Micro CHP implications for Energy Companies

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Executive Summary

Transition from monopoly to competition

Experience from the liberalised UK energy market shows that it will be necessary for Energy Companies to make radical changes in their operations and seek advantages from technological innovations if they hope to survive in an aggressive competitive environment. The change from central control and monopoly to private ownership and competition has had a strong impact on the energy industry in the UK. The first response to competition was to radically reduce operating costs to meet the immediate demands of new shareholders by:

- Reducing manpower, in many cases by over 40%
- Minimising capital expenditure
- Reducing or eliminating routine maintenance
- Reduced marketing

Impact of competition

Substantial cost reductions have been possible by the above measures due to earlier gross over-manning, over-capacity in generation and network assets and unnecessary revenue expenditure. However, there is a limit as to how long it is possible to obtain benefits through cost reductions and most Energy Companies in the UK are now considering more creative ways of improving their competitiveness. Experience has shown that it is not possible to continue with existing business and assume that your competitors will not take over your customers due to customer acquisition costs or customer loyalty or inertia. The reality seems to be that if you do not take over your competitors' customers, they will take over yours. In the initial trial area in the South West of England that was opened up for competition, the local gas supplier (British Gas) lost over 25% of their customers in the first two years. It is estimated that between 25-50% of the consumers will switch energy suppliers nationally over the next five years, and that many Energy Companies will fail or be absorbed by more aggressive competitors.

Retention and acquisition of customers

Customers demand some tangible benefit in order to be motivated to change supplier. So how have the Energy Companies attempted to do this? Essentially they have become smarter in operational efficiency, customer service and marketing. UK experience indicates that there are three potential routes to success:

1. Price reduction
2. Added value services
3. Branding/affinity marketing

Micro CHP as a strategic competitive tool

As far as price reductions are concerned, customers can in the future (as cost cutting eventually will reach its limits of practicability) only be profitably acquired *if there is some technological or commercial edge over competitors*. In this respect Micro CHP may be a very powerful tool. It provides Energy Companies with very high value kWh (based on generation profile and point of generation) and enables them to be sold to customers at a lower price, whilst simultaneously giving a higher profit margin. Moreover, it makes it easy to brand the energy (especially the electricity) that is sold to the customers as it is produced on-site and possibly through equipment owned by the Energy Company. Also, if the Energy Company owns the Micro CHP systems, it will obtain added value services by performing installation and maintenance. Finally, Micro CHP is the cheapest form of new generating capacity particularly if infrastructure costs are included in the calculations. Therefore, from an investment and operational perspective, Micro CHP offers significant competitive advantages. The competitive advantage it confers on the participants is however, seen from the outsider's perspective, a significant threat to existing and future business. It can result in loss of customers and stranded assets.

General prerequisites for Micro CHP viability

Any viable market for Micro CHP requires an existing natural gas infrastructure and an installed base of natural gas fired domestic central heating systems (boiler + hot water distribution system). Viability is also determined by the ratio of the prices for electricity and gas, and is particularly enhanced by a high electricity price.

Inevitable advent of micro CHP

It is generally accepted that micro CHP in one form or another, will become established within the next 2-3 years, although the specific technology to be implemented (fuel cells, Stirling Engines, etc.) remains a matter of debate.

Whichever technology is adopted for micro CHP, Energy Companies need to understand the commercial and operational implications of its introduction. They should, therefore, undertake detailed studies and trials of appropriate systems in order to evaluate the consequences of micro CHP and formulate their own approach to succeeding in the face of this radical concept. Those Energy Companies who do not acquire the necessary competence at an early stage may face a powerful threat from aggressive micro CHP competition.

Impact of Competition

Alongside the liberalisation of the existing market, environmental considerations are beginning to have a significant influence on the energy industry at national and international level. It is therefore natural to consider environmental aspects, and in particular their commercial implications, within the context of market liberalisation.

Liberalisation

The first response to privatisation in the UK was to radically reduce operating costs to meet the immediate demands of new shareholders. This was achieved by:

- reducing manpower, in many cases by over 40%
- minimising capital expenditure
- reducing or eliminating routine maintenance

Already there are indications of a similar process occurring in Germany as RWE recently announced plans to restructure and shed staff.

A number of companies, believing they had survived the tide of change, then simply carried on with business as usual. Substantial cost reductions have been possible in all the above areas because, as in most European countries, the UK electricity industry's overriding concern was reliability of supply. This had led to over-manning, over-capacity in generation and the network and unnecessary revenue expenditure. However, there is a limit as to how long it is possible to obtain benefits in this way and most companies considered more creative ways of improving their competitiveness. Initially this led to more focussed use of manpower and technical improvements such as condition monitoring to permit preventative maintenance. These changes have created the more efficient electricity companies which have survived so far, but the challenge is far from over.

Further rationalisations have occurred and there is a move towards larger, vertically integrated utility companies dealing in gas and electricity with generation, distribution and supply business. A number of these include other utilities such as telecommunications, water and sewage. This makes better use of manpower and reduces overheads relative to turnover. It also enables such companies to offset losses in their generation and supply businesses by corresponding gains in the supply and generation businesses respectively.

At the other extreme, there are some companies who may choose to focus on specific areas such as supply or distribution. The very slim margins available in supply have tempted some to consider abandoning this activity in favour of monopoly distribution business. This initially attractive option does however, leave such companies vulnerable to the impositions of other companies who wish to use (or abuse) their network. It also abandons once and for all a valuable customer base which could have been offered additional, more profitable services.

Experience has shown that it is simply not possible to continue with existing business and hope that your competitors will be discouraged from taking over your customers by the substantial costs of customer acquisition. The harsh reality is that if you do not take over your competitors' customers, they will take over yours. If the experience of British Gas in the South West of England is repeated throughout the industry, it is only a matter of time before we see the emergence of a small number of "winners" and another group of "losers".

As far as customers are concerned, there has to be some tangible benefit to motivate a change of supplier, so how have the energy companies attempted to do this? Essentially they have become smarter in operational efficiency, customer service and marketing.

The three potential routes to success are considered to be:

- **Price reduction.** Given the very slim margins in energy supply today it is unprofitable and ultimately counterproductive to participate in a price war with other energy companies who are all paying the same for wholesale electricity. All these companies have very substantial capital resources and could indeed fight a war of attrition for some time. This strategy was followed in the commercial supply market with initial success in customer acquisition, but with ever-reducing margins. In the light of this experience many companies have withdrawn from this unprofitable market and none consider price reduction alone as a means of profiting from customer growth.

- **Branding and affinity marketing**. Familiar household names previously without involvement in the energy industry are lending their marketing weight to established energy suppliers. With their vast customer base and reputations, food retailers such as Sainsburys and Tesco have teamed up with British Gas for example, to sell discounted energy. As a sub category we may also consider that the promotion of "green" electricity, sometimes at a premium, tends to be more a branding exercise than an environmental operation.

- **Added value services**. There are two aspects to this approach. One is the reduction in costs associated with supplying a range of services through the same billing system, the other is the provision of additional services beyond those which the customer received from all suppliers. In the first case customers enjoy the simplicity of paying one bill for all utilities and in the second they may be prepared to pay extra for services (such as itemised billing, remote control, automated control), although this has been of limited success so far. However, that is not to say that other cultures such as Germany may not respond more positively to this approach.

However, bearing in mind these three strategies, it is in the area of price reduction where potential exists and where customers can be profitably acquired *if there is some technological or commercial edge over competitors*. Micro CHP is just such an option. It provides the energy company with very high value kWh (based on generation profile and point of generation) which can be sold to customers at a lower price, whilst simultaneously giving a higher profit margin.

In the UK, a typical profit of less than £6 per customer can be increased to as much as £370 for a large family home by the implementation of micro CHP as a strategic tool.

Environmental

The full impact of the emissions targets agreed at Kyoto has yet to be felt. It is, however, clear that EU governments will need to take active measures to comply with their commitments to reduce emissions. These may be both “stick” and “carrot” incentives. That is, there may be penalties in the form of Carbon Taxes, or incentives such as grants and subsidies for improved performance. It is probable that CO_2 emission quotas will become tradable and that consequently, products such as micro CHP will acquire an increased value to their owners, particularly if those owners are energy companies.

Even without such measures, energy companies throughout Europe have implemented schemes designed to encourage the more efficient use of energy. These have been motivated by enlightened self-interest as well as a growing public awareness of such issues. Such schemes have included subsidies on energy saving appliances (energy saving light bulbs, heat pumps) or improvements to home insulation.

It is clear that micro CHP, which produces effectively CO_2-free electricity (electrical generation being a by-product of heat production that takes place anyway), could play a major part in a company’s strategy in emission control.

Although not a “renewable” when using natural gas as a fuel, Stirling engine technology will eventually permit the use of bio fuels on a local scale and is in any case, more environmentally friendly and makes better economic sense than other CO_2–free fuels such as nuclear.

In a truly competitive market there will no longer be the distorting influence of government intervention in the form of job preservation in the coal industry, and the vested interests in nuclear generation although admittedly this may take some time. *However, as a general principle it will be the most cost-effective forms of emission reduction which will be implemented.* The section on alternative generation below considers this in more detail, but there is no doubt that micro CHP as envisaged will be a very effective means of implementing energy efficiency, emissions reduction and improved network efficiency. It should also achieve this without any of the environmental impact associated even with renewables such as wind-power and hydro.

It is assumed that micro CHP generation will displace the most inefficient and polluting existing generating plant, which in the UK is older coal-fired plant without flue gas desulphurisation. Compared with this plant, the annual reduction in emissions achieved by each PCP-based micro CHP unit is 8.8 tonnes CO_2, 136 kg SO_2 and 50.4 kg NOx. If we take the eventual market for the units at an estimated at 15 GW in the UK and a similar figure for Germany within 15 years, the potential for reduction in CO_2 emissions alone is 45 million tonnes. If CO_2 emission quotas become tradable at the rate of $20 per tonne, (as suggested at Kyoto), this would have a value to the owner of the CHP units of $900 million per year. On an individual basis the CO_2 quota would add about one third to the economic value of the micro CHP unit.

Business opportunity

Scope of the opportunity

The scope of the business opportunity is primarily determined by the number of currently installed domestic gas central heating systems in the territory under consideration.

Within this limitation, the level of sales and rate of market penetration depend primarily on the Energy Company's approach. The figures given are based on the premise of profitable business operation from the outset, although of course it may be considered advantageous to invest in acquiring a substantial market in order to gain market dominance. In this latter case measures such as "give-away" installation with low cost leasing perhaps subsidised by government grants or energy saving measures or to comply with CO_2 emissions targets may be used.

It is estimated that a total installed market of 7 million systems in Germany, 5 million in the UK and 2 million in the Netherlands could ultimately be achieved. Further analysis indicates a prime potential viable market in Germany of 200,000 and in the UK of 165,000 units per year. This includes an allowance for the type of boilers, for example, combi boilers which would not be suitable for direct replacement.

The value of the market depends on which area of business the activity is intended. There are three areas in which profitable activity may take place:

1. **Sale of units**. The value to a company of simply selling the micro CHP units is the number of units multiplied by the anticipated sales price. The sales price can be adjusted to suit the type of installation, so that for example a small hotel which would benefit most from such a system would pay significantly more than a private house where the potential savings are somewhat less. If we take the German market as an example, with an average selling price of 8000 DM, the potential turnover of this operation would be 8000 x 200,000 = 1600 millionDM per year for the whole of Germany. Seen from the perspective of one of the major players in the German market (Preussen Elektra), and limiting the activity within PE's existing area of operation, the value would be around 20% of this figure or 320 million DM pa.

2. **Lease of units.** The logic behind leasing the units as a business in its own right is clear, indeed it is arguable, particularly within the public sector, that leasing of gas boilers would also provide a valuable business opportunity. However, the use of leasing as a tool to acquire and retain new customers in energy sales is also substantial.

3. **Energy customer acquisition and retention.** This is by far the most significant area of opportunity provided by micro CHP. It is difficult to assess the value of acquiring new customers as the market is distorted by companies competing for longer term business. The "true" value of an electricity customer in the UK for example is estimated at around £40, but could be significantly higher if that same customer could be persuaded to purchase additional services from the same supplier. On this basis, existing energy companies and new

players are investing up to £400 to acquire new customers. The potential role of micro CHP as a tool to acquire new customers with relatively low marketing costs is therefore significant. Such a mechanism may be that the CHP unit is offered at a nominal cost to customers wishing to obtain a new boiler without themselves incurring cash outlay. The marginal cost would be recovered by the additional profit available on energy sales. The lease mechanism also serves to overcome the problem often faced in a competitive market, namely the rapid turnover of customers who do not show loyalty to a supplier without incentives. Examples include the mobile phone market where customers tend to switch service providers who offer better deals, unless tied into some form of lease which requires them to repay the true cost of the product in the event of switching service providers.

Additional business benefits of micro CHP

The installation of numerous embedded generators as a substitute for central plant might seem quite radical to a utility historically dependent on large generating plant such as nuclear. However, on an aggregate level the potential for 3 kWe micro CHP in Germany is 7 million installations which corresponds to a generating capacity of 21 GW. In the UK the corresponding figures are 5 million installations and 15 GW respectively. Although this would not be considered “firm” capacity in the traditional sense, the very large numbers of units would mean a diversified risk of plant failure and it would probably be safe to assume that a certain proportion of the total could be considered “firm” on a statistical basis. Furthermore, the generating profile would be particularly beneficial to a network operator as the capacity generating at any given time would vary broadly in line with demand. It would also vary in line with demand location. Additional benefits include:

1. **Incremental risk.** Unlike central plant where the entire capital investment is committed before a single kWh is produced, the installation of micro CHP units results in incremental availability of capacity. In other words you get power as soon as the first unit is operating and the amount of power increases daily as investment is made and units are installed. This means that capacity can be made available flexibly and rapidly without a need to select and acquire sites, obtain planning consent and incur the substantial associated administrative costs.

2. **Strategic risk.** Central plant, particularly nuclear stations, suffers from long lead times between a decision to invest and the plant coming on line. This can often be in excess of 10 years and, even with CCGT which is generally regarded as having shortest lead times, can be 3-4 years even after sites are acquired. During that period circumstances may have changed and the plant may either no longer be required, be in the wrong location, may no longer comply with emissions or other environmental or performance demands or may simply not be permitted to operate at all.

3. **Proximity to consumer.** By definition, micro CHP capacity is located at or near the point of use, so in addition to avoiding the costs and efficiency losses of distribution infrastructure, it is inevitable that as the generation follows the

demand profile on a time basis, it also follows it on a locational basis. It also avoids the very problem which most besets new central plant, namely that the capacity is required where people live, but they do not want that capacity in the form of central plant, and most certainly not nuclear, anywhere near where they live.

4. **Environmental impact (local).** The global environmental impact of micro CHP is discussed elsewhere, but pollution at a local level must also be considered. Central plant cannot be located near point of use without substantial investment in emission control. With micro CHP, the emissions are no different than that already existing for the central heating boilers. Other issues that need to be considered are the cost and the hassle involved in acquiring sites for constructing central plant as well as access to other resources such as cooling water and the distribution network.

Business threat

The potential business opportunity is substantial, but so is the potential threat from other existing energy companies as well as new entrants to the market. A detailed appraisal of the issues would involve somewhat different perspectives for generators, transmission companies, distribution companies and suppliers. However, in general terms, the threat falls into four main areas:

1. **Loss of opportunity**. This is the least significant issue here and relates simply to the reality of losing the business and profit with operating a micro CHP business in the existing territory or wider afield. This amounts to the £600 million per annum or so mentioned above.

2. **Loss of revenue and customer base**. If another company uses the same mechanism to steal existing customers, there is a cumulative potential loss of around £120 million per year in the example mentioned earlier. This results from loss in direct energy sales to the effected customers, together with the loss of those customers from the energy company's customer base for the provision of *any* services. Of course, it will also put the competitor in a stronger position both within that energy company's territory and throughout the surrounding area. UK experience has shown that those companies which do not grow at the expense of others are doomed to be absorbed by their larger competitors within a 2-3 year timescale.

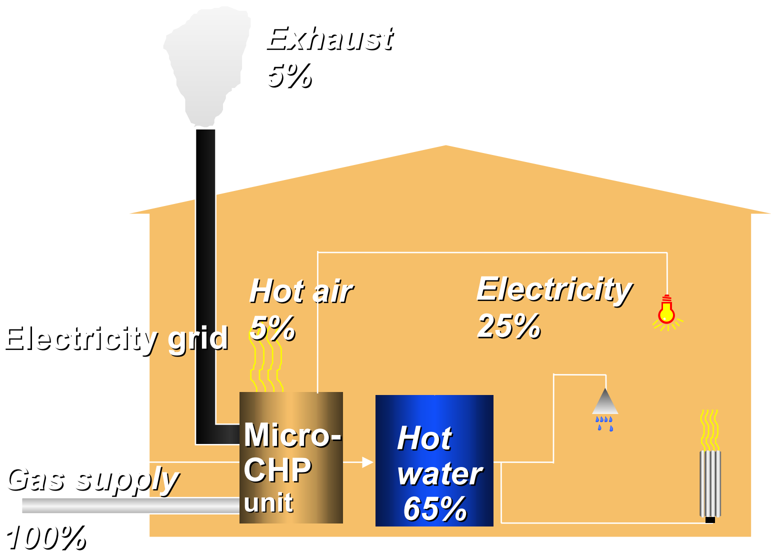
3. **Stranded assets**. For energy transmission and distribution companies there is the added penalty if energy is not sold to customers, that is the under-utilisation of assets. A generator will suffer still further from this "stranded asset" syndrome and be faced with loss of revenue and no means of gaining a return on substantial fixed assets. For a generator to install micro CHP resulting in his own stranded assets might seem unattractive. However, to allow a competitor to do so on the same network is even less attractive.

4. **Network costs**. From a commercial viewpoint, the DSM (Demand Side Management) measures which seem so attractive to the owner of CHP systems can be a significant

problem if acting against the energy company's interests. Provided the micro CHP systems comply with safety requirements, it will be very difficult within a competitive market to prevent them being installed anywhere on the network, regardless of the implications this may have for network reinforcement. In extreme cases it may be necessary to reinforce a network where the energy company has no control of the generation and no benefit from the sale of kWh. The only income will be derived from the distribution business which may not even be enough to cover the existing network costs, let alone the additional reinforcement costs.

APPENDICES

How micro CHP works



Micro CHP concept.
Natural gas is consumed in a Stirling Engine to provide heat and electricity for use within the home. A total of 70% of the energy value of the gas is converted into useful heat, with 25% being converted into electricity. Around 5% is lost in the exhaust gases. This compares with a conventional gas central heating boiler where 70% of the energy in the gas is converted into useful heat and the remaining 30% is lost to the flue gases. The electricity generated in the home has a value which covers the investment cost of the micro CHP unit and provides a net saving.

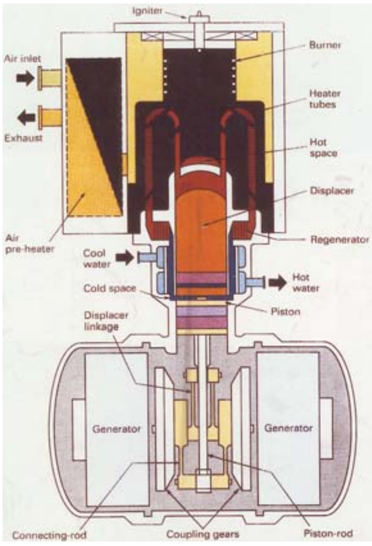
Sigma *PCP* ™ - based micro CHP system

PCP ™ (Personal Combustion Powerplant)

The PCP is the heart of the CHP system and comprises two elements, the Stirling engine and the generators. The Stirling engine, fuelled by natural gas, drives a pair of balanced counter-rotating electrical generators. The cooling water from the Stirling engine heats the home, whilst the generators supply electricity. A number of controls, ancillary components and safety devices are required to operate the PCP.

The Stirling engine operates by continuous heating and cooling of a fully enclosed working gas. This causes the working gas to alternately expand and contract. The alternate compression and expansion of a fixed amount of high pressure helium gas produces mechanical work that is transformed into a rotating movement to which the electric generators are connected. The continuous external combustion process of the Stirling engine provides good combustion control and low exhaust emission levels. Within the closed Stirling cycle, pressure variations of the working gas follow an almost sinusoidal curve, which is one of the basic reasons for the low noise and vibration level of a Stirling engine.

Compared to internal combustion engines, heat losses in a Stirling engine are more concentrated into the cooling water. This characteristic can be utilised to allow the Stirling engine to provide the necessary heat for hot water requirements in a house.



WORKING PRINCIPLE

1. Displacer piston moves the working gas (Helium) enclosed within the PCP between the hot and cold volumes, inducing pressure changes.
2. The pressure changes drive the working piston beneath the displacer.
3. The working piston drives the crank mechanism which converts the reciprocating movement to rotational movement required for running the generators.
4. Smooth pressure changes combined with the special design of the crank mechanism provide for oil-free operation.
5. Combustion takes place externally creating very low emissions.

The output and efficiency of the Stirling engine are influenced by the pressure of the Helium and the temperature difference between the heated and cooled ends of the engine respectively. The pressure and the temperature difference should both be as high as possible to achieve maximum power and efficiency.

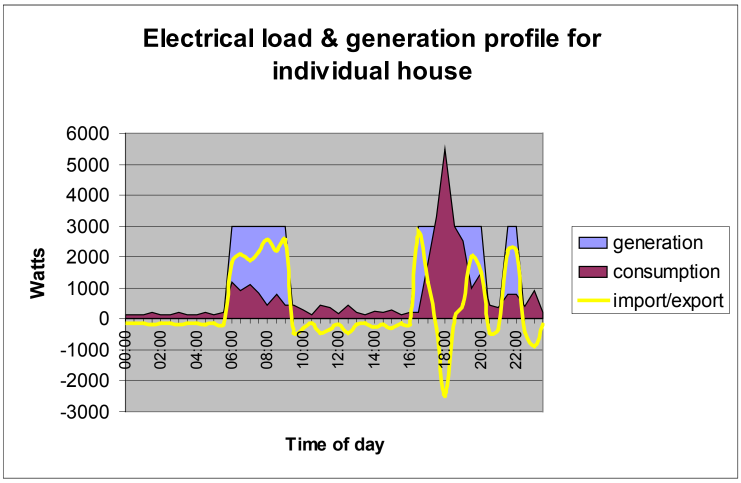
Commercial viability of micro CHP

Cost recovery

The viability of micro CHP is dependent on recovery of capital investment costs from the value of electricity generation. It is anticipated that micro CHP units will be installed to replace obsolete gas central heating boilers.
Clearly the micro CHP unit costs more to install than an equivalent conventional gas boiler. The marginal cost is around £1500 based on an installed cost for the micro CHP unit of £2700. The marginal cost must be recovered by the value of the generated electricity, both as avoided purchase of electricity and sale of surplus units (seen from the consumer's perspective). It is assumed that the alternative investment cost is for a conventional boiler with a seasonal operating efficiency of 70% (Gross Calorific Value). As the micro CHP unit has a similar thermal efficiency the electricity is effectively a free by-product. Seen from the utility perspective however, the cost recovery should be seen as though the micro CHP unit were a small power station.

Value of micro CHP generation

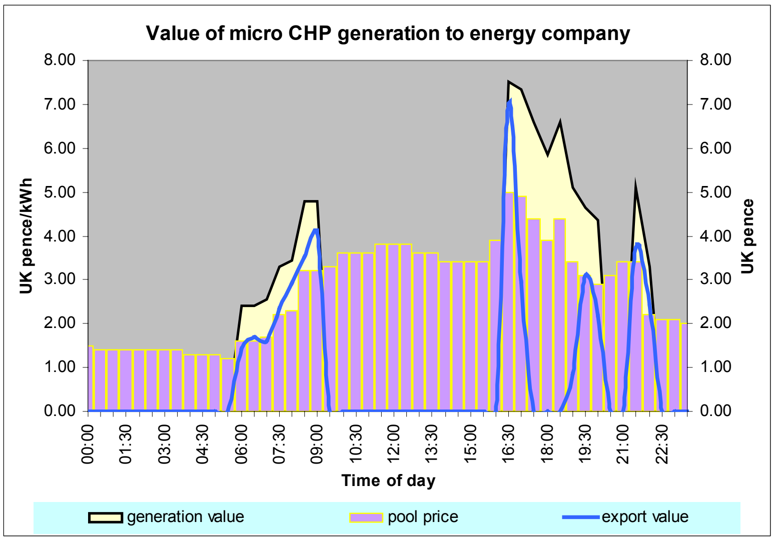
Operation of the micro CHP unit is thermally led, so that generation occurs when there is a demand for space heating. This generation is largely coincident (on a diversified basis) with electrical demand, although it is not possible to modulate the electrical output in line with highly variable individual domestic demand. There will, therefore, be periods when some "top-up" electricity will be imported from the grid. There will also be periods when surplus electricity is generated and it is anticipated that this will be exported to the network.



In the UK the price of electricity throughout the day is determined by the central market for wholesale electricity currently known as the "pool". The price depends on a number of factors including the demand on the network. The highest prices tend to occur during cold weather and at certain times of day, primarily early morning and early evening when domestic demand is at its peak. These are the same periods when micro CHP will operate most, so that the resulting generation is, almost by definition, load following.

The graph below shows (in principle) the value of exported kWh, the value of generated kWh and the pool price during the 24 hours of a typical winter day. The generation profiles are derived from same data as the previous graph. The average pool price is 2.8 p/kWh, the weighted value of exported units is 3.0 p/kWh and the weighted value for all kWh generated is 3.2 p/kWh. Thus the value to the Energy Company is the avoided cost of purchase from the pool i.e. 3.2 p/kWh. Of course this capacity is available at the point of consumption. No TUOS (Transmission Use Of System) charges are applicable and it is arguable that DUOS (Distribution Use Of System) charges should also be insignificant.

However, all the scenarios for market viability have been calculated on the far more pessimistic basis of the consumer perspective, which only attributes a value of 2.8 p/kWh to exported units.



Note:

Export value (p) is the product of instantaneous pool price (p/kWh) multiplied by surplus (exported) generation (kWh).
Generation value (p) is the product of instantaneous pool price (p/kWh) and all electricity generated by the micro CHP unit (kWh). The total value, V, generated in one 24-hour period is represented by yellow shaded area on the graph and is calculated using the formula:

$$V = {}^{00:00}\Sigma_{23:30}\,(G*P)$$

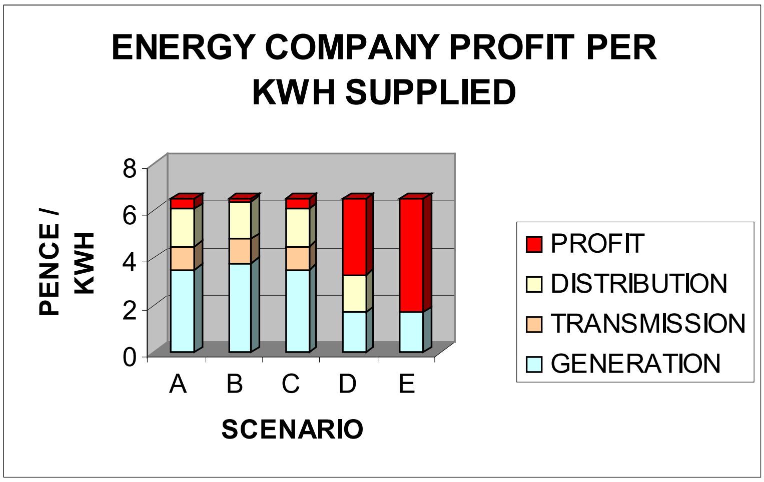
$$= \Sigma\,((G_{00:00})*(P_{00:00}) + (G_{00:30})*(P_{00:30}) + \ldots + (G_{23:30})*(P_{23:30}))$$

The average (demand weighted) value of kWh, P_{wav} produced during the same 24-hour period is equal to the total value divided by total production in that period:

$$P_{wav} = \frac{\Sigma\,((G_{00:00})*(P_{00:00}) + (G_{00:30})*(P_{00:30}) + \ldots + (G_{23:30})*(P_{23:30}))}{\Sigma\,((G_{00:00}) + (G_{00:30}) + \ldots + (G_{23:30}))}$$

where P is price per kWh and G is kWh generated.

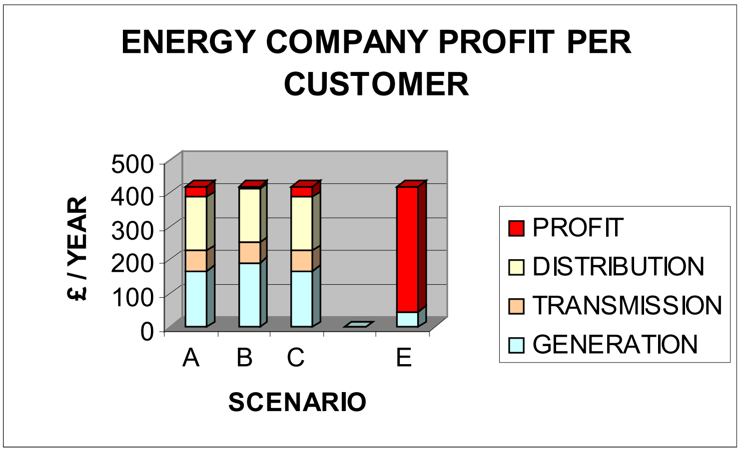
Currently the net profit gained from retail electricity sales in the UK is extremely small, often as little as £4-6 on a typical annual bill of £260 (consumption around 3300kWh pa). The graph below illustrates the build-up of costs included in a typical UK marginal electricity price of 6.5 p/kWh. As all suppliers pay the same pool price for units, there is very little flexibility to reduce prices. However, if electricity is owned at the consumer's meter it has a significantly higher value and is obtained at a lower cost as explained above.



A	existing situation based on average pool price
B	existing situation with demand-weighted pool price
C	ESCO purchases generation from end user
D	ESCO owns units & sells to other retail customer
E	ESCO owns units & sells to end user/host

Of course, scenario E is only relevant for baseload operation of a CHP unit owned by the energy company, such as in a small hotel with a continuous demand for hot water and an electrical load continuously in excess of the 3 kWe output of the micro CHP unit. In all other scenarios it is necessary to include an element for import/export to and from the home respectively. Taking the example of a customer operating a micro CHP unit owned by the energy company for 3000 hours per year, a total of 9000 kWh will be produced annually. Around 4000 kWh will be consumed within that home avoiding transmission and distribution costs and providing the supplier with a profit of 4.8 p/kWh after paying the amortisation and maintenance costs of the CHP unit. The remaining 5000 kWh produced will be exported and sold to another customer within the low voltage network, avoiding transmission but not distribution charges. Assuming this (larger than average) home consumes 6000 kWh per year, the supplier will still have to purchase an additional 2000 kWh either from the pool (worst case) or from a nearby CHP unit. Even taking the worst case scenario, the value of each such customer increases from £6 per year to £370.

The following chart illustrates the impact of micro CHP in this example, with the profit component of the total electricity bill (shown red) clearly indicating the dramatic improvement in



A	existing situation based on average pool price
B	existing situation with demand-weighted pool price
C	ESCO purchases generation from end user
E	ESCO owns 9000kWh & sells 4000kWh to end user/host, imports 2000kWh & exports 5000kWh

profit. Note that the "generation" component in this case is the net cost of the generation after the export value (at demand-weighted pool price) has been deducted.

Capital costs of generating plant

In addition to the issues discussed earlier, there are direct financial benefits when considering the implementation of micro CHP in relation to central plant. Specifically these relate to the cost of constructing capacity as well as the cost of generation, transmission and distribution.

This section considers the costs for a range of alternatives. Although there are many alternatives for new capacity, the following are considered to be the most relevant for the UK and German markets and are indeed those most commonly proposed. Nuclear is included for historical reference purposes and because it may, in extreme cases be advocated as a CO_2-free power source and hence environmentally advantageous. The costs for the range of plant types considered are summarised in the following table, with further explanations below.

Plant type	Distribution cost per kW (£)	Plant cost per kW (£)	Total cost per kW (£)
Nuclear	300-600	1700	2000-2300
CCGT	300-600	300-650	600-1250
CCGT with CHP	300-600	700	1000-1300
Waste	300-600	2000	2300-2600
Lignite	300-600	1000	1300-1600
Micro CHP	None	500*	500

Note:
1. *Costs are based on the 1995 UK Electricity Handbook*
2. **marginal cost*

It is arguable that micro CHP should be attributed with some distribution costs, perhaps at least to cover the cost of providing reactive power, and other network services such as voltage and frequency control and start up capacity. However, it is clear from the table that the true cost of micro CHP is by far the cheapest given an honest comparison. One of the reasons for the current emphasis on CCGT stations is that they can be installed on the same sites as existing coal-fired plant, thus avoiding a large part of the network cost if the old plant is shut down. However, micro CHP is still competitive even in just capital terms.

Nuclear

The quoted cost for Sizewell B nuclear plant was £2,030 million for a stated capacity of 1,188 MW. This equates to £1,700 per kW. However this is only part of the story as this cost does not include the cost of enquiries, transmission, land and planning consent, and most importantly, decommissioning. Even assuming straight-line depreciation with no interest cost over a 30 year life, this equates to a cost of ~0.7 p/kWh, before fuel costs, manpower, etc. Nuclear generation operates as base load capacity and therefore represents the lowest value kWh on the network.

British Energy (the largest UK nuclear generator) claims generating costs of 1.98 p/kWh overall. Even without the environmental and political obstacles to nuclear plant, it is clear that this relatively high cost is a primary reason behind British Energy's planned move into CCGT generation.

CCGT

There is a wide range in the quoted cost of CCGT plant, depending on a number of factors such as location, proximity to existing infrastructure and scope of the installation. These range from ~£300 /kW (Didcot B), ~£320 /kW (Connah's Quay) to ~£650 /kW (Dagenham). These are intended for installation alongside existing thermal plants on the same sites and with the same distribution infrastructure. Otherwise, it is unlikely that they include the cost of land, planning consent/enquires, and network infrastructure. For example, Connah's Quay required a pipeline from Ellesmere Port, ~10 miles, for gas supply which will have cost tens of millions of pounds. Typical transmission reinforcement is likely to cost between £300 and £600 per kW (EA Technology estimates, based on distribution costs).

Note: CCGT and indeed all gas power only schemes are currently effected by the UK moratorium on new gas-fired plant.

CCGT with CHP

A 214 MW CCGT plant providing heat to Courtaulds Chemicals at Spondon is quoted at £700 per kW.

Waste

Belvedere (London) proposed waste to heat site for Cory Environmental quoted as £200 to £225 million for a 112 MW plant, which equates to ~£2,000 per kW. This was refused a permit from the pollution inspectorate at the time of publishing, but hoping to be successful when re-submitted. Also required NFFO (Non Fossil Fuel Obligation- a government levy/subsidy to promote environmentally friendly generation) support to succeed. Of course when considering waste-burning schemes, the fuel often has a negative cost so that the overall economic case is improved.

Lignite

Only one plant was listed for Ballymoney in Northern Ireland, with approximate costs of £500 million for a 500 MW plant, which equates to £1,000 per kW.

Micro-CHP

If you consider the micro-CHP unit at a total installed cost of ~£2,700 with a capacity of 3 kWe, the overall cost is ~£900 per kW, which is still competitive with most other options.

However, if we consider the overall situation where the micro CHP unit displaces an obsolete gas boiler, a more sensible comparison is that of the marginal cost compared to conventional gas boiler practice. In this case, the marginal 'construction' costs reduce to £1500 or about £500 per kW, and if we assume that the micro CHP unit replaces a conventional boiler with 70% conversion efficiency (gross calorific value), no additional gas is used by the CHP unit to produce electricity.

Therefore the comparison with CCGT is at least £300 per kW construction cost (excluding all infrastructure and other costs described earlier) and ~0.6 p/kWh fuel cost, plus labour for the CCGT, as against £500 per kW for the micro-CHP option, with effectively no fuel cost. If we consider the impact of capital investment on the resulting cost of generation, it is possible, in a simplified model, to divide the cost per kWe by the total number of running hours over the financial life (10 years) of the plant. The CCGT runs for ~8000 hours per year, whereas the micro-CHP runs for ~3000 hours per year, so taking straight line depreciation over 10 years of electricity production (excluding interest), the micro-CHP units cost 1.67 p/kWh, whereas the CCGT units cost 1.6 p/kWh (plus labour).

ILLUSTRATION OF CCGT COSTS

CCGT capital cost per kW	=£300
80,000 kWh per kW over 10 years	=£300/80,000 per kWh
	=0.375 p/kWh
fuel cost	=0.6 p/kWh for gas
conversion efficiency	=50%
electricity cost	=0.6/50%
	=1.2 p/kWh
total cost of CCGT electricity	=0.375+1.2
	=**1.575 p/kWh** plus labour

The CCGT generated power then requires transmission and distribution, but it must be remembered that this CCGT capacity represents base load and more expensive, flexibly generated units must be purchased at peak times. The typical marginal selling price is 6.5 p/kWh under the current fierce competition, whereas the micro-CHP can deliver kWh for less than 2 p/kWh and with a generation profile broadly in line with peak demand profile.

ILLUSTRATION OF MICRO CHP COSTS

Micro CHP capital cost per kW	=£500
30,000 kWh per kW over 10 years	=£500/30,000 per kWh
	=1.67 p/kWh
fuel cost	=1.2 p/kWh domestic gas
conversion efficiency	=∞ (free by-product)
electricity cost	=1.2/∞
	=0.0 p/kWh
total cost of micro CHP electricity	**=1.67 p/kWh**

In addition to the financial points discussed above, the major issues for anyone considering micro-CHP as a distributed generation opportunity are:

- No planning consent problems - positively welcomed by users
- No pollution consent problems - as above
- No resource problems (cooling, network access)
- Likely to be financially encouraged by governments
- Real costs are identified
- No requirement for other infrastructure (which may increase real costs considerably)
- Although there are risks with new technology, the risk is distributed, as is the risk of failure in the supply stream or network

Technical implications for the network

- **Back feed voltages and system instability.** Most distribution systems are designed with certain assumptions being made about the power requirements at each respective voltage level. If the power requirement is higher than anticipated the result is a fall in voltage and all systems are designed to cater for this eventuality. However, it is most unusual for the power requirement at any level to be negative, that is for there to be a net voltage rise downstream of a low voltage substation. Such an event would almost certainly lead to problems throughout the local network and possibly as far as the high voltage network. Although, of course it is possible to use automatic tapping on substation transformers, this is not common in the UK for distribution substations and will incur additional capital expenditure. This is just one of the many investment implications of embedded generation.

- **Power quality and security of supply**. This is often cited as a major cause of concern for network operators. However, in practice, if the embedded generator is required to comply with statutory standards there should be no problem with power quality issues such as harmonics. Nor should there be a problem with loss of supply. It is far more likely that one nuclear station will be taken off line than that an equivalent micro CHP capacity should instantaneously be lost. It is indeed difficult to imagine how 300-400,000 micro CHP units could simultaneously fail, although even so micro CHP may not be considered as firm capacity.

- **Reactive power.** The Sigma PCP-based micro CHP package currently envisaged makes use of induction motors as generators. The use of asynchronous generators requires reactive power from the grid for excitation, although it also ensures that the units remain synchronised permanently with the grid. However, this feature means that the network operator is paying for the provision of reactive power, which is not normally metered for domestic installations. The approximate cost for this service would be £50-60 per year (or less depending on level of power factor correction used).

- **Anti-islanding protection.** One benefit of this dependence on grid-reactive power is that in the event of mains failure the micro CHP system automatically ceases to generate so that the network fails safe and permits on-line working. However, if many of these units are in operation on the same low voltage network there is a risk that they may mutually excite and operate in what is known as “island mode”. To prevent this, the units are provided with sensitive frequency and voltage relays which will trip them in the event of fluctuations in either parameter, which would certainly occur in the absence of a stabilising network power supply.