MICRO COMBINED HEAT & POWER
POTENTIAL IMPACT ON THE ELECTRICITY SUPPLY INDUSTRY

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Micro CHP is a "disruptive technology". It has the potential to substantially disrupt the established electricity supply industry both economically and technologically. It has a predicted capacity of similar order of magnitude to the existing nuclear generating capacity in the emerging liberalised energy markets in Europe.

Micro CHP, installed in individual homes, will in time remove a substantial electricity demand on a dynamic basis at the low voltage level, and may, in some instances, neutralise or even reverse the power flows in distribution transformers. This will clearly have economic consequences for the Distribution Network Operator (DNO) in terms of lost revenue, but will also have profound consequences for LV network design.

The economic opportunities, and to a lesser extent environmental drivers, which are leading to the imminent advent of micro CHP, will disrupt and will require a response from electricity companies. There are those who will no doubt seek to obstruct the new technology and maintain the status quo of their business. However, in the long term, the considerable economic benefits to the operators of micro CHP should prove irresistible. At the other extreme are those companies who will enthusiastically embrace the new technology and significantly improve their competitive position. These latter companies are already in the process of establishing strategic alliances with technology providers, manufacturers, service, installation and energy service companies and are acquiring technical and commercial experience by undertaking laboratory and field trials.

A range of micro CHP technologies are approaching commercial launch and the remaining challenges relate less to core technology and more to peripheral and interface components and commercial packaging.

It is at this stage that the implications for energy companies, suppliers and network operators, are becoming clearer. In general these challenges fall into two main areas, commercial and technical. Within the commercial area, the complexity of metering and settlement of domestic import/export represents a formidable challenge, whilst the technical standards appropriate to integrating numerous very small generators raises entirely new issues both at the customer interface and throughout the LV network.

This paper summarises the status of micro CHP technologies, potential applications and scope of markets. It describes the potential commercial and technical impact on existing electricity companies, their networks and customer base as well as identifying likely new market entrants.

Background

CHP has been identified by the UK government as a key component of its CO_2 abatement programme (1) and it also represents the most significant individual measure in achieving the European Union's CO_2 reduction targets (150Mt of a total of 800Mt) (2). In order to meet their CO_2 emission reduction targets agreed at Kyoto, the EU aims to double the proportion of power generated by CHP to 18% of total capacity.

However, it is now clear that the emerging micro CHP technologies which were not included in this original target may help to make up for the disappointing growth currently being experienced in conventional CHP markets. CHP generally represents a cost effective CO_2 abatement measure and micro CHP is potentially an even more cost effective measure. Perhaps more importantly, it can be readily implemented in the vast majority of existing homes for which relatively few substantial energy efficiency measures can be implemented in a realistic commercial manner.

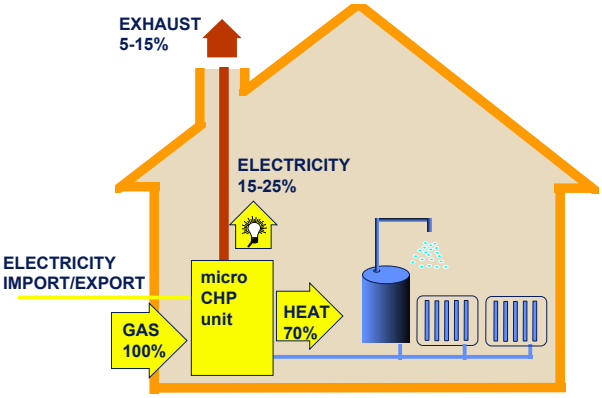
Sceptics might question the potential for micro CHP on a significant scale in a market which has been so hostile to conventional CHP and where market development has stagnated and even in some countries, where existing CHP plant is no longer being operated. However, the causes of this severe economic environment are less applicable to domestic CHP. In markets which have opened to competition, prices of electricity have fallen due to the incumbent generators' use of amortised plant to undercut new market entrants who have to finance their investment from improved overall efficiency. It is not surprising that the use of anti-competitive, predatory and unsustainable pricing has had an adverse effect on CHP developers, particularly those intending to supply large industrial customers. Recent developments in gas prices have further

undermined the economic case for larger scale CHP as the gas/electricity price ratio has become unattractive to those who do not have long term gas purchase contracts. Although domestic customers have seen significant real electricity price reductions since privatisation in the UK, domestic prices are still considerably higher than industrial prices. More significant though is that the element of these prices represented by the energy component is relatively small, at least 50% comprising transport charges and other overheads. The avoided cost of supply if power can be generated at a domestic customers point of use therefore has substantial economic benefits which are less susceptible to predatory energy pricing. At the same time, the gas prices which are causing such anguish to industrial CHP operators have virtually no impact on micro CHP. As will be explained later, the implementation of micro CHP has a negligible effect on gas consumption, and an increase in the price of gas has an almost identical effect with or without micro CHP.

Micro CHP concept

For those unfamiliar with the concept of micro CHP it may be helpful at this stage to consider the basic principles of operation. Although the energy flows indicated in figure 1 apply to Stirling engine based units, the illustration can be applied conceptually to other technologies including fuel cells.

Figure 1 - Micro CHP schematic energy flows



Natural gas is consumed in a Stirling engine to provide heat and electricity for use within the home. A total of 70% (GCV) of the energy value of the gas is converted into heat, principally in the form of hot water which is used for space heating and domestic hot water as in a normal central heating system. Between 15-25% is converted into electricity, and the remainder (5-15%) is lost in the flue gases. This compares with a conventional gas central heating boiler where 70% of the energy in the gas is converted into heat and the remaining 30% is lost in 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.

Although there are those who consider generators of 3kWe and below to be somewhat trivial, the key to micro-CHP is the very large numbers of units which may be installed and their significant cumulative impact. Based on a simplistic model considering end-user economics as the basis for implementation, micro CHP has a potential installed capacity of 15GW in the UK alone (3) of a similar scale to the nuclear industry. A more recent study considering the more complex, but more profitable economics from an ESCo perspective, indicates a potential market for micro CHP product sales alone in excess of 1,000,000 units or £2 billion annually (4) throughout Europe.

Impact on energy supply companies

The economic impact of micro CHP should be a major cause of concern to energy companies. In a competitive market where wholesale power is available to all at the same price and DUoS (distribution) and TUoS (transmission) charges are equitable and transparent, there is very little margin and little scope for competitive advantage unless a company has some technological or commercial edge over competitors.

Micro CHP provides just such an edge, by delivering electricity at a lower cost than is possible through the conventional distribution chain. Let us consider first the end-user economic case. Although it is unlikely that end-users will install and own micro CHP units, this simplistic approach at least identifies and quantifies the economic issues. It is assumed that micro CHP units will be installed in homes to replace existing gas boilers which have reached the end of their useful life. The householder is then faced with the choice of installing a new gas boiler (of which 95% in the UK are conventional boilers with a seasonal efficiency around 70%), or a micro CHP unit. Naturally the micro CHP unit is more expensive than the boiler, but the additional investment cost is repaid from the savings in electricity bills as well as the value of electricity sold back to the electricity supply company. The marginal cost varies depending on the micro CHP unit selected, a factor which

determines the appropriate market for each product. The two examples below consider the 3kWe Sigma unit and the 1kWe WhisperTech unit with marginal costs of £1500 and £600 as representative products for larger and smaller homes respectively.

On the basis of this simplistic model, it can be seen that both products have a payback of around 4 years. However, no account is taken of the benefits to the electricity supplier of the reduced cost of supplying such customers and, seen from the electricity supply company's perspective, the economics of micro CHP are even more attractive. The reduced demand will, however, result in loss of revenue for the DNO.

Example 1) Sigma (3kWe/9kWt) unit installed in a large UK family home with an annual heat demand of 27000kWh.

		kWh	£
Annual heat demand		*27000*	
Running hours	*3000*		
Electricity generated		*9000*	
Own use of generation	*45%*	*4050*	
Unit cost of avoided import			*0.07*
Value of avoided import			*284*
Generation exported		*4950*	
Unit cost of export			*0.03*
Value of export			*149*
Total value of generation			*433*
Marginal cost			*1500*
Simple payback (years)	*3-4*		

Example 2) WhisperTech (1kWe/6kWt) unit installed in small UK family home with an annual heat demand of 15000kWh.

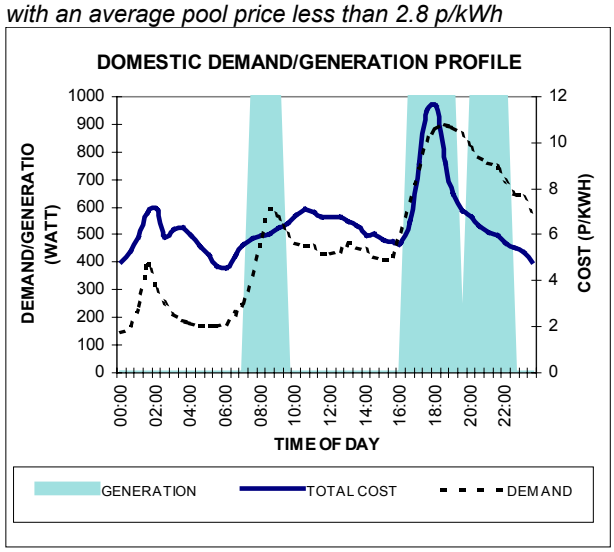
		kWh	£
Annual heat demand		*15000*	
Running hours	*2500*		
Electricity generated		*2500*	
Own use of generation	*70%*	*1750*	
Unit cost of avoided import			*0.07*
Value of avoided import			*123*
Generation exported		*750*	
Unit cost of export			*0.015*
Value of export			*11*
Total value of generation			*134*
Marginal cost			*600*
Simple payback (years)	*4-5*		

The electricity generated in a micro CHP unit is available to the energy company at the point of demand. Although it has high value (based on generation profile and point of generation) it 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 and around £150 for a smaller home.

The reason for the high value attributable to micro CHP generation is that it is produced at the time of highest wholesale price and at the geographical location where it is required. This latter point simply means that the transport cost is eliminated and the cost of supply reduced by more than 50%.

Micro CHP operation is thermally led, that is the unit operates when there is a demand for heat, and electricity generation is a by-product. As the pool price is substantially influenced by domestic loads and these coincide with periods of peak thermal demand, micro CHP units tend to operate most during periods of highest pool price. Micro CHP generation is therefore worth considerably more than the average pool price. Even if most of this power is consumed on site by the householder so that the resulting export occurs only during less highly priced periods, (such as is the case for smaller output units such as the WhisperTech product), the cost of supplying the home is reduced. Figure 2 shows this variation of cost and demand during a typical winter day, illustrating the value of micro CHP generation.

Figure 2 - Variation of electricity cost throughout a typical winter's day shows the value of micro CHP generation. Generation coincides substantially with peak supply cost, as does domestic demand. Demand weighted value of micro CHP is around 3.4 p/kWh over the year compared with an average pool price less than 2.8 p/kWh



However, even though the value of generation varies with time, the complexity of half-hourly metering and settlement would be prohibitively expensive under current conditions. Net metering has been advocated, both in order to simplify the process and to act as an incentive to encourage such an environmentally beneficial form of generation. This is likely to meet with justifiable resistance in a competitive market and is clearly unsustainable in the long term.

However, net metering against a modified unit rate provides the benefits of simplification without imposing unrealistic economic demands on the

DNO. This concept is already widely used for domestic supply settlement. Domestic loads vary substantially with time, despite being charged at a fixed tariff. Settlement based on a relatively small number of representative load profiles is used to arrive at a demand weighted cost of supply for domestic customers. There is no apparent reason why the same logic could not be applied in reverse, although it would require monitoring of a number of micro CHP installations to build up a database of representative profiles. It may well be that intelligent meters, capable of half hourly point of supply settlement, will become available within the next few years, providing an alternative settlement method.

Impact on generators

In terms of investment cost per kW, micro CHP is also set to become the cheapest form of new generating capacity, particularly if infrastructure costs are included in the calculations. However, financial considerations are not the only motivating factor for companies aiming to acquire generating assets or to achieve customer growth. Compared with conventional central plant solutions, micro CHP offers a wide range of benefits including avoidance of planning, resource and pollution consent problems, low incremental risk, short lead times, flexible location, and reduction in network losses.

Micro CHP as an ESCo business

The direct competitive benefits arising from micro CHP are significant in their own right. However, having once established an energy supply business with an unassailable competitive edge, it is possible to package the offering in such a way as to exploit a range of additional commercial opportunities in the delivery chain. These may well represent a substantially greater profit stream than micro CHP itself. UK householders are notoriously reluctant to invest in energy efficiency devices even with significant, short paybacks. This inertia can be exploited by offering an ESCo package with a guaranteed total bill lower than previously. Within this bill would be profitable product supply and leasing, installation and service business as well as highly profitable energy supply.

Impact on distributors

We have seen that, 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. At the anticipated level of market penetration, micro CHP generation, fed into the network at low voltage, may begin to have an impact on network stability within a decade, with implications for network design (to accommodate reverse power flow) and asset recovery.

The potential number of micro CHP installations will require a fundamental reassessment of network design and on technical standards for connection. The cost and manpower requirements both to micro CHP operators and to DNOs of complying with current engineering standards intended for substantial project engineered generators (such as G59) are excessively onerous and inappropriate for 1kWe generators. An agreed EU standard is therefore required as a matter of urgency and work in this area has already commenced (5).

Environmental considerations

The full impact of the emissions targets agreed at Kyoto has yet to be felt, but a number of EU governments have implemented pollution taxes, or incentives such as exemptions for improved performance. Already the UK has a Climate Change Levy (CCL) and Denmark has set a price of up to $13 per tonne for CO_2 emissions (6). 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.

The actual mitigation effect of micro CHP will depend on the particular technologies to be implemented and the generation mix they displace. On the assumption that it will be the most cost-effective forms of emission reduction which will be implemented, micro CHP generation will initially 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 typical (3kWe) micro CHP unit is 8.8 tonnes CO_2, 136 kg SO_2 and 50.4 kg NO_x. Taking the eventual market for the units at an estimated 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. On an individual basis the CO_2 quota would add about one third to the economic value of the micro CHP unit.

However, as the market develops it cannot be assumed that all displaced generation is coal and a more realistic figure would be 6 tonnes annually for this unit, based on a projected displaced generation mix of 700g/kWh (7).

Fuel cells with a rather high power/heat ratio would have a larger environmental impact on an individual basis, but the level of market penetration in the EU is likely to be relatively low for the foreseeable future. However, even within the Stirling engine based products there is a fairly

broad range of impacts varying from the Sigma 3kWe/9kWt unit with a relatively high electrical conversion efficiency leading to 8.8 tonnes CO_2 saving per year, to the WhisperTech unit with a lower electrical output (1kWe) and efficiency resulting in only about 1.7 tonnes CO_2 saving.

Technology status

It is self evident that without the maturity of one or more of the emerging technologies, little will be achieved, whatever the commercial and environmental drivers. Micro CHP prime mover technologies have been under development for many years. However, it is only recently that advances in materials technology and market focused development have brought the Stirling engine close to market. It is, perhaps optimistically, assumed by fuel cell manufacturers that investment in automotive applications will spin-off into micro CHP, accelerating development and reducing production costs.

Stirling engine based micro-CHP has evolved from being a research concept to the product development stage, and a number of manufacturers are trialling products in collaboration with energy companies. In the UK, Advantica (formerly BG Technology) have demonstrated a prototype 1kWe Free Piston Stirling Engine (FPSE) based unit (using the US, SunPower engine) which is being trialled in a test house during the 2000/2001 heating season. New Zealand based WhisperTech are in a similar position with a Stirling engine based product, already on sale as a DC version for the leisure market. A 3kWe Stirling engine based unit has been demonstrated by Sigma in Norway which is currently undergoing trials with Statoil.

Fuel cell based products have also been demonstrated and, in the USA, Plug Power and HPower have ambitious plans to field trial fuel cell units for "domestic" use. A similar unit is being trialled in Germany, although none of these would be considered appropriate for individual European homes. Sulzer Hexis have a prototype Solid Oxide Fuel Cell (SOFC) with a more suitable output of 1kWe, but production costs remain a major obstacle.

As mentioned earlier, the actual technology and the specific product under consideration has a significant impact on the resulting economic and environmental consequences. Units with higher thermal and electrical outputs will be most profitable in larger family homes with high energy bills where substantial savings are available. On the other hand, a larger mass market may be exploited by a cheaper, but less efficient, lower output unit. It is estimated that, of a total potential UK market of 12-13 million installations, about 5 million of these could be viable for the 3kWe Sigma unit (or eventually the HGC fuel cell unit) with the remainder being suitable for 1kWe units such as the BGT or WhisperTech units (8). It is anticipated that the first micro CHP units will become commercially available during 2002, being installed and operated by ESCo. Only one product (from ENATEC in the Netherlands) is proposed to be delivered through conventional product delivery chains for individual homeowners to purchase.

TABLE 1 - REPRESENTATIVE MICRO CHP PRODUCTS

Manufacturer	**Type**	**kWe**	**%**
Sulzer Hexis	SOFC	1	25
Plug Power	PEM	7	29
Hamburg Gas	PEM	3	25
Sigma	Stirling	3	25
SunPower/BGT	FPSE	1	15
WhisperTech	Stirling	1	12

Conclusion

The imminent availability of micro CHP products from a significant number of potential suppliers and the coincident appearance of potent economic drivers, confirm the probability of commercial launch of micro CHP within the next two years.

Whichever technology is adopted for micro CHP, energy companies need to understand the commercial and operational implications of its introduction, evaluate the consequences of micro CHP and formulate their own approach to succeeding in the face of this radical concept.

Energy Companies who fail to acquire the necessary technical and commercial competence at an early stage may face a powerful threat from the implementation of micro CHP by established competitors and new market entrants.

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