Micro CHP (Combined Heat & Power) and its relevance to the gas industry

Potential for micro CHP

Given the dire current market conditions for CHP in the liberalised European energy markets, the optimistic prognosis for micro CHP might come as something of a surprise. Even before the first true micro CHP systems have been commercially launched, the UK government has identified this technology as its most cost-effective carbon mitigation measure, and a key feature in its energy policy. It is anticipated that ultimately over 12 million systems will be installed in the UK and more than 50 million in the EU as a whole, representing a considerable business opportunity to manufacturers, installers and operators and a significant challenge to electricity distribution network operators. It has also been variously suggested that micro CHP will have a substantial impact on the gas distribution network, some commentators believing it will increase gas demand, whilst others believe exactly the opposite. Ultimately, it will depend very much on which "prime mover" technology is adopted, but for the next 10 years or so, there is likely to be little or no impact on the gas network.

What is micro CHP?

For those unfamiliar with the concept of micro CHP it may be helpful to consider the basic principles of operation as illustrated in figure 1. Natural gas is consumed in, for example, a Stirling engine to provide heat and electricity for use within the home. A total of 80% (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. Around 15% is converted into electricity, and the remainder (5%) is lost in the flue gases. This compares with a modern gas central heating boiler where 80% of the energy in the gas is converted into heat and the remaining 20% 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.

At these ratios, it is clear that there is no change in domestic gas consumption when a micro CHP unit is installed in place of a conventional modern boiler, although when replacing older inefficient boilers, there will be some gas saving. However, if high *electrical* efficiency prime mover technologies (such as fuel cells at 40% electrical and 40% thermal efficiency) are introduced, there will be a significant increase in gas consumption to meet the heat load.

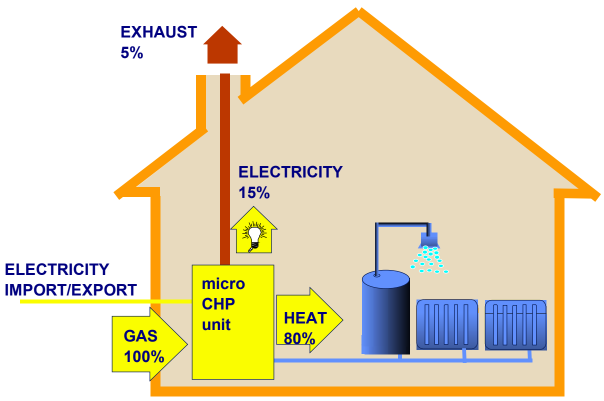


Figure 1 - Micro CHP schematic energy flows

Economic and environmental drivers

The key drivers for the introduction of micro CHP are environmental, economic and technological. However, as with the introduction of any new technology, economics are the pre-eminent driver, and it is the liberalised energy market in Europe that is creating a favourable competitive environment. Micro CHP offers the potential for significant energy cost savings and substantially higher profits for energy suppliers. In the competitive UK electricity market, for example, new retail customers generate as little as £4-6 net profit annually[i]. This is hardly surprising in a commodity market where all players have access to the same wholesale supplies (generation) at the same cost, and where all transport costs are identical for all players regardless of volume. The conventional way to increase net profit has been firstly to minimise staff costs, and secondly to optimise customer service costs by maximising customer numbers, but profit margins remain extremely slim.

However, only about half of the domestic energy supply tariff is due to energy costs, the remainder being transport and other costs. Clearly, micro CHP which generates at the point of consumption avoids transport costs and thus potentially halves the energy bill, (on average £330 per year), and creates potential profit in excess of £150, a factor of 30 higher! Energy suppliers thus have a powerful and profitable tool to acquire new customers and, equally importantly, to retain their existing customers, valued variously between £30-£400 each[ii].

As technology has evolved to meet the operational parameters of micro CHP, the remaining technical barriers relate more to the interface between products and the electricity network and the operation of these distribution networks. Current Stirling engine-based products have demonstrated adequate performance in real homes and appear to be able to achieve viable production costs.

The environmental benefits of micro CHP have long been recognised and EU and UK governments support the implementation of the technology. However, regardless of any idealistic motivation, it is generally the case that environmental measures are only implemented if there is some parallel economic benefit, and energy saving alone, however cost effective, is rarely sufficient motivation for domestic customers[iii]. Experience has shown that, until legislation was introduced, (the EU Boiler Efficiency Directive) condensing boilers were largely ignored in the UK, even where the economic case was proven.

Depending on assumptions regarding displaced generation[iv], micro CHP will reduce a typical household's annual CO_2 emissions by between 1.7 tonnes (WhisperTech 1kWe unit compared with UK average mix) and 9 tonnes (Sigma 3kWe unit compared with coal fired generation). Based on the anticipated ultimate levels of market penetration, this could represent a CO_2 emission reduction of as much as 60 million tonnes annually for the UK. However, it is the attribution of economic value to these emissions through measures such as CCL (Climate Change Levy) which is the key driver, and even this is only a significant factor for "rational" decision makers[v].

According to the PIU (UK government's think tank), not only is micro CHP economically viable for the end-user without any form of subsidy, it also represents the most cost effective carbon[vi] mitigation strategy of all technologies at or near market. In terms of carbon mitigation costs, micro CHP has a negative cost of *minus* £600 per tonne carbon displaced, compared with *plus* £1200 for PV generation, based on current UK conditions.

At a strategic level then, micro CHP is a powerful economic tool, but it cannot be applied in all markets, and there are a number of fundamental climatic, technical and other parameters which must be fulfilled for a viable micro CHP market.

The principal markets are those where there is a substantial thermal demand (space and water heating) for a significant part of the year, as it is generally accepted that the primary application for micro CHP will be as a replacement for gas-fired central heating boilers. Further, relatively high electricity prices and the availability of a natural gas network are of importance in achieving economic viability. It is for these last reasons that Scandinavia is not considered a viable market, whilst the relatively low thermal demands of Southern Europe limit applications in that region. The key European markets are therefore Germany, UK, and the Netherlands, with further potential in Italy and Spain. On a world-wide basis, many parts of Japan and USA also represent considerable potential markets, although it is too early to determine the potential for FIS and Accession States due to the highly complex political and socio-economic environment.

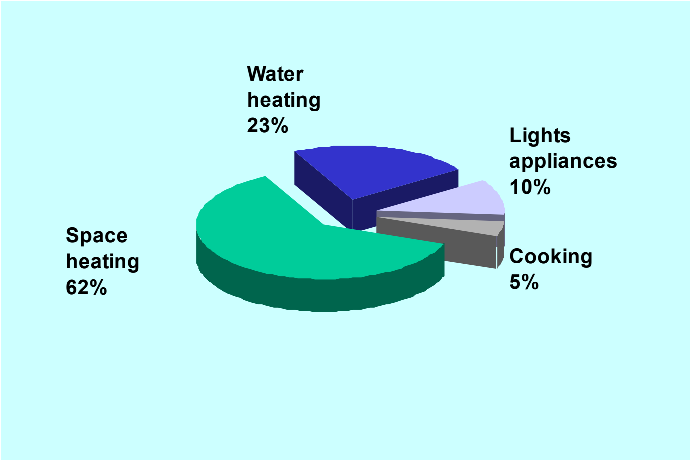
Even within the key national markets, not all homes are suitable for micro CHP either on grounds of practicality or economics. For example, smaller (or better insulated) homes may have insufficient heat demands to provide the energy savings required to recover the investment cost, and others may not have sufficient space for the units which are currently larger than conventional boilers. However, as new technologies, such as fuel cells, emerge it is possible that their thermal and electrical characteristics may be better suited to smaller homes.

Micro CHP operation is led by the thermal demand of the home and will generate power substantially in line with peak electrical network demand (which follows winter heat loads within the identified key markets). This peak capacity is generally provided by central gas plant (OCGT) and it is therefore this capacity which will tend to be displaced. Additionally, overall central capacity (including CCGT) may be reduced by the micro CHP output at other times. Thus bulk gas consumption at centralised power plants is likely to be somewhat reduced. However, if micro CHP is introduced to replace existing condensing boilers, there will be a marginal increase in gas consumption (around 10%) at the domestic level. (For replacement of older inefficient boilers, gas consumption may actually fall). There may therefore be an incremental shift from bulk gas supply to domestic supply, although it is unlikely that more than 1 million systems will be installed by 2010, so that this impact will be at a relatively slow rate.

Micro CHP as an energy efficiency measure in housing

The UK domestic sector represents around 30% of the nation's primary energy consumption and thus forms a major feature of the new energy policy, and a source of potential efficiency gains. Within this context, micro CHP can be considered a cost-effective energy efficiency measure, and as such, it must stand the test of comparison with other measures. With an investment cost of 1.6p/kWh saved, it rates well against cavity wall insulation and substantially better than double-glazing. However, it is less effective than loft insulation or wall insulation installed during construction. The logical conclusion then, is that micro CHP is an effective measure for existing homes, particularly when for example, there is no cavity to insulate.

Figure 2: Domestic energy consumption by end use[vii]



As the majority of installations are likely to be in existing homes, it is significant that over 60% of energy in a typical UK home is used for space heating, with an additional 23% for water heating. Only 15% in total is for lighting and appliances which may require electricity[viii]. These proportions are similar for other N European countries (e.g. France with 60% space heating, 19% water, 21% other)[ix]. It is thus more effective to invest in targeting the 85% thermal energy demand rather than the relatively small potential in electricity, particularly bearing in mind the high cost and poor generation profile of "power only" alternatives, such as photovoltaic generation.

In the longer term, it is worth noting that some micro CHP technologies (e.g. Stirling engines) are fuel flexible and, whilst they can make use of the current natural gas infrastructure, they could in the future make use of biogas or hydrogen when those fuels become widely available. They thus represent both a transitional technology and a potential Renewable Energy converter.

Obstacles to market introduction

Environmental and economic factors certainly appear to make micro CHP an attractive proposition. However, sceptics point out that micro CHP has been "near commercialisation" for several years.

Whilst it is true that a number of early contenders have failed to fulfil their promise, this is a common feature of technology development. What is perhaps surprising is that so many technologies have managed to overcome the severe technical challenges with minuscule budgets. Much was made of a recent announcement that BG Group and Rinnai were jointly investing $40 million in bringing their 1kWe unit to market. In terms of Stirling engine development it is an impressive investment and an order of magnitude greater than many of their competitors. However, compared with the billions which have been invested in fuel cells which remain a long way from market, their progress and that of the smaller players who are launching products within 12 months, is remarkable.

Although a number of manufacturers have successfully overcome the technical challenges, there remain numerous administrative, regulatory and economic obstacles to the widespread uptake of micro CHP.

Until recently, it was necessary in the UK to apply to the local DNO (Distribution Network Operator) for a connection agreement prior to connection of any generator. This procedure and the technical standards related to it were the same for all generators up to 5MWe. Clearly it would have been inappropriate in administrative terms if several million individual technical assessments and site validation tests were required. However, co-operation between micro CHP developers and DNO representatives has led to the introduction of standard procedures which allow type approved products to be installed by certified installers without prior agreement provided that the location and type of generator is notified to the DNO immediately on connection. A similar advisory standard has been produced by CEN for Europe, but this may take several years to become mandatory. However, little has yet been done to develop a method for enabling DNO to recover the cost of connecting large numbers of small generators and, indeed, even the costs themselves are poorly understood within the complex generation and demand scenarios encountered within LV networks.

The other area of concern is that of attributing economic value to the micro CHP generation which is exported to the network. There remains a significant amount of work to identify the true value of such generation, to effectively meter it and to agree a methodology for settlement. A number of subsidised schemes operate, for example in Germany, which either operate on net metering (where export is valued at the same price as import and meters simply run backwards as well as forwards) or at a predetermined level designed to support the introduction of particular technologies (requiring separate metering of exported power). However, neither of these approaches is sustainable within competitive markets. Activities are currently under way to address metering and settlement issues, but in the meantime, export is not credited within the competitive market and is simply “spilled” onto the network.

Summary

Micro CHP has a potential larger than that of the current nuclear generating capacity in Germany and the UK. As commercially viable micro CHP products are about to be introduced to the UK and other EU markets, it is clear that the technical product obstacles have been largely overcome. Despite the remaining procedural issues, government support for micro CHP is encouraging all parties to actively seek solutions to remaining obstacles which hinder, but do not block commercialisation.

It is likely that a number of products will be commercially available within the next year based on Stirling engine technology, followed by other prime mover technologies and fuel cells after 2010.

The consequences for the gas distribution infrastructure are not anticipated to be particularly substantial, although gas suppliers who choose to take advantage of micro CHP to enter the electricity supply market, can cheaply and profitably expand their customer base.

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Illustration:
WhisperTech 1kWe Stirling engine micro CHP installed in typical kitchen.

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