vfcpp.htm.

[6] The function to dispatch (start-stop) the micro-generator depends on the technology: while micro-CHP linked to sufficient hot water storage has a certain operational flexibility within the domestic heat demand, PV and micro wind depend on the weather conditions.

Table 1: Three deployment models for micro-generation

	Plug and Play	Company Control	Community Microgrid
A) SOCIAL			
Agency	Consumer	Company Energy supplier	Community energy company
Ownership	Consumer Homeowner	Energy Supplier (potential ownership shift to customer at the end of financing contract)	Community Energy Company (with private wire network) owned by community / citizens
Consumer Involvement	Consumer may adjust behaviour depending on income structure	Passive consumer, but provides 'site' for micro-generation unit	Consumer possibly adjusts behaviour. May have financial stake in energy company
B) ECONOMIC			
Up-front financing	Cash; Bank loan; Credit card.	*Company:* Balance sheet Upfront customer payment *Customer:* Upfront payment; Lease payments; Contracting (micro-CHP).	*Company:* Balance Sheet *Customer:* Lease payments; Premium energy price.
Income for micro-generation owner	Avoided power import; Generation reward; Export reword.	Generated electricity at system buy price; Avoided grid losses; Embedded benefits.	Retail price for micro-generation electricity since direct supply via private wires
Implications for			
Consumers		No up-front costs and energy service contract	No up-front costs, energy service contract and potentially influence on company strategy
Energy Supplier	Loss of sales; Potential new market for home energy services.	Avoidance of buying wholesale electricity and lower grid losses;	Direct supply of micro-generation electricity to customers via private network.
DNO	Loss in income from system of usage charges	Loss in income from system of usage charges	n.a.
C) TECHNICAL			
Operation *micro-CHP*	On-site balance according to domestic heat demand	System balance as additional component to on-site balance	Shared operational interest
PV, micro wind	Weather dependent	Weather dependent	Weather dependent
Metering, Communication & Control	Import-Export meter - possibly read remotely. Possibly consumer access to time of day pricing information	Remote multifunction meter; facility for control signals to micro-generator. Integration into company balancing systems.	Import-Export meter - possibly read remotely. Facility for control signals. Consumer access to time of day pricing info

Source: based on Sauter and Watson (forthcoming)

4 Domestic micro-generation technologies and electricity consumption

Three domestic micro-generation technologies are covered in this working paper: micro-CHP, PV and micro wind. This section will briefly explain the three technologies, their estimated installation costs and how their electricity output matches different domestic consumption levels and patterns. It first explains the data used for the analysis in this paper.

4.1 Data and assumptions

Domestic electricity consumption data were from field trials for 4 different households with an annual consumption of around 2800 kWh (unit 7), 3700 kWh (unit 6), 6000 kWh (unit 5) and 7000 kWh (unit 4). Furthermore one generic UK consumption profile based on ELEXON data with an annual consumption of around 3900 kWh was used.

PV output data were also used from the above field trials for three units with an installed capacity of 1.5 kW_p – typical for a domestic installation. Two of them are south facing (unit 5 and 6) with an annual output of around 1300 kWh, one array is west facing (unit 7) with an annual output of around 850 kWh. For these units output, import and export were measured. For the other consumption profiles (unit 4 and ELEXON) a generic PV output profile with an annual output of around 1300 kWh was used.

The micro CHP modelling is based on the assumption of a nominal electric capacity of 0.85 kW (and a nominal thermal capacity of 6 kW) and a maximum electric capacity of 1.2 kW (and 8 kW thermal). Heat generation between 0 and 6 kW generates a scaled electric output of up to 850 W electric, heat generation between 6 and 8 kW a scaled output of up to 1.2 kW electric and heat generation between 8 kW and 12 kW generates 1.2 kW electric output. The thermal efficiency is 85% as compared to a condensing boiler of 92%. The heat to power ratio was 7.

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^2K, glazing u-value of 6.3 W/m^2K), b) poor building, poor double glazing (wall u-value of 1.8 W/m^2K, glazing u-value of 2.8 W/m^2K) and c) part L building, part L glazing (wall u-value of 0.4 W/m^2K, glazing u-value of 1.8 W/m^2K). Additionally, separate electricity output profiles were generated for whether occupants are at home or at work during the day, and for the building's location (London or Aberdeen).

These generic building types were combined with the electricity demand data for unit 5, 6 and 7 to model the heat requirement and calculate on-site consumption, import and export. The potential influence of the building type on the electricity demand could therefore not be considered. At this stage, it is not clear how big this influence might be. Further work within the project will be carried out to investigate the consistency of this approach. As a first step, the results in this working paper only include combinations of electricity demand and building type that are broadly consistent with each other – i.e. they both assume that occupants are at work or at home during the day.

For a high demand of above 30,000 kWh for a 4 bed detached house (poorly insulated) the power output would be around 4,000 kWh. The lowest heat demand of around 6000 kWh occurs in a 2 bed part L compliant bungalow with an electricity generation of below 1,000 kWh. For a heat demand of 16,500 kWh around 2,200 kWh of electricity is generated.

Micro wind data were calculated for different wind sites comparing three different power curves. Both curve 1 and 2 are based on a 1 kW device, where curve 1 is more conservative as compared to curve 2. Curve 3 represents a possible performance of a 1.5 kW device. This power curves are combined with real-wind data from different UK sites where the data are corrected to close to 7 m above ground level as it might apply for most roof mounted micro wind turbines. The corrected average wind speed for the urban environment varies between 2.66 m/s and 4.09 m/s. Annual electricity generation is therefore quite different. In our modelling a 1 kW device (under optimistic assumptions) will hardly achieve an annual electricity output of more than 1,000 kWh (site: Aberdeen) and can be as low as 100 kWh (site: Coombe 2). A 1.5 kW device can achieve an annual electricity output of around 1,700 kWh (site: Aberdeen).

Total installation costs were set at £9,000 for a 1.5 kW domestic PV system, £3,000 for micro CHP unit and £1,500 for a 1 kW micro wind turbine. The upfront costs for a company (including a bulk purchase discount of 30% and costs of £50 for an import-export meter) were assumed to be around £6,300 for PV, £2,100 for micro CHP and £1,100 for micro wind.

The current electricity retail tariff for households was assumed to be £0.08/kWh. In view of recent and expected price rises, the effects of an increased import tariff of £0.12/kWh on payback times under 'Plug & Play' were also tested. Costs for gas for the contractor of micro CHP unit was set at £0.01/kWh. Where households bear the costs for gas, no higher gas consumption for micro CHP was considered since it was assumed that consumption would be equal or less than in the existing boiler and only slightly higher that in a new condensing boiler. Operation and maintenance costs were not included in the calculations due to high uncertainty. It is possible that future costs for inverter replacement in the case of micro wind and PV could be significant. For micro-CHP, it has been claimed that maintenance costs would be similar to those for current boiler service contracts. However, it is too early to tell whether this will be the case. The ROC value was set at a rather conservative level of £39.[7]

4.2 Domestic micro-generation technologies

All three domestic micro-generation technologies are expected to have lower carbon emissions than existing centralised generation technologies. Micro wind and photovoltaic (PV) are renewable energy technologies and do not emit any emissions when generating electricity. Natural gas based micro combined heat and power production (micro-CHP) is also expected to emit lower CO_2 emissions than central power plants due to a higher overall efficiency through the concurrent production of heat and electricity and avoided transmission losses.

While the electrical output from micro wind and PV depends on wind and solar irradiation respectively, micro-CHP is heat driven and its output depends on the domestic heat demand. Certain flexibility in micro-CHP's electrical output can be achieved through the use of a hot water tank as a storage facility.

[7] This was the ROC auction price under 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.

PV is a well-established technology and its performance in terms of electricity output throughout the year well known. Both micro-CHP and micro wind are new technologies and still in the latter stages of demonstration and commercialisation. Within this paper, assumptions about their performance in terms of electricity and heat output as well as carbon savings relies predominantly on modelling results.

Early results on CO_2 savings from micro CHP from field trials run by the Carbon Trust show, however, ambiguous results. They indicate that carbon emissions from micro-CHP depend on the operating environment. A more continuous thermal load reduces emissions from micro-CHP (The Carbon Trust, 2005). This effect plays a marginal role in the thermal modelling in this paper 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. Different assumptions about the CO_2 emissions for imported electricity from the grid are used: first, for the average UK grid supply mix (0.43 kg/kWh), second, for a very efficient CCGT (58% efficiency) (0.32 kg/kWh) and finally for a coal plant (0.85 kg/kWh). If micro CHP replaces electricity from CCGT CO_2 emissions are around 10% lower, for the UK grid supply mix the savings are around 15% and for coal around 30%.

Electricity output from heat driven domestic micro-CHP is determined by the domestic heat demand that varies considerably depending on the building type, building standard and location of the house. Figure 1 shows different heat demands of buildings that were modelled and their related annual power output.

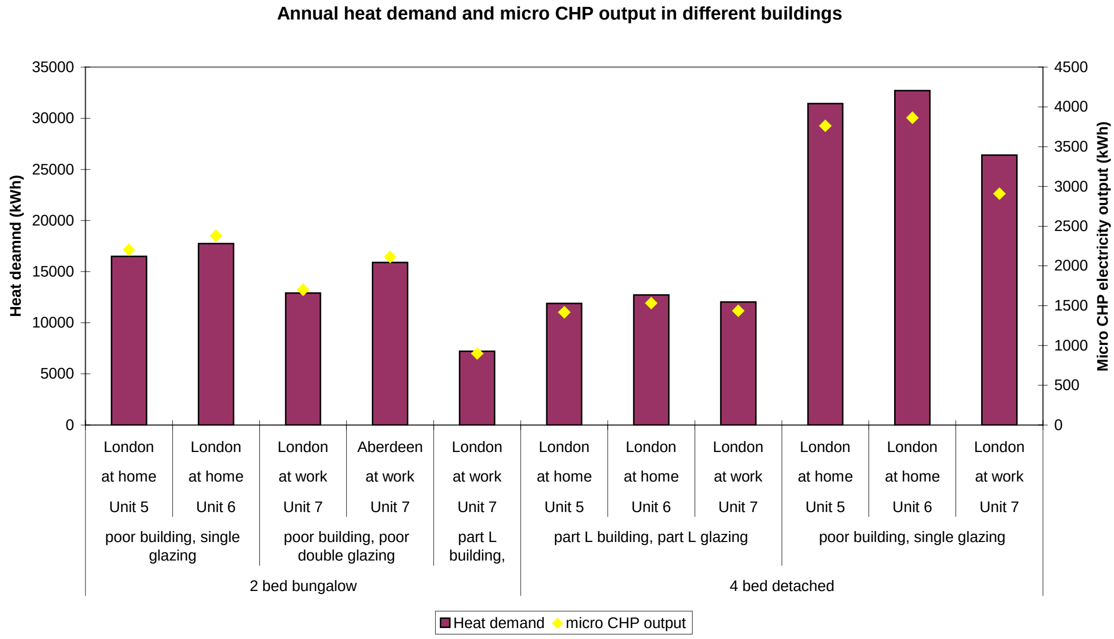

Figure 1: Annual heat demand and micro CHP output in different buildings

Figure 2 shows the influence of the annual heat demand on the electricity output of a heat driven domestic micro CHP unit for a winter day. While the annual heat demand 1 of around 18,500 kWh in a poorly insulated building leads to an annual electricity output of around

2,500 kWh, annual heat demand 2 of around 12,500 kWh in a better insulated building where occupants are at work during the day results in annual electricity output of around 1,700 kWh. It shows also the influence of the electricity consumption on the demand for heat. Heat demand 1 is lower than heat demand 2 in the evening since demand 1 is offset by a high electricity consumption that generates significant amounts of heat.

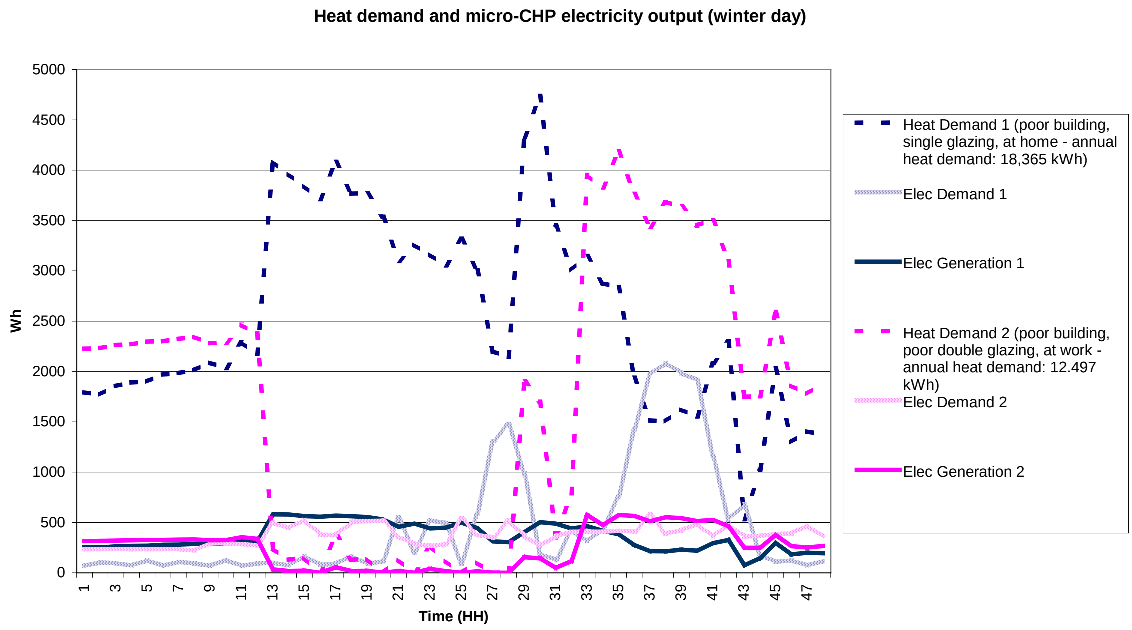

Figure 2: Heat demand and micro CHP electricity output (winter day)

For micro wind the most important factors for the electricity output are the assumed power curve and the wind site chosen. Figure 3 shows the electricity output for a day in autumn comparing three different power curves for two different wind sites. Both curve 1 and 2 are based on a 1 kW device, where curve 1 is more conservative as compared to curve 2. Curve 3 represents a possible performance of a 1.5 kW device.

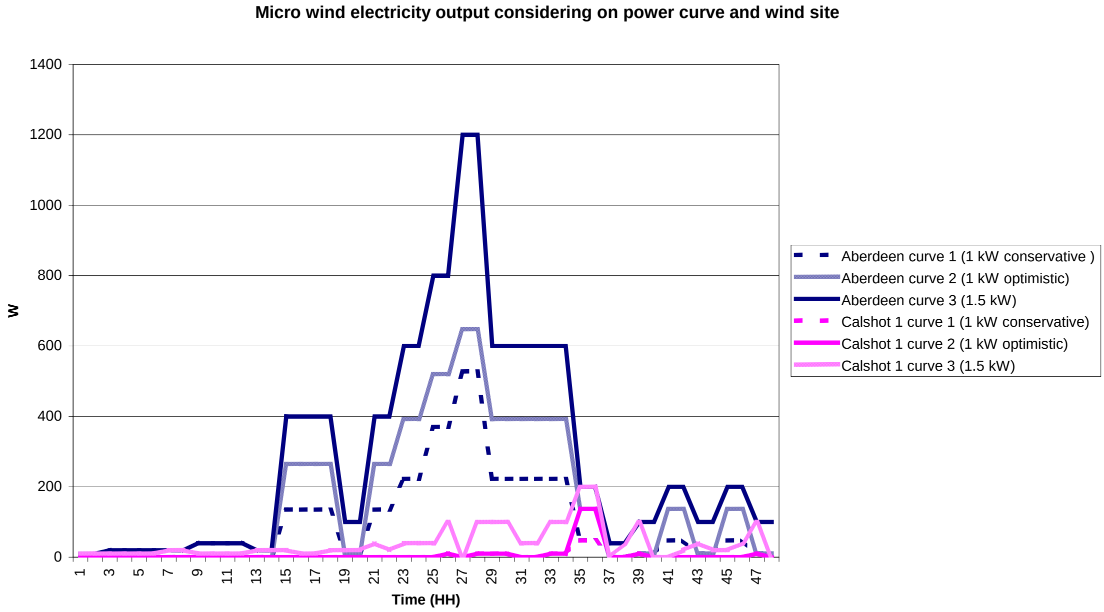

Figure 3: Micro wind electricity output for different power curves and sites

The annual output varies between around 130 kWh and 950 kWh for an optimistic 1 kW turbine and between 420 kWh and 1,700 kWh for a 1.5 kW turbine (see Figure 4).

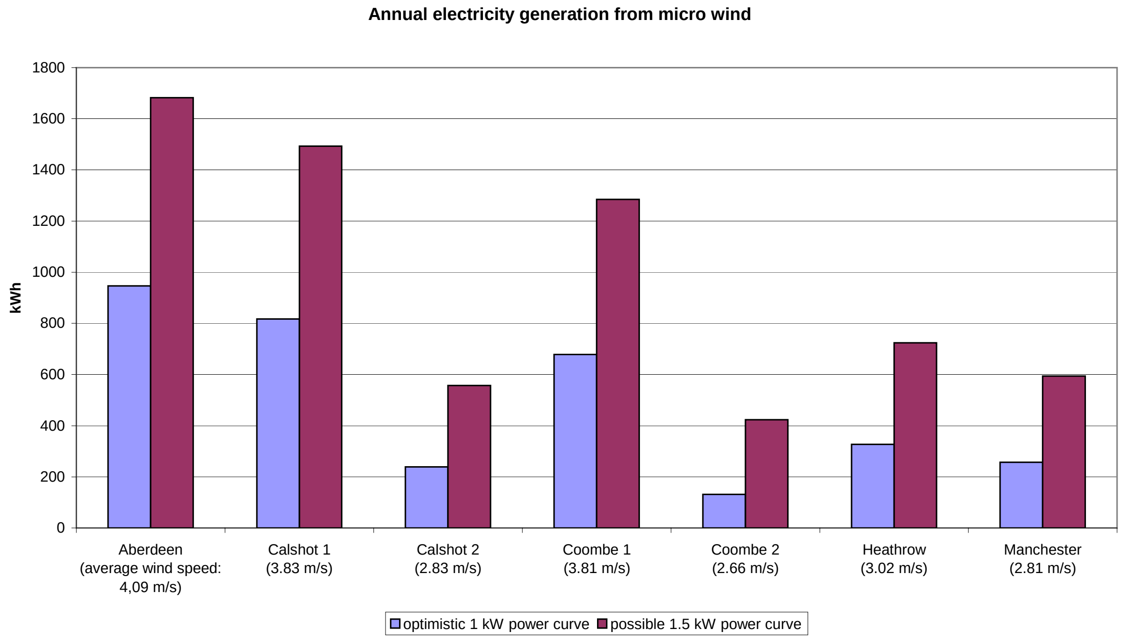

Figure 4: Annual electricity output from micro wind

PV output depends on the solar irradiation and the alignment of the array installed. Figure 5 shows two typical south facing PV outputs with peak output midday where the west facing array generates a slightly lower output and later in the day.

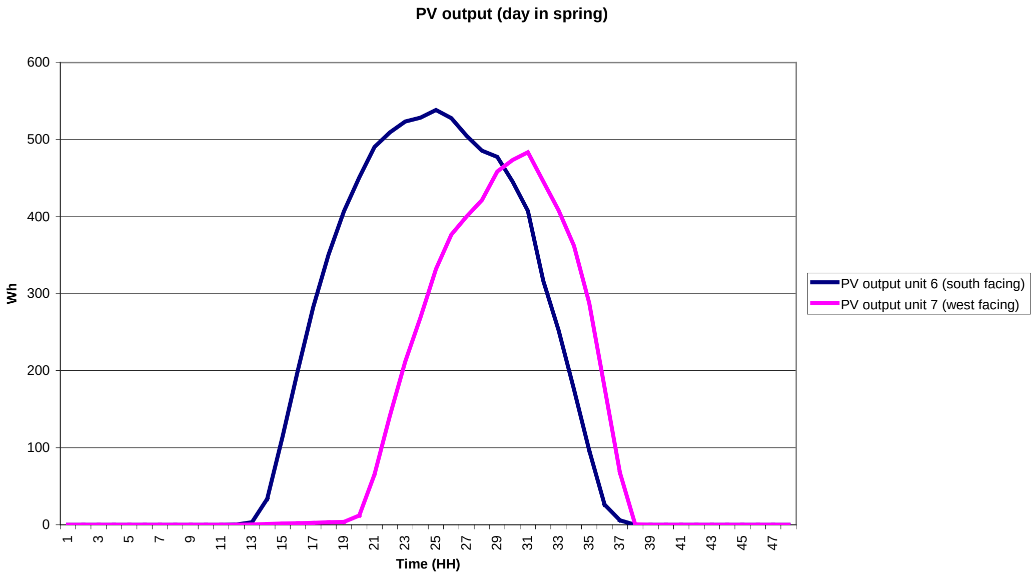

Figure 5: PV output (spring day)

4.3 On-site consumption, import and export

A central issue for the economic performance of domestic micro-generation – particularly if households purchase a micro-generation unit under current conditions – is to what extent the output matches domestic load, i.e. how much of the electricity produced is used on-site, how much electricity still needs to be imported from the grid and how much is exported to the grid.

These parameters depend on the electricity output and the consumption pattern. The output of all three micro-generation technologies is influenced by the weather – solar irradiation for PV, wind speed for micro wind and temperatures for micro-CHP. The micro-CHP output is also influenced by the heating requirement in the home which depends on the heat comfort level, the number of occupants as well as the building type and standard. The electricity consumption also depends on the occupancy, lifestyle and domestic technical appliances used in the household.

Micro CHP output and how it compares to a domestic electricity demand is shown in Figure 6. During periods of peak demand, electricity has to be imported while during low electricity demand surplus power is exported to the grid.

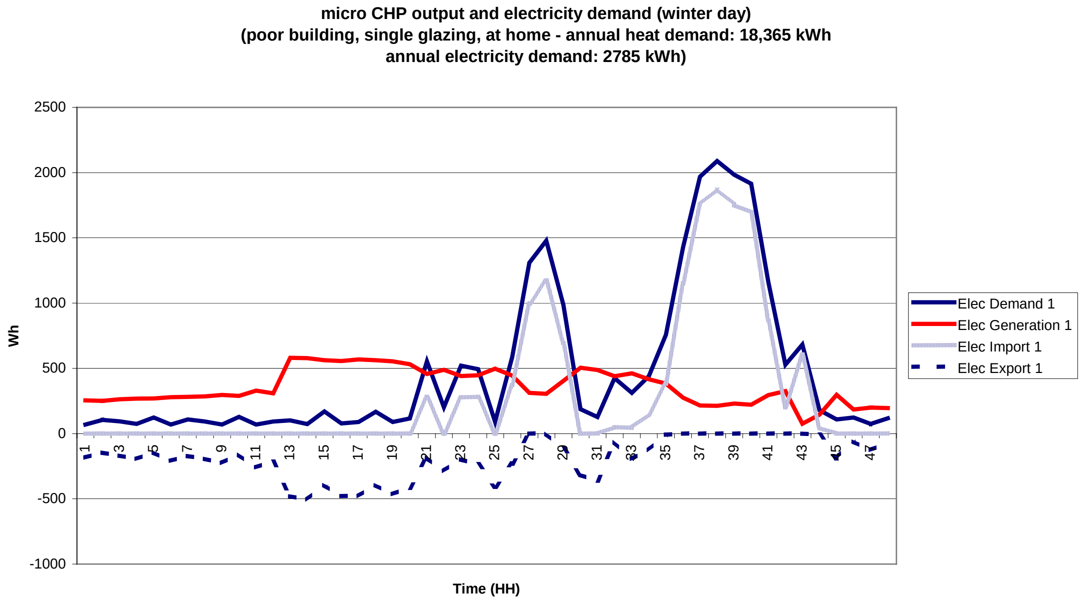

Figure 6: Micro CHP output and electricity demand (winter day)

In the case of wind power the output will in general be lower than the domestic demand as shown in Figure 7. Therefore more power will be consumed on-site, thereby avoiding electricity imports.

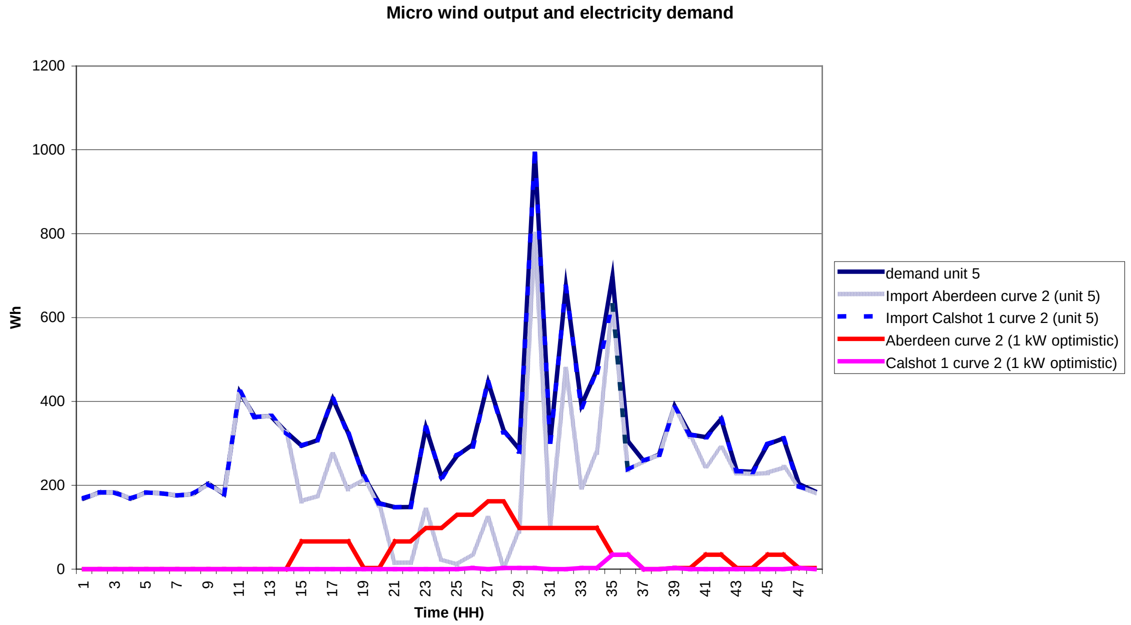

Figure 7: Micro wind output and electricity demand

Figure 8 shows a daily PV output in spring as compared to domestic electricity demand and the associated imports and exports.

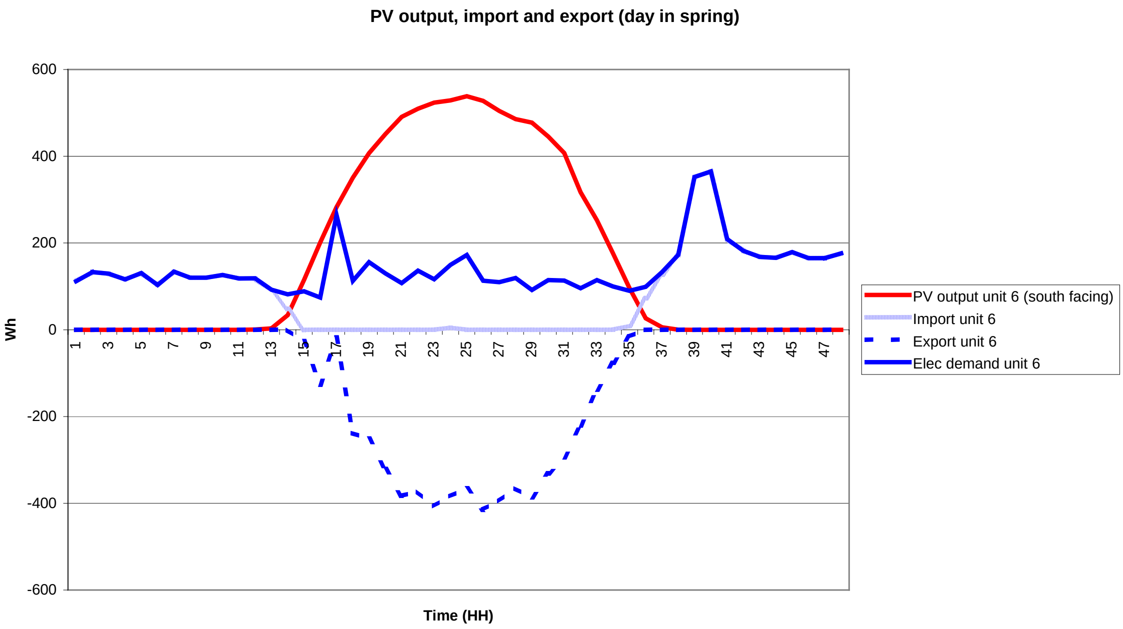

Figure 8: PV output, import and export (day in spring)

This section has shown the potential contribution of different micro-generation technologies to the domestic electricity supply and the influence of consumption patterns with respect to the generation/on-site consumption ratio. The central factors in the economic analysis of the micro-generation deployment models are the available income streams for micro-generated electricity, and the associated balance of exports and imports.

5 Micro-generation in the UK market and policy framework

The income from a micro-generation unit to the owner might be quite different to the value of micro-generated power for the electricity system. The value of micro-generation includes the value of the electricity generated and the value that stems from its location within the system. The latter component of the value comprises embedded benefits such as avoided losses and the avoided or reduced usage of the transmission and distribution network. The extent to which this ‘systemic value’ is actually rewarded and ‘passed through’ to the owner of the unit is influenced by the settlement system and the regulatory framework as well as the contractual arrangement used to sell the electricity. In addition to that systemic value, additional income for micro-generation owners could come from support policies.

This section draws partially on recent previous studies dealing with the value of micro-generated electricity in the UK (DGCG Technical Steering Group, 2004; ILEX Energy Consulting, 2005a; ILEX Energy Consulting, 2005b; Power Planning Associates Ltd, 2005; SOHN Associates, 2005). Section 5.1 explores the value of micro-generation to the electricity system by focusing on its individual components. Section 5.2 considers different income arrangements for micro-generated electricity. Section 5.3 explores current and possible future support policies that provide additional income.

5.1 The value of micro-generated power in the existing UK electricity system

5.1.1 Wholesale market value

The British Electricity Trading and Transmission Arrangements (BETTA) introduced on 1 April 2005 set the rules for the British energy market. Licensed suppliers have to participate in BETTA and comply with the arrangements in the Balancing and Settlement Code (BSC). Under BETTA market participants have to submit forecasts of the production and demand an hour in advance. Unpredictability of power output reduces the value of the output at the wholesale market level (e.g. this affects the value of wind power output). The electricity wholesale market is volatile and prices vary with time of day (peak / off-peak) and season (higher wholesale prices during winter).

The wholesale market price is the reference price for contracts on electricity output. Micro-generation units have to comply with the BSC to get access to wholesale prices. Currently, the UK balancing and settlement system is not prepared for the inclusion of micro-generated electricity. Exports are only ‘spilled’ into the distribution network and are not included within wholesale market balancing.

To help explore the consequences of micro-generation exports in the settlement system, the modelling in this paper allows for the inclusion of System Buy Prices for micro-generation output and exports. It does so in two ways – on a half hourly basis and as the annual average for 2005. The average SBP for 2005 was relatively high at £42/MWh. The extent to which a micro-generator will actually have access to SBP will depend on the predictability of its output.

5.1.2 Embedded benefits

Due to its embedded character micro-generation is likely to reduce the costs for grid operation and maintenance (Mott MacDonald, 2004). Suppliers that make contracts for distributed generation profit from these benefits in terms of reduced grid charges that are levied according to their grid usage. The details of these charges are summarised in other reports (ILEX Energy Consulting, 2005a; ILEX Energy Consulting, 2005b; SOHN Associates, 2005), and only a summary of key issues is given here.

At the transmission network level micro-generation reduces the supplier’s demand on the transmission network and therefore the Balancing Services Use of System charges (BSUoS). BSUoS vary on a half-hourly basis, but were on average 0.06 p/kWh in the financial year 2004/05 and are expected to be stable over the next years (ILEX Energy Consulting, 2005b; SOHN Associates, 2005).[8] Additionally Transmission Network Usage of System (TNUoS) charges are levied on generators and suppliers for maintaining and building the transmission network. Micro-generators are exempt from this charge due to their capacity of less than 100 MW and no direct entry point to the transmission system. Suppliers’ TNUoS charges are reduced since the contracted micro-generation output is netted off of their supply volume in the settlement process[9]. Demand TNUoS charges depend on the UK network area. They vary between 0.97 p/kWh and 2.73 p/kWh with an average value of around 2 p/kWh in England

[8] The so called Residual Cashflow Reallocation Cashflow is not considered here since its (dis-)benefit to embedded generation varies annually and very small.
[9] If within the same Grid Supply Point (GSP)

and Wales for non half-hourly metered generation. For non-half hourly customers TNUoS demand charges are calculated on the basis of the consumption at peak times between 16:00 and 19:00. Therefore the TNUoS benefit depend on the micro-generation output at these peak times.

In the distribution network, Distribution Network Usage of System (DUoS) charges are levied. A supplier's payments to the DNO consist of the electricity consumed (DUoS charge per kWh consumed) and a fixed charge per Meter Point Administration Number (MPAN) per day. A domestic micro-generator where micro-generated electricity is consumed on-site reduces therefore a supplier's use of system charges (less units transported through the DNO). Assuming that fixed charges account for around half of the total DUoS payments, a supplier will reduce its DUoS payments by half for each unit of avoided import (DGCG Technical Steering Group, 2004). DUoS charges vary between distribution networks. In this paper an average DUoS charge of 1p/kWh is assumed.

Due to its embedded location in the electricity system, domestic micro-generation avoids losses within the transmission and distribution networks. Normally losses are recovered by scaling down the metered output of generators and scaling up the electricity imported by suppliers[10]. An embedded micro-generator avoids both the scaling up and down and therefore increases the value of the output by the loss factor. It reduces suppliers' procurement of loss-adjusted energy. Losses are quite different among UK regions. It is between 1.5% and 2% in the transmission network and around 6.5% in the UK distribution networks[11]. In the spreadsheet calculations the output of a micro-generation unit therefore is scaled up by 2% whereas micro-generated electricity consumed on-site is scaled up by 8%. This up-scaling is also considered for the calculation of the DUoS, TNUoS and BSUoS benefits.

The embedded benefits (summarised in table 3 below) constitute savings for the supplier which contracts for the output from (but does not necessarily own) the micro-generator. For the owner of the micro-generation unit who has contracted the generation output or exports to a supplier, it is crucial to what extent these embedded benefits are passed through.

5.2 Income arrangements for micro-generated electricity

This section explores different income arrangements available for the sale of micro-generated electricity under current UK electricity market regulations.

5.2.1 On Site Generation

On-site generation is the most straightforward arrangement for micro-generation where the micro-generated electricity (or a share of it) is consumed on-site. Thus the usage of the distribution and transmission network is avoided and the value is the price that would have to be paid for the imported electricity. The avoided import price can depend on the households' electricity consumption due to the tariff structures used by some energy suppliers. In some cases, a higher unit rate is charged for initial units in lieu of a standing charge, with additional units being charged at a lower rate. The model used in this project includes a facility to include two level tariffs of this type.

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[10] Ofgem: "Charges and Embedded Benefits", http://www.ofgem.gov.uk/ofgem/shared/template2.jsp?id=843, 02/02/2006

[11] Ofgem: "Electricity Distribution Losses", http://www.ofgem.gov.uk/ofgem/shared/template2.jsp?id=9990, 25/11/2005

5.2.2 Supplier contract

Under this arrangement the micro-generation owner makes a contract with a licensed supplier or consolidator that purchases the overall micro-generation output or only the export. If settlement and industry standards were changed, the supplier may use the micro-generation output to comply with system balancing requirements or sell it in the wholesale market. Owners of micro-generation units may get the System Buy Price (SBP) for the output of their unit or the part of the output that is exported to the grid. For the latter case, they would also receive income from avoided electricity imports.

5.2.3 Licensed supplier

A licensed supplier may also use micro-generation as part of their supply portfolio.

5.2.4 Trading

At present, the output of a single micro-generation unit is too small to be traded at the wholesale market since transaction costs are too high. Only the pooled output of many micro-generation units might achieve the necessary threshold to make this an economic option. The combination of several micro-generation units and different technologies would not only provide the critical mass to be submitted to the wholesale market system. This can also lower the economic risk that the target output is not met due to intermittent generators such as PV and wind. Consolidators may offer this pooling service. They buy the generation output of micro-generation units which they will then offer at the wholesale trading market. Administrative costs may however be prohibitive to consolidate micro-generators' output unless there are more than a certain number of micro-generators installed.

5.2.5 Private Networks

Instead of using the public distribution network micro-generation units could be connected to a private network. This would avoid 'Use of System' charges, but such an arrangement would need to be weighed up against up-front and running costs for a private network.

In the case of private or community networks for micro-generation, it is more likely that the local network is hired or leased by a local supplier pooling several thousands of micro-generation units to supply its local customers. While this would save system charges it would require compliance with the BSC and the provision of ancillary services.

As regards the spreadsheet modelling, the main difficulty lies in the quantification of the costs for the leasing or development of a local network as well as the costs for the compliance with the BSC and the provision of ancillary services. This possibility is therefore only treated in a qualitative way in this paper.

5.3 Support policies

Support policies help to build a market for new technologies that have to overcome initial barriers such as high costs (lack of economies of scale), immaturity, consumer mistrust in technological innovations or non-internalised external costs (e.g. from carbon emissions). Current and potential support policies in place for micro-generation technologies in the UK can be distinguished between: market based instruments (e.g. the Renewables Obligation), fiscal measures (e.g. Levy Exemption Certificates, reduced VAT and tax allowances), capital grants and regulations (e.g. the Energy Efficiency Commitment).

5.3.1 Renewable Obligation Certificates (ROC)

The Renewables Obligation (RO) was introduced in April 2002 and obliges electricity suppliers in the UK to prove that a certain share of their electricity is generated from renewable energy sources. The share is increasing annually from 3% in 2002/03 to 15.4% in 2015/16.[12] ROCs are available for electricity generated from renewable energy sources but not for electricity from micro-CHP. The minimum electricity generation is 500 kWh per year. The amount generated is then rounded up or down to the next full MWh.

Suppliers can fulfil their obligation in three ways (Smith and Watson, 2002): by producing ROCs from generated or bought electricity from accredited renewable electricity generators, second, by buying ROCs on the ROC market from other suppliers selling them, or by paying the ‘buyout price’ (currently at 3.2p/kWh) if they cannot meet the target. The buyout fund is every year recycled to certificate holders. In October 2005 ROCs were traded at £39 which is their lowest level since the first auction in October 2002 when their value was around £47. Since only electricity supplied by licensed suppliers to British customers is eligible for ROCs the private owner of a micro-generation unit needs to conclude a ‘sell and buy back’ contract with a licensed supplier. According to DTI’s final decision on the latest RO consultation – depending on the outcome of the legislative process – this will be changed from 1 April 2007 when private micro-generators should be able to claim ROCs directly.

To avoid administrative costs, an alternative to an annual payment to each individual household would be an upfront payment from an energy supplier in return for all future ROCs. The owner of the unit would receive a share of the value of future ROCs upfront for the lifetime of the plant, or for the period of the renewable obligation. The amount of money given to the householder is likely to be discounted to reflect the uncertainty of future ROC prices.

5.3.2 Levy Exemption Certificate (LEC)

Generators of electricity from renewable energy sources and Good Quality CHP that are exempted from the climate change levy (CCL) receive LECs for each MWh of power exported to the grid. The CCL was introduced in April 2001 as a tax on the use of energy in industry, commerce and the public sector to reduce carbon emissions. The levy is fixed at 0.43p/kWh for electricity. It does not apply to the domestic and transport sector. LECs enable suppliers to avoid the payment of CCL eligible supply if the renewable source electricity and Good Quality CHP output is supplied to non-domestic customers. Under existing regulation it is therefore only relevant to the ‘Company Control’ deployment model.

5.3.3 Reduced VAT

For the three micro-generation technologies considered in this paper a reduced VAT rate of 5% instead of 17.5% is applicable.

[12] The initial RO set a target only until 2010/11 but was extended until 2015/16 on April 2005.

5.3.4 *Tax allowances*

Companies investing in certain energy efficiency measures have access to enhanced capital allowances (ECA). This means that they can write off 100% of their investment in certain energy efficiency measures against their taxable profits in the year of investment. Since main corporate tax in the UK companies is 30%[13] this means that investment costs are typically reduced by this percentage. At present, company investments in micro-generation technologies are not eligible for ECA, but only for a standard capital allowance of 25% over several years. Our calculations show how access to ECA would improve payback times for these investments. Investments by householders in energy efficiency or micro-generation are not eligible for tax allowances (Chesshire, 2003). In fact, there is some suggestion that electricity exports from micro-generation that are sold to an energy supplier should *attract* tax at the prevailing rate.

Since it is possible to extend capital allowances to householders, the model includes a provision for this. Depending on a householder's marginal tax rate, the appropriate enhanced allowance for micro-generation investment can be set at the standard rate of 22%, the higher tax rate of 40% or another rate.

5.3.5 *Capital grants*

Capital grants are another incentive that is usually paid up-front and can depend on the total investment costs or the investment costs per kW installed. Some micro-generation technologies have been eligible for government grant schemes under schemes such as Clear Skies for a number of years. It is expected that from April 2006 grant support for some technologies will be available under the new Low Carbon Buildings Programme.

The option of ROC upfront payment mentioned above (see section 5.3.1) would have a similar impact to capital grants.

5.3.6 *Energy Efficiency Commitment (EEC)*

The first EEC scheme was introduced in 2002 and ran until 2005. This was followed by EEC II which runs from 2005 to 2008. EEC II imposes a domestic energy efficiency target of 130TWh shared by all UK energy suppliers. Ofgem set up a list of approved measures and calculates their discounted value of their lifetime energy savings. The suppliers are free to choose from this list to encourage households to invest in one of these energy efficiency measures (e.g. cavity wall insulation, energy saving light bulbs, energy efficient household appliances). Supplier costs associated with to EEC implementation can be recovered from customers' energy bills.

New in EEC II are 'Innovative Actions' that encourage suppliers to use new measures to achieve their target. Micro-CHP is included as innovative action. An innovative action contributes 50% more to the energy efficiency target than it would have done as a normal action. The share of innovative actions must, however, not exceed 10% of one supplier's EEC target (Ofgem, 2005a: 4).

[13] http://www.hmrc.gov.uk/rates/corp.htm

The EEC scheme is however not considered in the modelling results due to the difficulty of valuing micro-CHP as EEC-measure for a supplier as compared to other available measures. Feedback from the project interviews will be used to consider this support mechanism in the economic analysis.

5.4 Summary

The different components of the value of micro-generation for the energy system are summarised in Table 2. For the economic analysis it is important to distinguish between up-front and annual income. While up-front payments reduce effective installation costs, annual income is related to the performance of the micro-generation unit, e.g. its generation or exports. Future income therefore carries with it a certain amount of risk for the investor (e.g. no income in the case of the failure of the technology if the support is performance related). Table 3 therefore differentiates between up-front and annual incentives.

Table 2: Income related to micro-generated electricity

Income / incentive	Description
Up-front income / incentive	
Reduced VAT	5% instead of 17.5%
Tax allowances	Investment costs are written off against taxable income – dependent on tax rate and type of tax allowance (e.g. standard or ECA)
Capital grants	As a share of the installation costs or per kW installed
EEC*	Micro-CHP as possible 'innovative action' to fulfil suppliers' energy efficiency target
ROC (up-front)	Up-front payment of ROCs to micro-generation owner
Annual income	
ROC	Available for electricity generated from renewable energy sources. The minimum generation is 500 kWh per year. The amount generated is rounded up or down to next full MWh whatever is higher.
LEC	Businesses can be exempted from the climate change levy (CCL - a tax on the use of energy in industry, commerce and the public sector), if they use renewable electricity sources or good quality CHP.
Wholesale value / System Buy Price (SBP) (market price according to actual generation)	Average per unit generated *(or)* Real-time value (HH)
Embedded benefits	
BSUoS	Per unit generated
TNUoS	Avoided Triad charges (HH) Avoided demand charges per kWh generated (profiles)**
DuoS	Per unit consumed on-site
Avoided transmission losses	~ 1.5%
Avoided distribution losses	~ 6.5%

* Not included in modelling
** Calculated on the basis of avoided imports during peak times between 16:00 and 19:00 as defined for TNUoS charging calculation

6 Implications for different deployment models

For each of the three deployment models being considered, different sales arrangements are possible. Under 'Plug & Play' the owner of the micro-generation unit may contract the output to a supplier or consolidator. A minimum threshold of installed micro-generation units is likely to be necessary to ensure enough flexibility for consolidators to include micro-generation into their portfolio. Under 'Company Control' the micro-generation unit is owned by an energy company, which will use the micro-generation output as part of its supply portfolio, or by an energy service company (ESCO), which may sell to a supplier or consolidator. A Community Microgrid could be based on a private network used by a municipal or regional licensed supplier (see Table 3).

Table 3: Deployment models and sales arrangements

Plug & Play	**Company Control**	**Community Microgrid**
Supplier Contract Consolidator Contract	Licensed Supplier Trading [a)]	Private Network Trading [a)]

[a)] Minimum threshold of installed capacity / output.

6.1 Income streams

This sub-section identifies the income streams for each deployment model distinguishing between up-front and annual income. It considers both support policies that are already available and possible future support measures. The economic analysis will compare different policy frameworks, and conclude with some initial policy recommendations.

6.1.1 Plug & Play

Available income streams for the homeowner to recover the upfront costs are mainly avoided electricity imports through on-site consumption of micro-generated electricity, ROCs for PV and micro wind and potentially export rewards. The electricity retail price therefore has a central influence on the payback time under 'Plug & Play'.

Under current market conditions there is no suppliers' obligation to purchase electricity exports. Some suppliers may however offer export rewards as a way to attract new customers or establish a long-term customer relationship (see Box). The export rewards would pass through a proportion of the value of micro-generated electricity to the supplier (e.g. ROC, embedded benefits).

Box: Examples of existing offers for micro-generators in the UK

Powergen offers a micro-CHP unit for the purchase price of around £3,000 including installation to households. In addition to the avoided electricity import as income stream, the household gets an export credit for each unit of micro-generation electricity exported to the grid. This export credit is around 3.5 p/kWh exported depending on the tariff area. The payment of this export reward is however combined with a dual fuel supply contract with Powergen, i.e. only if the homeowner purchases gas and electricity from Powergen at the standard retail price will they be eligible for Powergen's micro-generation export reward.

Under **Good Energy**'s Home Generation contract Good Energy customers receive 4.5 p for each kWh generated from micro-renewables – whether it is consumed on site or exported to the grid. Micro-generators need to have an Ofgem approved generation meter, but do not need a settlement export meter. Generation data are read annually.

Table 4 summarises potential income streams for a micro-generator under the deployment model ‘Plug & Play’.

Table 4: Income from micro-generation under ‘Plug & Play’

Income criteria	Metering requirements	Income source	Value for micro-generation owner
Up-front income			
Installation costs		*Reduced VAT*	5% instead of 17.5%
Installation costs		*Tax allowance*	12%, 22% or 40% depending on income tax if ‘enhanced’ allowance in the year of investment
Installation costs		*Capital grants*	per kW installed or % of installation costs
Annual income			
Generation	Generation meter	*ROCs**	ROC*
Avoided import	Generation, import and export meter	*On-site consumption*	Import price
Export	Export meter	*Supplier contract / Settlement*	Export reward

* PV and micro wind only

Only some of these income streams may be available under certain contracts. In general the *annual* income for the micro-generation owner under ‘Plug & Play’ can be expressed as follows:

Annual income = G · ROC + AI · IT + EX · ER

where:

G: Generation
AI: Avoided import / on-site consumption
IT: Import tariff / retail price[14]
EX: Electricity exported to the grid
ER: Export reward

[14] As already discussed above the import tariff may depend on the electricity consumption under a block tariff structure. The model allows for the inclusion of a ‘First Block Unit Rate’.

6.1.2 Company Control

Income flows under this deployment model have to be distinguished between:

a) Up-front income / incentives (e.g. from capital allowances)
b) Income directly from the output of the micro-generation unit
c) Income from supply/service contracts with customers

a) Up-front income / incentives

Companies have access to enhanced capital allowances (ECAs) if they invest in certain energy efficiency measures such as good quality CHP or solar thermal systems. It is tested how this instrument would improve the economic performance of domestic micro-generation technologies under 'Company Control' as compared to standard capital allowance (SCA). Furthermore investment costs will be reduced due to reduced VAT and bulk purchase discounts for company orders that would effectively reduce technology costs.

b) Income directly from the output of the micro-generation unit

Under 'Company Control' all output from the micro-generation unit is valued at the system buy price (SBP) without distinction between avoided imports and exports. Embedded benefits[15] are scaled up by 2% for the transmission network and by 8% at the distribution level.

$$G \cdot (ROC + LEC) + G \cdot (TNUoS + BSUoS) \cdot 1.02 + G \cdot SBP \cdot 1.08 + AI \cdot DUoS \cdot 1.08$$

where:

G: Generation
SBP: System Buy Price
AI: Avoided import / on-site consumption

As outlined by the DGCG (2003) the current supply licence obligations require that the charges for 'goods and services' like for the provision of a micro-generation unit have to be separated from the charges related to the supply of electricity and gas[16]. This distinction also applies to the duration of the contract. While a contract on the supply of electricity and gas can be terminated within 28 days, the contract on 'goods and services' can be fixed for a longer duration to allow the company to recover its investment. This limits the number of possible energy service contracts where for example the up-front costs could be linked to the income from gas and electricity sales. We assume that the 28 day rule is not an issue[17], which allows for more flexibility in supply contracts.

[15] It is assumed that grid operator and supply company are not vertically integrated. In order to take into account of avoided DUoS charges metering must distinguish between output and avoided imports.
[16] Condition 42.5 of the Electricity Supply Standard Licence Conditions
[17] Ofgem is currently overseeing a trial suspension of the 28 day rule for a limited number of consumers.

c) Income from supply/service contracts with customers

A third income stream – in addition to up-front income/incentives and the income from micro-generation output – may arise from the customer contract:

1. *Supply contract (possibly linked to upfront payment)*: the customer continues to pay the standard retail price for electricity and gas consumed. The only source of income for the supplier would be from the micro-generator's output. This contract could however potentially linked to an upfront payment by the customer to support the installation of the micro-generation unit. The company might offer to freeze the import tariff for a certain period of time. No additional annual income will occur from the customer contract.[18]

2. *Leasing*: The customer will have access to a special micro-generation tariff for electricity that will be lower than the standard retail price, but pay a fixed lease payment for a fixed period of time (included in the spreadsheet on an annual basis). Thus the supplier will lose in lower income from electricity supplied:

   $C_{ELECTRICITY} \cdot (ITL_{ELECTRICITY} - IT_{ELECTRICITY}) + L$

3. *Contracting (for micro-CHP only)*: The customer pays for the electricity and heat consumed, but not for gas. Additional income will occur form the heat sold, but be reduced by the wholesale costs for the imported gas:

   $C_{HEAT} \cdot IT_{HEAT} - C_{GAS} \cdot WT_{GAS}$

Where:

IT: Import tariff – L for leasing; C for contracting
WT: Wholesale tariff
C: Consumption
L: Lease payment

Table 5 summarises income streams under 'Company Control' deployment arrangements.

[18] Although gas consumption in the case of micro-CHP will be slightly higher as compared to a new condensing boiler, additional income from higher gas consumption is not included since micro-CHP is likely to replace an older boiler with a higher gas consumption than micro-CHP.

Table 5: Income under ‘Company Control’

Income criteria	Metering requirements	Income source	Value for supplier
Upfront income / incentives			
Installation costs		*Reduced VAT*	5% instead of 17.5%
Installation costs		*Tax allowance*	*SCA* *ECA*: 30% (tax rate) of installation costs
Units ordered		*Bulk purchase disc.*	
Income from micro-generation		**Sales arrangement**	
Generation	Generation meter	*Licensed supplier*	ROC* LEC Avoided TNUoS charges** Avoided BSUoS charges (0.06 p/kWh)
		Settlement	SBP
Avoided import	Generation, import and export meter	*On-site consumption*	Avoided DUoS charges (1p/kWh)
Income from customer contract		***Customer contract***	
		Supply contract	Upfront payment
		Leasing	Lease payment
Heat consumption	Heat meter or calculated based on gas throughput	*Contracting*	Contracting heat tariff

* PV and micro wind only; ** depending on generation profile

The spreadsheet calculation considers the household perspective for ‘Company Control’ as well. It identifies saved upfront and annual costs as compared to a ‘Plug & Play’ model and allows for the calculation of income from the avoided capital outlay.

6.1.3 Community Microgrid

The main difficulty for the economic analysis of this model is the quantification of the costs of setting up and maintaining a private network, or the costs of gaining access to a third party private distribution grid.

This regional approach could also involve regional balancing markets combining different local grids. While the DUoS charges per kWh generated and supplied should be equal to zero since distribution losses are considerably reduced, fixed DUoS charges per consumer meter point (or MPAN) to run the distribution network may be similar to current ones. Due to the fact that electricity is consumed in a private grid where it is generated, the value of micro-generated electricity is equivalent to the retail price. This would lead to higher margins at normal retail prices, which could be used for the operation and maintenance of the local grid, and to cover additional costs linked to ancillary services (e.g. provision of reactive power, frequency response or reserve).

Citizens' involvement in this deployment model could take various forms such as buying shares and/or changing their energy consumption pattern. This could be achieved through special supply deals such as[19]:

- A share of the company provides access to a certain amount of electricity supplied at a discounted rate per year;
- Acceptance of behavioural / lifestyle changes to allow for best balancing conditions for the company (e.g. lower inside temperatures for a short period if the company has excess supply because heat-driven micro-CHP units' output has to be decreased).

Due to these uncertainties, it was not possible to quantify the core parameters for a full economic analysis. During the project interviews, some further discussions will be held to explore how this initial scoping of the key features of 'Community Microgrid' might be taken further.

6.2 Infrastructure costs

The access to some of the above-outlined benefits is, however, subject to additional data requirements about domestic generation and consumption as summarised in Table 6. In most cases this brings with it additional costs – both transaction costs and up-front costs.

Table 6: Functions and different data requirements

Function	Data Requirement
Payment and billing	Consumed units of energy
Export rewards (e.g. wholesale price)	Exported energy
Generation rewards (e.g. ROCs)	Generated units of energy
Real-time monitoring and control	Real-time load profile
Interaction between diverse DG units	Control over operational level of the micro-generation unit
Settlement	HH metering or profiles
New customer services (time of day pricing)	HH / multi rate metering

Source: based on Sauter, Watson et al., 2005

Transaction and additional up-front costs are basically linked to metering / profiling, communication, collection and aggregation and depend also on the underlying deployment models. The following paragraphs will briefly discuss these cost assumptions (Sauter, Watson et al., 2005).

[19] The supply contracts outlined for 'Company Control' are equally applicable to the 'Community Microgrid' approach for customers who might not be interested in getting more involved.

Metering

In order to have access to major income streams, most domestic meters installed measuring only imported units from the grid have to be replaced by meters being able to measure consumption, generation and export.

An import-export meter is expected to cost slightly more than a conventional import meter, i.e. £12 per installation as compared to £7. A half-hourly import, export and generation meter is expected to cost around £30 (Sauter, Watson et al., 2005: 13f). Total installation costs for a new import-export are expected to be around £50.

The replacement of existing meters may not only be strictly necessary for the installation of new micro-generation units. However, this is likely to be essential if better information is to be provided to consumers. This may, in turn, lead to behavioural changes and reduced consumption[20].

Communication

Assuming the usage of profiles for the settlement process it is unlikely that communication (i.e. meter reading) will have to change as compared to the current situation. If there was the requirement for half hourly metering reading or real-time control as in the case of company control, this could be based on a broadband Internet connection and therefore no additional costs would occur.

Settlement

Conditions for the consideration micro-generation output in the settlement system have still to be set up. Basically there are two options: whether to use half-hourly metering (HHM) or a profile for each micro-generation technology. In 2003 a regulatory modification (known as 'P81') has made it possible for suppliers to include exported electricity without the obligation to install half-hourly metering in the settlement system. The transaction costs are however very high (DGCG Technical Steering Group, 2004). The profiles used under P81 are not very accurate which prevents suppliers to use them.

Cost implications to improve these conditions cannot be attributed to individual units and therefore cannot be included in the spreadsheet calculations. At the first stage the usage of half-hourly data is unlikely due to general resistance by grid operators to deal with new volumes of data (see next paragraph). Costs related to the establishment of new profiles will be shared between suppliers via the existing profile class mechanism.

Collection and aggregation

The system requirements for data collection and aggregation are the most difficult to assess. DNOs suggest that their systems are not able to cope with half-hourly data from thousands of micro-generation units. Furthermore due to the small amounts of power generated by these units the upgrading and transaction costs would outweigh the benefits of half-hourly data collection and aggregation. This would require considerable and costly upgrade of the

[20] See for example the latest Ofgem initiative and consultation on 'smart-metering' (Ofgem, 2006).

existing IT system in order to being able to handle these big volumes of data. Instead of one data set, the system would have to deal with at least 17,520 half-hourly data points on exports per MPAN registrant (or customer) and year.

7 Economic analysis

The economic evaluation based on the above-discussed inputs does not include systemic costs such as those related to the settlement system, data aggregation and processing.

The simple payback analysis can be expressed as follows:

$$P = \frac{(I - G)}{(S - C)}$$

where:

P = Payback time
I = Up-front investment costs
G = Grant / Capital Allowance
S = Annual savings or income
C = Annual costs (O&M and possibly data retrieval)

As opposed to the individual homeowner companies are interested in sufficient returns on their investments. Companies evaluate possible investments on the basis of a discounted cash flow (DCF) analysis, where the cash flow in and out of an investment is discounted by a discount rate often similar to the rate of return obtainable on other investments of similar risks:

$$\sum_{t=0}^{n} \frac{A_t}{(1+r)^t}$$

where:

A_t = Project's cash flow (either positive or negative)
t = Year
r = Annual discount rate

For the analysis of corporate investment in micro-generation technologies a discount rate of 8% was chosen.

7.1 Economic evaluation of the deployment models

The following paragraphs give an overview on payback times for micro-generation technologies under the existing policy and regulatory framework and discuss the impact of different changes in the existing framework on payback times. It will first discuss payback times for individual households investing in micro-generation technologies (under Plug and Play) and then outline companies' perspectives on investments in domestic electricity generation technologies (under Company Control).

7.1.1 *Plug & Play*

For households investing in micro-generation the major sources of income are avoided electricity imports - and therefore reduced electricity bills - if no capital grants or export/generation contracts are voluntarily offered by a supplier.

For PV (1.5 kW, installation costs of around £9,000) under current conditions (including access to ROCs valued at £39/MWh generated, no export rewards and avoided imports valued at £0.08/kWh) it takes over 80 years to pay back in most cases. The precise payback depends on the consumed PV output on-site and the extent of avoided imports. A capital grant of £2,500/kW installed (as for the Major Demonstration Programme) can decrease payback times to roughly between 40 and 60 years (see Figure 11).

For micro-CHP installed in a 2 bed bungalow (poor building and poor double glazing) payback times are between 20 and around 60 years depending on the building standard (see Figure 9) if installation costs of £3,000 and an import tariff of £0.08/kWh (but no annual service costs) are considered. Since micro-CHP will in most cases be a replacement or alternative for a condensing boiler, only the cost difference between a new condensing boiler and a micro CHP unit may be used. An additional cost assumption of £1,500 leads to payback times of between 10 and 30 years; £500 to paybacks between 3 and 10 years[21]. If the import tariff was set at £0.12/kWh payback times are considerably reduced (see Figure 10). Consequently annual income for the household in terms of avoided imports ranges between £50 and over £150. Access to enhanced capital allowances for private households investing in micro CHP could further improve payback times by several years.[22]

Our data suggest – in line with the first results from the Carbon Trust micro CHP field trials – that on-site consumption of micro-CHP output is likely to be close to 50%. Exports constitute therefore a considerable share of the micro-CHP output.

[21] The range of £500 to £1500 is based on anecdotal evidence since it is hard to get comprehensive market data on replacement boiler costs.
[22] It might be difficult administratively to apply ECA to the differential costs approach.

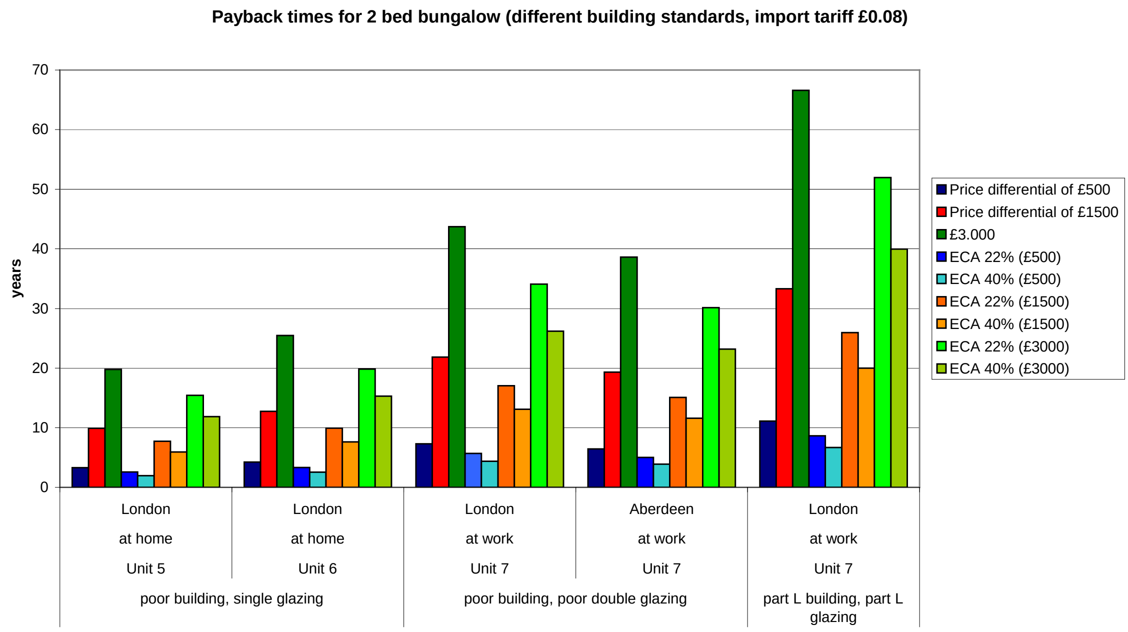

Figure 9: Payback times for micro CHP in 2 bed bungalow (import tariff: £0.08/kWh))

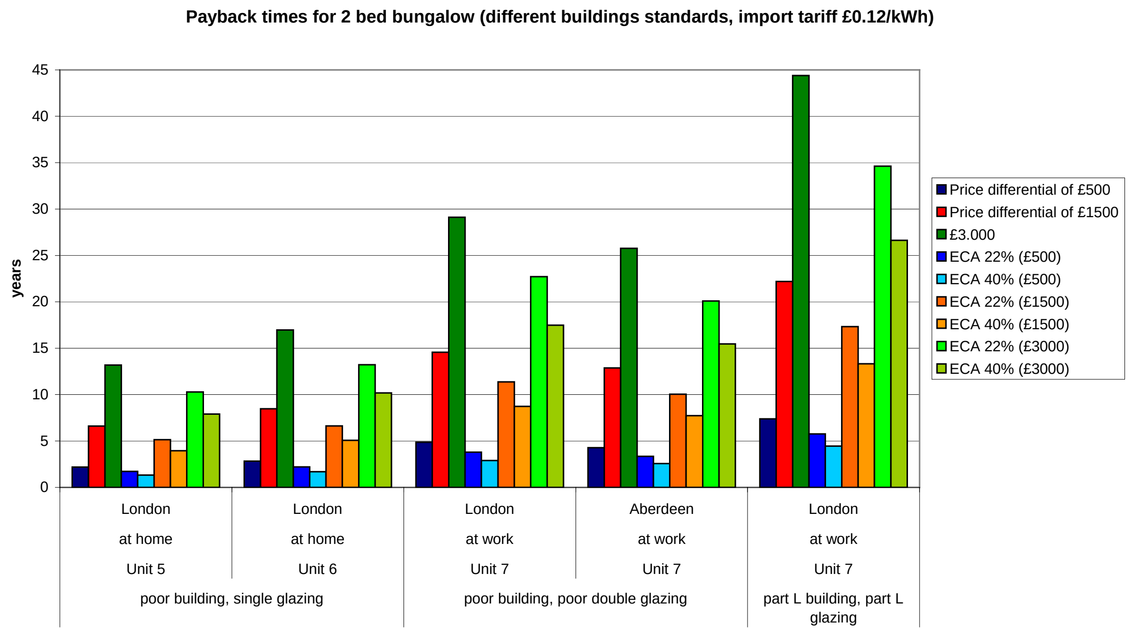

Figure 10: Payback times for micro CHP in 2 bed bungalow (import tariff: £0.12/kWh)

Under current conditions micro wind (£1,500 installation costs) has payback times of between 14 and 19 years for an optimistic 1 kW power curve if the threshold of 500 kWh to have access to ROCs is achieved. Otherwise it would take more than 60 years to payback. Our data sample suggests that most of the micro wind output is consumed on-site. This is contrast to previous studies that assumed that 60% of micro wind output will be exported to the grid (Energy Saving Trust, Econnect et al., 2005)[23].

[23] The EST study's assumptions on exports are based on ILEX 2005a.

In the following the impact of different policy and regulatory measures is considered: capital grants, enhanced capital allowances for income tax payers and export rewards.

Figure 11 shows the impact of single policy measures on simple payback times for PV. Access to export rewards or higher import prices have little impact on payback times and will not reduce them to less than 60 years. Only a combination of capital grants (£2,500/kW installed) or enhanced capital allowances and export rewards bring payback times closer to between 40 and 50 years (see Figure 12).

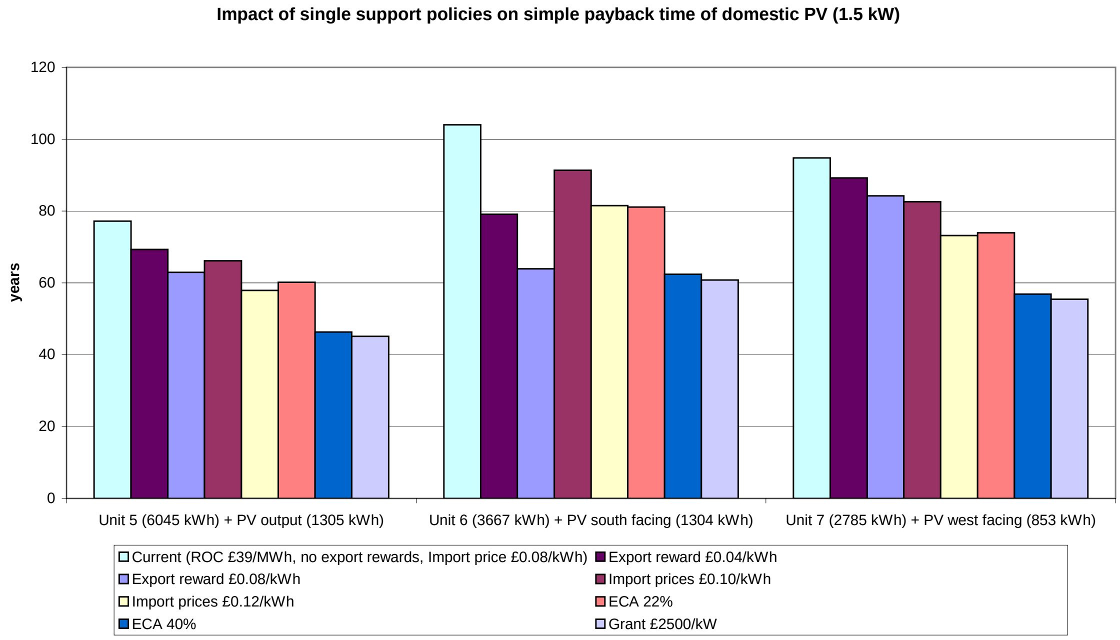

Figure 11: Impact of single support policies on simple payback times for domestic PV (1.5 kW)

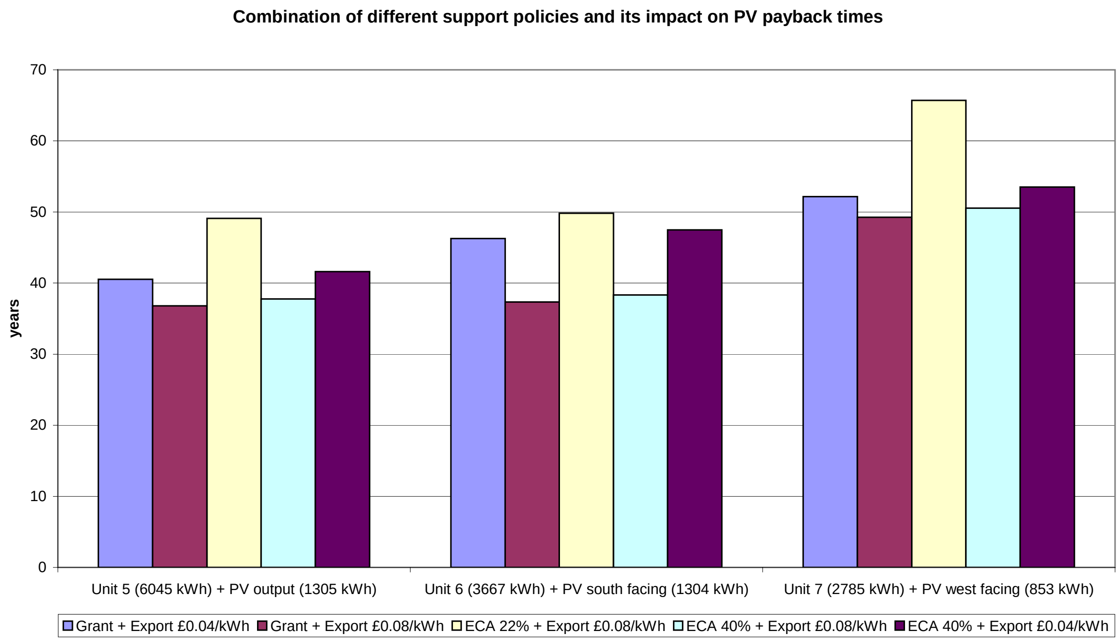

Figure 12: Combination of different support policies and impact on simple payback times for PV (1.5 kW)

Export tariffs have a different impact on payback times of the three micro-generation technologies depending on the output exported to the grid. In the case of micro wind export rewards (even at a retail price of £0.08/kWh) would improve payback times only marginally by one or two years due to a high share of on-site consumption of the micro-generation output.

In the case of micro CHP export tariffs would have a considerable impact on payback times. Average payback times for micro CHP with an average heat demand of 21,000 kWh could be reduced from 7 years to between 4 and 3 years for an export reward of £0.04/kWh and £0.08/kWh respectively (assuming additional costs of £500) or from 16 to between 11 and 9 years (assuming additional costs of £1500) with an import tariff of £0.08/kWh (see Figure 13).

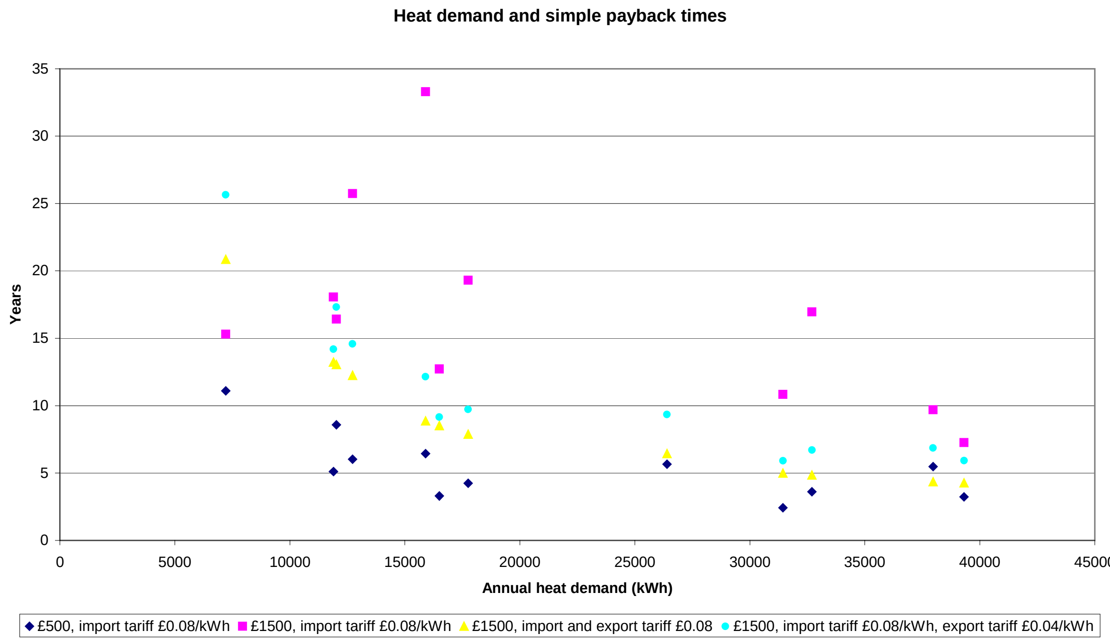

Figure 13: Export tariffs and payback times for micro CHP

Having shown that export tariffs are important to improve payback times for micro CHP and PV, this raises the question what a 'fair' export tariff would be that reflects the micro-generation value for the energy system. Using System Buy Price (SBP) as reference value for exported electricity to the grid our data suggest that the usage of an average SBP of around £0.04 per kWh exported would undervalue exports from micro CHP and PV since they occur also at peak times when SBP is high. If average half-hourly export data for micro-CHP and PV are used to calculate the average half-hourly SBP value during 2005, a 'fair' export tariff for both technologies would be around £0.05 per kWh. This tariff does not include embedded benefits that may also be considered in such an export tariff.

Even an export reward of £0.08/kWh (here equivalent to import tariff) cannot increase the economic attractiveness of micro wind installations significantly. Enhanced capital allowances that allow households to write off their investments against their tax will reduce average payback time for 1 kW micro wind turbine considerably – in particular for high rate taxpayers. A higher import tariff of £0.12/kWh would reduce payback times for a 1 kW wind turbine, but not to less than 10 years based on our data for the Aberdeen wind-site and different domestic electricity consumptions (see Figure 14).

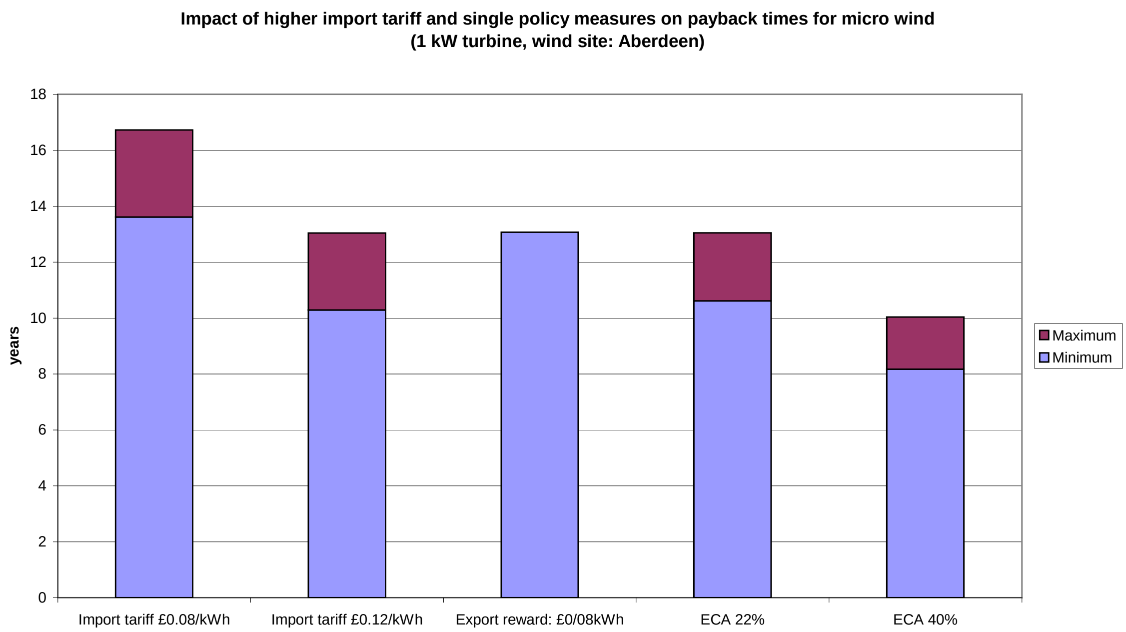

Figure 14: Impact of policy measures on simple payback time for micro wind (1 kW)

An upfront payment of ROCs seems attractive since it reduces upfront installation costs. A company offering such a contract would however discount the value of future income for ROCs for the uncertainty of their value and the decrease in net present value due to discounting. It may therefore not be an advantageous option for householders.

7.1.2 Company Control

In this sub-section three approaches are considered how an energy service company or energy supplier could invest in domestic micro-generation technologies: first, a normal dual-fuel supply contract in combination with an upfront payment (potentially linked to a frozen or reduced import tariff over a certain period of time), second, a lease contract (rent or purchase) and, third, a contracting model for micro CHP.

The following paragraphs discuss the economic implications of these models – from both the company's and household's perspective. These calculations are aimed to highlight possible alternatives to 'classic' approaches to domestic electricity generation technologies. A companies investment decision will be based on a much more sophisticated approach particularly based on more detailed information on underlying costs and potential benefits.

As outlined above (see section 6.1.2) for a company there are three sources of income available: first, upfront incentives/income, second, from the micro-generation output and, finally, from the customer contract. The power output of the micro-generation unit is valued at the system buy price (SBP) and includes ROCs, LECs and embedded benefits. Figure 15 gives an example about the different parts of the company's income from the micro-generation output – for PV and micro wind ROCs (here valued at £39/MWh) constitute a major source of income, whereas over 80% of the income for micro-generation output is related to the SBP. Embedded benefits (here 50% of the theoretical value discussed in 5.1.2 is considered as income) and LEC contribute still almost 20% of the income. The share of the income streams will however vary for each micro-generation unit installed depending on its actual power output.

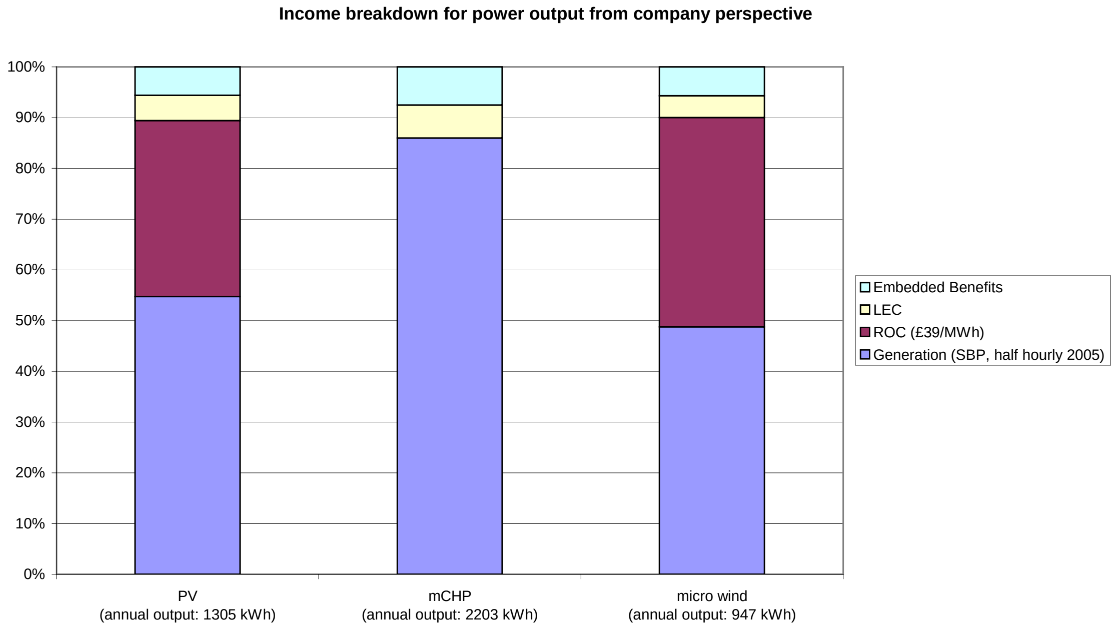

Figure 15: Income breakdown for micro-generation power output from company perspective

As already outlined above PV output data are very similar with exception of the west facing array whereas micro-CHP output depends on the building type/standard and micro wind generation on the location of the installation. The domestic electricity consumption pattern is however relevant if the customer supply contract – the second income stream – includes a discount on the import tariff.

The analysis includes standard capital allowances (SCA) as well as enhanced capital allowance (ECA) on the installation costs (including VAT) in the year of investment. It therefore reduces the capital outlay.

Supply contract

The continuation of a traditional supply contract where the customer does not contribute with an extra payment for the installation of micro-generation unit but ‘only’ provides the site for the unit would only be attractive if the power output of the unit is above average. In the case of micro CHP a heat demand of over 30,000 kWh would be required to reach discounted payback times of around 10 years. A 1.5 kW micro-wind turbine would have to generate more than 1,500 kWh to generate enough electricity to reach the threshold to get access to two ROCs per year. This would lead to a discounted payback time of under 10 years. For PV this is not a viable option.

In order to make this approach also attractive for closer to average power outputs, an upfront payment from the customer would be required. Assuming an upfront payment of £600 by the customer, micro-CHP could achieve discounted payback times of close to 10 years when heat demand is above 15,000 kWh and electricity output likely to be above 2,000 kWh.

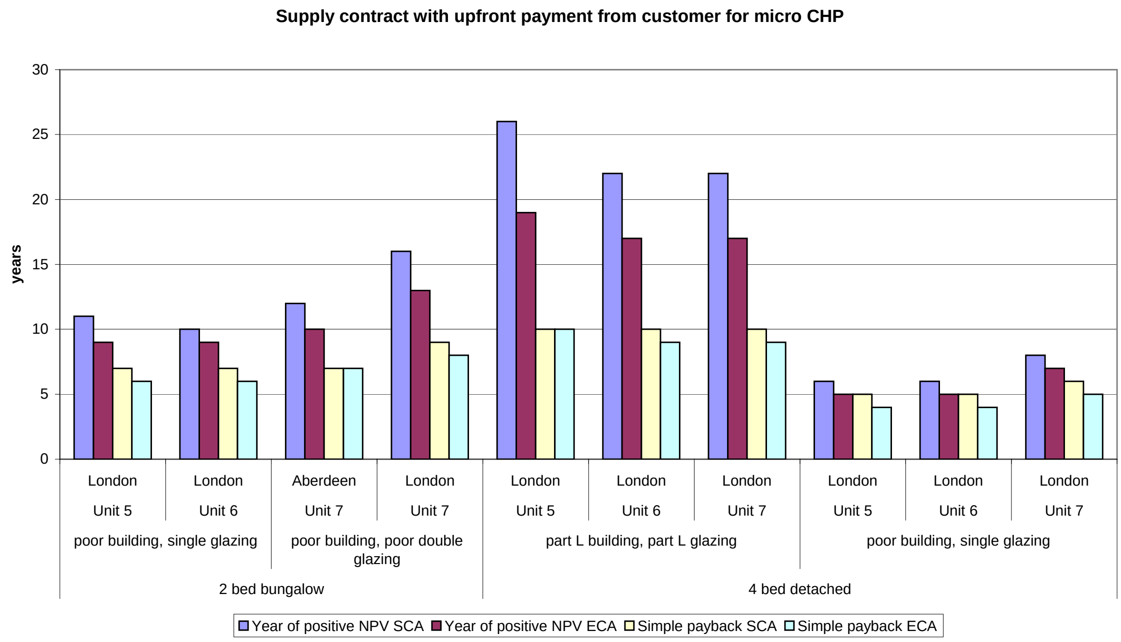

Figure 16: Payback times for supply contract with upfront payment from customer for micro CHP

Similarly micro wind investment could achieve payback times of below or close to 10 years with an upfront payment of £300. This would require wind sites with an annual electricity output of above 600 kWh for a 1 kW turbine or above 1,500 kWh for a 1.5 kW turbine – again to achieve the threshold for two ROCs (see Figure 17).

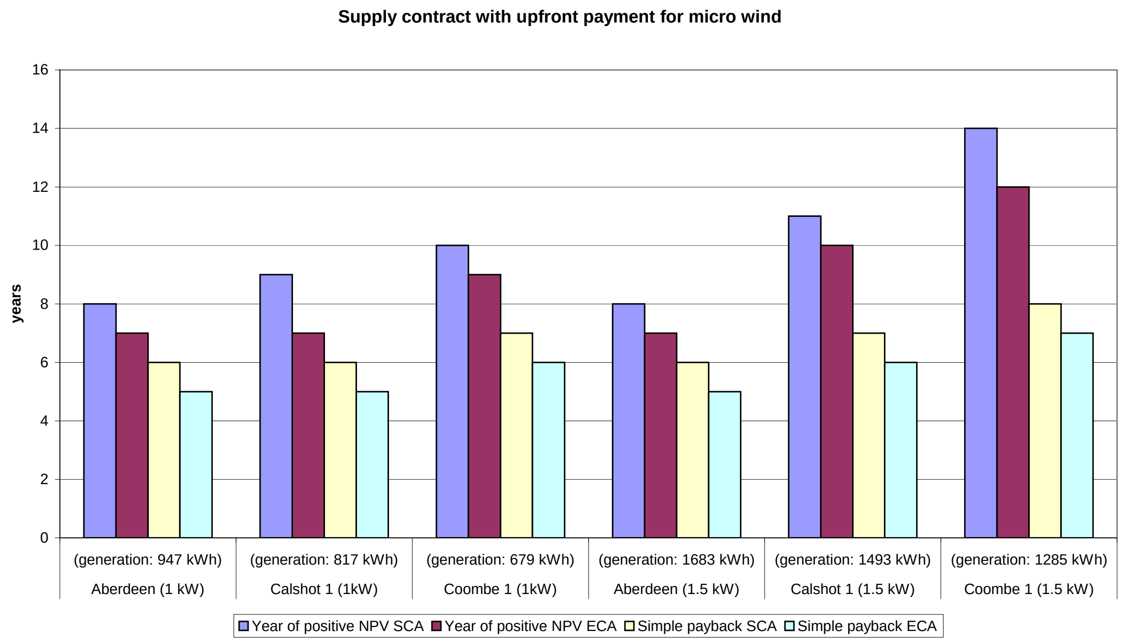

Figure 17: Supply contract with upfront payment for micro wind

Lease supply contract

An annual lease payment and a discount of 10% on the import tariff (of £0.08/kWh) could increase the attractiveness of all three MG technologies with considerable difference in the annual lease payment.

For a 1.5 kW domestic PV system an annual lease payment of £600 would reduce discounted payback times to around 10 years if companies had access to ECAs. In the case of micro wind an annual lease payment of £100 would lead to discounted payback times of between 7 and 12 years (see Figure 18). Payback times would be lower for housing unit 6 due to the lower electricity consumption and therefore the lower reduction in company income from the supply contract. It shows clearly the influence of the ROC value on the payback of 1.5 kW turbines. If the threshold of 1,500 kWh is achieved and two ROCs are available as in the case of the output for Aberdeen, the payback time is reduced by 4 years.

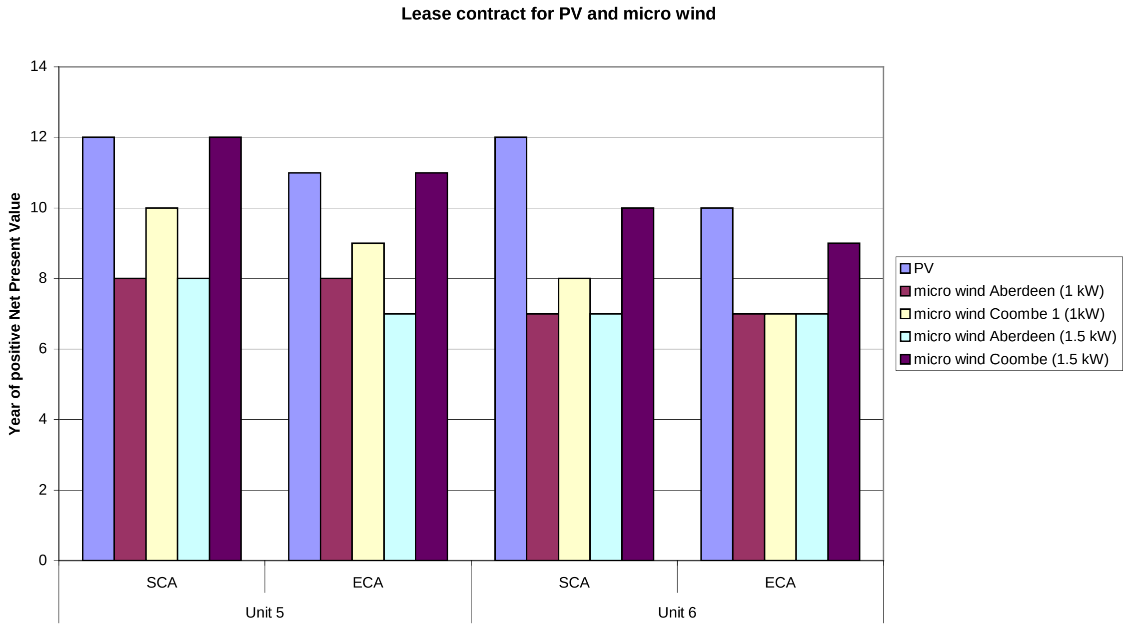

Figure 18: Lease contract with upfront payment - payback time for PV and micro wind considering different capital allowances

For micro-CHP an annual lease payment of £150 combined with a 10% reduced import tariff (at £0.08/kWh) can reduce discounted payback times close to or to less than 10 years – with exception of a part L 2 bed bungalow which has a heat demand that is too low. However, under this contract arrangement payback times depend not only the heat demand, but also on the amount of electricity consumed and the reduced company income due to import tariff discount. Households with a heat demand of around 12,000 kWh show differences in payback times (see Figure 19).

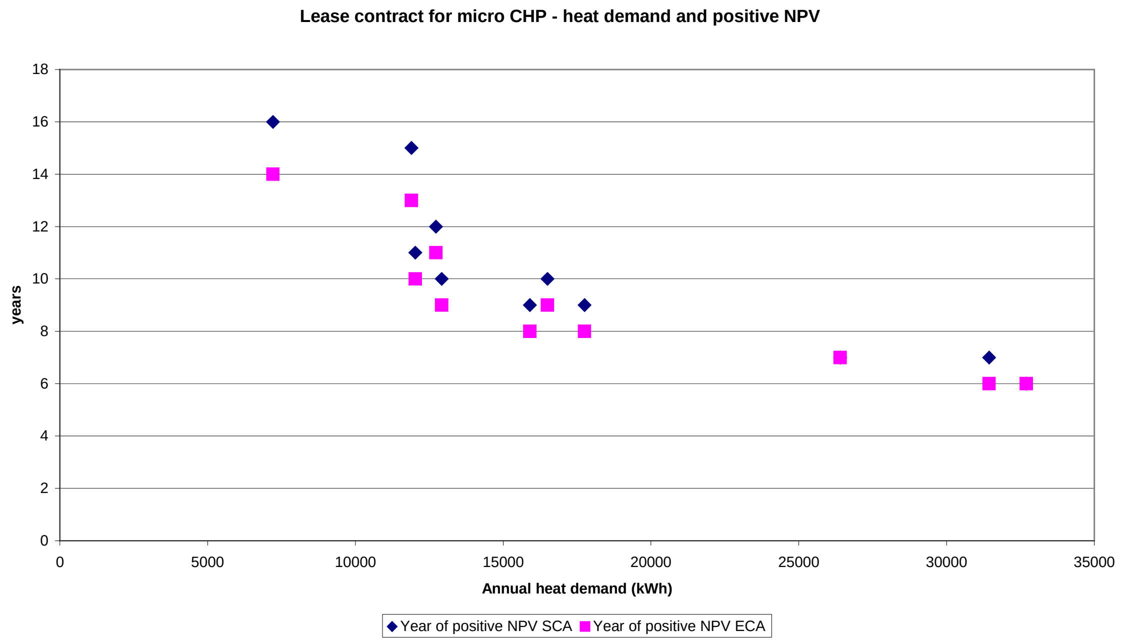

Figure 19: Lease contract with upfront payment for micro CHP

From the household's perspective a leasing approach may be attractive if they wish to invest in micro-generation technologies anyway, and to avoid paying the total upfront cost in one go. An annual lease payment would be slightly higher than the costs for a boiler service contract (though, in reality, this is likely to be inflated by an additional maintenance charge).

Contracting

Contracting for micro CHP is based on the same cost assumptions as the supply and lease contract. The income from the customer contract is determined by the heat price. Under this contract the heat demand is the central factor since it influences both income streams. The heat demand determines the electricity output of the micro CHP unit and therefore the income from output sales and the income from heat sales. Gas costs for the contractor are assumed to be £0.01/kWh.

A heat price of £0.02/kWh would allow an energy contractor to achieve a positive NPV for the micro CHP unit after between 4 and 15 years depending on the heat demand and fiscal regime (see Figure 20). This result excludes cases when heat demand is below 10,000 kWh The customer would have extra costs of between £25 and £50 annually as compared to costs for gas for the same heat demand generated with a new condensing boiler of an efficiency of 92% and a gas price of £0.017/kWh.

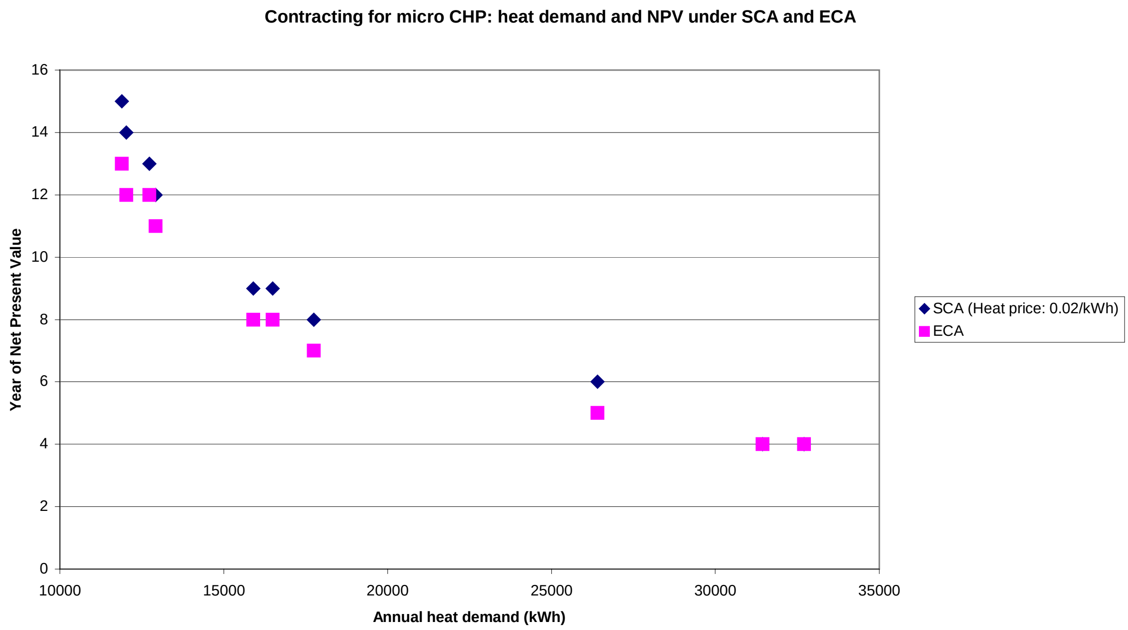

Figure 20: Micro CHP contracting: heat demand and payback times

For all company driven approaches the income generated from the micro-generation output is a central income component. In our model it was not possible to include potential costs or benefits from the use of micro CHP units for balancing purposes.

7.1.3 Community Microgrid

As already mentioned above, the complexity and novelty of this third deployment approach no quantitative analysis is possible based on the data and information available so far. Of major importance for this approach are the actual savings in terms of embedded benefits, on the one hand, and costs for the operation and maintenance of a community microgrid on the other hand.

8 Conclusions

The core question of this paper is the extent to which different deployment models can potentially increase the attractiveness of micro-generation technologies for both private households and energy suppliers or energy service companies. It has taken an economic perspective and has aimed to show how changes in policy and regulation can improve the economic payback of domestic micro-generation technologies. A central underlying assumption has been that shorter paybacks should lead to higher levels of micro-generation investment. However, it is not yet clear how short payback periods will need to be for consumers or energy companies to invest significantly in micro-generation. Payback periods are only one factor that influences consumers' decision to invest in micro-generation technologies.

The three technologies considered – PV, micro CHP and micro wind – have considerably different features in terms of economic attractiveness. While PV is a rather expensive but proven technology, additional micro-CHP investment costs for consumers that are replacing their central heating boiler are relatively low. Costs of 1 kW micro wind turbine are around £1,500.

These features are reflected in the economic paybacks of these technologies under a conventional investment approach of an individual household. Payback times for a typical PV system are very long, and payback times for a 1 kW micro wind turbine are also measured in decades. The modelling results used in this paper suggest that payback times for micro wind turbine installations are greater than manufacturers' estimates[24]. In the case of micro-CHP the economic performance depends on the approach taken. As opposed to the two other technologies that are 'new' or additional technologies for the vast majority of households, micro CHP will in most cases be an alternative to the purchase of a replacement boiler. It seems therefore reasonable to use the additional costs which may be between £500 and £1500. Both ends of this range are considered in the above analysis and suggest payback times of several years.

For all technologies these payback times are still too long in most cases. We have therefore tested which changes in policy or regulation might improve this position. With respect to these policy measures, it is important to distinguish between the different micro-generation technologies. PV with its high upfront costs will profit from capital grants (as provided under DTI's Major Demonstration Programme) but also from export rewards. In the case of wind where most of the produced electricity is consumed on-site, capital grants could also make a substantial contribution to increasing economic attractiveness. Our data suggest that electricity export to grid from micro-CHP will be likely to be close to 50% of the unit's output. Instead of spilling these units 'for free' in the grid, the valuation of the exported electricity at the System Buy Price (SBP) would help to improve payback times. This is also of particular importance since micro-CHP is regarded as the technology that could contribute most to the potential micro-generation supply in the UK (Mott MacDonald, 2004; Energy Saving Trust, Econnect et al., 2005). Rewarding exports at a higher level than the average System Buy Price (e.g. a flat rate of 8p/kWh) would shorten payback times further.

[24] For example the micro wind turbine manufacturer Windsave claims a payback of less than 5 years including ROCs and grants (http://www.windsave.com/financial.htm).

An obligation for export rewards would help stimulate the market for micro-generation output. Such an obligation would help micro-generation investors to get a fair value for the electricity that would otherwise be exported in the grid for free. This could stimulate a market for exports from micro-generation and could be a driver to extend the existing settlement system so that it allows for the consideration of micro-generation's actual value. Ways to implement a comprehensive export reward scheme are currently under discussion in the context of the Climate Change and Sustainable Energy Bill, a Private Members' Bill that is passing through the House of Commons.

Changes in the tax system in order to treat the investments on the demand and supply side of the energy system in the same way could be introduced instead of (or in addition to) capital grants. These are already available for some investments in energy efficiency technologies in the form of enhanced capital allowances for businesses. The same allowance for household investments in micro-generation would allow them to write off 100% of the investment costs against their taxable income. Depending on the tax rate this would mean that 22% or 40% of the investment costs would be recovered in the first year of investment. In contrast to capital grants the regressive impact of capital allowances would lead to a certain inequality in terms of support. In the absence of special provisions for those on low incomes, this may conflict with the attainment of other energy policy objectives such as the reduction of fuel poverty.

With a heat to power ratio of seven (as used in our thermal model), sufficient heat demand within a household is precondition to make micro CHP a viable investment option for private households. The modelling results suggest that a 2 bed part L compliant building with a heat demand of around 7000 kWh or below is not suitable for micro CHP. For £1500 additional installation costs above those of a replacement boiler and an export reward of £0.04/kWh, a minimum heat demand of 15,000 kWh is required to achieve payback times of around 10 years or less. Other micro CHP technologies (in particular fuel cells) with a lower heat to power ratios and a higher power output are likely to be more attractive for lower heat demand buildings.

Alternatively energy companies might be the driving force behind investment in micro-generation technologies. They could help to overcome different barriers for individual households' investments such as lack of access to capital or risk-aversion about new, 'unproven' technologies. In this paper, three different types of company approach were tested: a) a supply contract where the customer continues to pay for the electricity and gas consumed but agrees to support the MG installation with an upfront payment to the energy company which will be considerably lower than under 'Plug & Play'; b) a lease contract combined with a discounted import tariff; and c) a contracting arrangement for micro CHP where the customer pays – in addition to his electricity consumption – for the heat consumed and therefore shifts the risk of further gas price increases to the contractor.

All three arrangements could be attractive for both the energy company and the consumer, but this depends on the assumption that an energy company would receive a bulk purchase discount on the cost of micro-generation technologies. The above calculations can only give indications due to lack of data on how an energy company would value different aspects of micro-generation. This has to be investigated further. Customers can gain from reduced up-front investments, or from lower risks from the new technology.

Besides the obligation for export rewards the recognition of micro-generation technologies as approved technologies under the Enhanced Capital Allowance scheme could further help to make it a business opportunity for energy companies and attract new energy service companies to the market. These new and probably smaller companies might however achieve only a smaller bulk purchase discount and therefore might have to bear higher upfront costs.

Micro-generation could also provide an impetus to upgrade domestic metering. The costs for new meters are rather small when compared to overall micro-generation investment costs. Regulations for new meters should therefore consider potential future requirements. This means that the installation of import, export and generation meters should be the minimum requirement for new micro-generators since this would allow consumers to access a full range of incentives. Going one step further, ‘smart meters’ that also include half-hourly data collection and user-friendly display systems might also be mandated. This could increase the potential benefits of micro-generation by making it more likely that consumers will change their behaviour. Important questions remain about the costs for data collection, aggregation and processing associated with such a shift.

Overall, it is crucial that policy and regulatory measures do not only focus on the economic perspective considered in this paper, but also respond to other barriers to the uptake of micro-generation. The decision-making criteria used by consumers who consider investing in energy efficiency measures or in micro-generation are complex (e.g. Chesshire, 2003; Oxera, 2005). Economic criteria are important in most cases, but they are evaluated alongside many others including risk, aesthetics, the experiences of friends and colleagues, the ‘hassle factor’, the need for planning permission and the availability of well trained installers. Some of these additional criteria can be partly addressed using the policies and measures discussed in this paper, whilst others will need to be tackled by complementary approaches.

9 References

Chesshire, J., 2003. Energy Efficiency Projects and Policies for Step Changes in the Energy System: Developing an Agenda for Social Science Research. ESRC Seminar, Policy Studies Institute, March.

Devine-Wright, P., 2004. Towards Zero-Carbon: citizenship, responsibility and the public acceptability of sustainable energy technologies, in: C. Buckle (Ed.), Proceedings of Conference C81 of the Solar Energy Society, UK section of the International Solar Energy Society, 21 September, London, pp. 51-62.

DGCG Technical Steering Group, 2003. Lease financing through energy bills and the supply licence conditions on domestic energy suppliers. DGCG.

DGCG Technical Steering Group, 2004. Reward Mechanisms for Micro-Generation. DGCG.

DTI, 2005. Microgeneration strategy and low carbon buildings programme: consultation. DTI, London.

Energy Saving Trust, Econnect and Element Energy, 2005. Potential for Microgeneration. Study and Analysis. Energy Saving Trust.

ILEX Energy Consulting, 2005a. Metering, Settlement & Export Reward, Options for Micro-Generation. DTI.

ILEX Energy Consulting, 2005b. The Tradable Value of Distributed Generation. DTI.

Mott MacDonald, 2004. System Integration of Additional Micro-generation. DTI.

Myers, L., A. S. Bahaj and P. A. James, forthcoming. Matching domestic energy demands to micro wind and photovoltaic energy generation. Paper in preparation for the REMIC 2 conference, Dublin, Ireland, 26-28 April 2006.

Ofgem, 2005a. Energy Efficiency Commitment 2005-2008 Innovative Action (Decisions document, November 2005). Ofgem.

Ofgem, 2005b. Social Action Strategy. http://www.ofgem.gov.uk/temp/ofgem/cache/cmsattach/11775_15505a.pdf.
Ofgem, 2006. Domestic Metering Innovation. Ofgem.
Oxera, 2005. Policies for energy efficiency in the UK household sector. (unpublished report prepared for Defra for the CCPR).
Power Planning Associates Ltd, 2005. Distributed Generation Connected to the Local Network - A Guide. DTI.
Sauter, R. and J. Watson, forthcoming. Micro-Generation: A Disruptive Technology for the Energy System?, in: J. Murphy (Ed.), Framing the Present, Shaping the Future. Earthscan, London.
Sauter, R., J. Watson and L. Hughes, 2005. Metering, Communication and Control Technologies for Micro-Generation. http://www.sustainabletechnologies.ac.uk/PDF/Working%20papers/109_1.pdf, STP Working Paper 2005/1.
Smith, A. and J. Watson, 2002. The Renewables Obligation: Can it Deliver? Tyndall Centre Briefing Note No. 4.
SOHN Associates, 2005. Sale of Power Opportunities for Distributed Generators: Part B The Guide. DTI, http://www.distributed-generation.gov.uk/documents/16_11_2005_kel000620000partb.pdf, 23/11/2005.
The Carbon Trust, 2005. The Carbon Trust's Small-Scale CHP field trial update. The Carbon Trust, http://www.thecarbontrust.co.uk/carbontrust/about/publications/181105_01.pdf, 22/11/2005.
van Vliet, B., 2004. Shifting scales of infrastructure provision, in: D. Southerton, H. Chappells and B. van Vliet (Eds.), Sustainable Consumption: The Implications of Changing Infrastructures of Provision. Edward Elgar, Cheltenham, pp. 67-80.
Watson, J., 2004. Co-Provision in Sustainable Energy Systems: The Case of Micro-generation. Energy Policy 321981-1990.