Towards a strategy for micro CHP in the USA domestic markets

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Background

Micro CHP (Micro Combined Heat and Power) has been identified as a significant element in fulfilling the energy efficiency and environmental aspirations of a number of European countries and has evolved from concept to imminent commercial reality over the past decade or so. EA Technology undertook feasibility studies as early as 1989 and has since worked with a number of micro CHP developers, assisting them in their commercialisation process. At the same time, numerous strategic studies[1] have been undertaken to evaluate the potential impacts of micro CHP on the energy industry in Europe. A number of micro CHP developers have indicated a limited commercial launch in the near future and it is likely that several hundred systems will be installed in the UK alone over the next twelve months.

The USA Department of Energy has identified the potential opportunity for implementing micro CHP to the various domestic markets and is seeking to determine an appropriate strategy for the exploitation of this technology. This paper aims to outline the key issues in this context, based on experience gained from the European market development process. It is intended to elaborate on the slide presentation given at the National Micro CHP Technology Pathways Workshop in Washington DC on 11th June 2003, as well as to respond to some of the points raised at that time.

Potential markets in the USA

It is clear that the USA domestic energy markets are significantly different from those in Europe, and indeed have very different characteristics across the continent. It should be born in mind that, even within Europe, domestic environments vary considerably and that the principle markets identified relate to those with relevant heat and power requirements matching available technologies and therefore leading to commercial and technical viability. Those key markets for initial micro CHP implementation are generally considered to be Germany, Netherlands and UK, countries with a combination of widely available gas networks, reasonably long heating seasons, high electricity prices and liberalised energy markets[2]. Although other markets may eventually exist, for example, where electricity and cooling loads exist, the current state of technology development, combined with the economic criteria in such areas does not provide an attractive commercial proposition at this stage.

The first pre-requisite then is to identify the market requirements both from the end-users' and other stakeholders' perspective. This should include industry groups such as distribution network operators, existing generators, energy suppliers, and domestic heating product suppliers as well as "USA Inc.".

There appears to be a wide range of views, and little consensus regarding the purpose of introducing micro CHP to the USA. Some seem to be advocating "high efficiency" as a goal in its own right, others attributing key value to electricity generation (with the implication of electrically led operation) and others attributing value to the overall match of heat and power between home and system, leading to thermally-led operation. There is the further complication as to whether systems should operate in parallel with the grid, be capable of acting as standby generators or even whether they should operate wholly independently of the grid and incorporate sophisticated (and expensive) storage and load management ancillary components. In other words, how is it possible to prioritise the various component benefits of micro CHP in order to focus investment of resources most effectively?

Essentially this requires an iterative evaluation of potential applications and technologies in order to determine the availability of technologies and products with respect to individual installations and related networks, as well as development requirements to meet these market demands. It is, however, important to avoid the undue influence of those who seek to advocate any particular technology or concept on ideological grounds or who have a personal agenda in conflict with the broader public interest.

The European experience

Following the early feasibility studies in the 1990's, a number of contending prime mover technologies emerged, each with a particular characteristic, which favoured some or other application. However, the key requirements of low service cost, long service intervals, and appropriate performance characteristics represented serious challenges to all of these.

By the late 1990's it seemed that the leading technologies had largely overcome these obstacles and that development work was focussed on integrating micro CHP packages suitable for the target markets earlier identified. Our experience with the WhisperGen unit for example, demonstrated acceptable service life and other prime mover performance characteristics in 1998[3], although further laboratory and field trials continued to raise component integration issues throughout the programme. This product is now at a stage where it can, with reasonable confidence, be launched under controlled conditions to its clearly defined target market[4]. However, it is not and does not claim to be a solution for all micro CHP applications. What it can do well is to address the needs of typical family homes with a particular hydronic system configuration. Other technologies, which have attempted to address the needs of a wider market sector, are facing considerable difficulties in meeting the sometimes conflicting technical challenges of diverse applications, and look less likely to reach market in the near future.

However, it is fair to state that the majority of technical and product issues have been resolved. This might lead to the mistaken conclusion that micro CHP can now be readily implemented in the target markets. Indeed, it is tempting to focus all efforts on the immediate needs of product development, without expending a matching effort on resolving the other major requirements, namely, the connection of such systems to the public distribution networks and the home itself. This now represents a major area of concern from both a technical and commercial perspective, and it is salutary to consider how long technical standards and procedures can take to amend even with goodwill on both sides. Broadly speaking, the product technology issues have been the concern of manufacturers, and surprisingly little public support has been provided to the leading technologies. On the other hand, network connection and structural market issues fall into the public domain and are being addressed by, in the UK for example, by regulatory bodies.

Technology status

Although there is no guarantee that the micro CHP products developed for the European market will be appropriate for any of the USA applications, the availability of prime mover technologies is a clear facilitator for the development of micro CHP packages. However, it is important to bear in mind the relevant performance parameters of the various prime mover technologies and, in particular, their heat to power ratios and operating costs. This section is therefore intended to give an indication of the leading technology contenders for European market applications and to give some idea of the resources which may be required to develop USA products.

Internal Combustion engines

IC (Internal Combustion) engine based products are currently available in Germany with outputs of around 5kWe and are intended to serve small apartment blocks or hotels. Several thousand are now in operation, although at this scale they cannot be regarded as "true" micro CHP. They do, however, demonstrate that, subject to rather high production costs, it is possible to employ IC technology in this application. This has been achieved by using specialist components, such as long-life spark plugs and oversized oil reservoir and by adding multiple catalytic converters, acoustic attenuators and heat exchangers. Apart from the high cost (around $2500/kWe), this also results in a very bulky unit, unsuitable for typical family homes[5].

Stirling engines

All of the the leading "true" micro CHP products are based on Stirling engine technology. In 2003, PowerGen (a subsidiary of the German EoN Group) plans to launch commercial micro CHP products as part of an "energy Services" offering using the New Zealand WhisperGen unit. This unit flies in the face of Stirling "received wisdom". It has a relatively low electrical efficiency, four cylinders (and resulting mechanical complexity) and yet manages to demonstrate the low production costs and the kind of service intervals necessary for commercial viability. The current status of the WhisperGen unit

is a salutary lesson to those who have unsuccessfully pursued high efficiency as a good *per se*. High efficiency is only achievable in highly stressed, high temperature engines using exotic materials and Helium (or Hydrogen) as a working gas, requirements that lead to high production costs and severe challenges for service life. The WhisperGen unit on the other hand, has demonstrated that a pragmatic approach, which compromises theoretical gains against the true requirements from the market, can deliver a viable product.

Two other products nearing commercial launch (2004), also use Stirling technology, although in this case they are Linear Free Piston (LFP) concepts, one from Sunpower the other STC, both originally USA designs. However, although apparently elegant in engineering terms, both have suffered considerable technological challenges, which are slowing their progress to market. Both the BG Microgen[6] (Sunpower) and the ENATEC[7] (STC) units incorporate a flow boiler to supplement the thermal output of the engine and provide instantaneous hot water whilst maximising the operation of the engine at its peak operating point. The ENATEC unit is, like the WhisperGen unit, floor-mounted due to its bulk, weight and possible vibration, whereas BG Microgen are attempting to develop a product suitable for wall-mounting, a feature which has advantages for space requirements.

Rankine cycle engines

Of significant interest, although a relative newcomer in this application is the recent emergence of a number of Rankine cycle engines. These are of particular interest because they were initially ignored as being inappropriate, due to their relatively low electrical conversion efficiency. However, following extensive market studies over several years, this issue is now considered by many commentators to be of less importance than the match of heat to power ratios of the equipment with those of the demands of the home. The key feature of the leading units is their relative simplicity (in manufacturing terms) which is likely to lead to relatively low production costs and known durability and other performance characteristics.
The Inergen unit (originally conceived by the Battelle organisation and using an organic Rankine cycle) for example, uses mainly “off the shelf” components, combined with modified commercially available products such as scroll compressors. This unit is currently being developed by the Energetix Group[8] in the UK and is planned for trials within the next year.

Fuel cells

At the other end of the spectrum, a number of fuel cell products (with theoretically high electrical efficiencies) are being trialled, although none approaches the production cost aspirations of their developers, and it is difficult to see cost-effective products reaching the market within the next 5 or so years. Notable amongst these are the Plug Power PEM unit being integrated into the micro CHP package (5 kWe, 35kWt) by German boiler manufacturer, Vaillant[9] and the Hamburg Gas Consult (1.5 kWe) unit being developed by Baxi Technologies[10], based in the UK. The former unit is, again, not strictly speaking a micro CHP unit, as it is intended to provide baseload operation for a small apartment block with supplementary heat from a separate boiler, rather than meeting the needs of individual homes.

It is interesting to note that Baxi and Vaillant, two of Europe’s leading heating appliance manufacturers, were initially seen as a potential obstacle to the market development of micro CHP, as some believed they would resist the threat to their existing product base. However, both companies have embraced the opportunity of micro CHP, and now include fuel cell and IC based micro CHP technologies within their proposed product range. Indeed, most other European manufacturers have also initiated a development programme of micro CHP products.

Market evaluation & developing business models

The diverse climatic, social and other characteristics of such a large area as the USA, inevitably means that there is no clearly defined market for micro CHP. Indeed, it is clear from discussions at the workshop, that there are several potential markets, although it is no easy task to determine which of these is necessarily the most relevant. It is quite probable that, in the early stages, industry will determine which potential market best fits their available products, although there is an emerging consensus amongst those who have studied the key potential markets[11], that the NE seaboard appears to have the climatic and economic characteristics which could facilitate the transfer of European technology at minimum cost and therefore achieve commercial viability soonest. However,

some degree of caution should be applied to simplistic assumptions regarding space heating requirements. For example, it should not necessarily be assumed that "degree-days" are necessarily a good indicator of climatic viability. A short severe winter (such as is found in Scandinavia, Alaska) may not offer the running hours necessary for adequate electricity generation to payback the original investment.

It is absolutely vital that, from the USA Inc. perspective, no judgement is made regarding relevant technology investment before a thorough market analysis is undertaken to identify the requirements, not just of the individual households, but also of the wider network. This should feed into an analysis and evaluation of potential business models. For example, should the products be provided on an ESCo basis, and if so what benefits would accrue to the operator compared to the unit being owned by the end-user?

Issues to consider in this respect include the benefits of aggregation to minimise customer management costs, appropriate metering and settlement methods and the assurance of quality of installation (with attendant safety implications) and service support. This latter, often underrated issue, has been a major impediment for some European technologies; poor initial support has led to some products, such as heat pumps and condensing boilers being considered unreliable and therefore undesirable by the general public in some States.

Whatever business model is adopted or promoted it is clear that the utilities, particularly the electricity supplier, should be involved in the process at as early a stage as possible. They stand to lose most in a competitive market and cannot simply be ignored. This is particularly true of the network operators.

Network implications

Of all the assumptions made in the early stages of micro CHP development in Europe, the most naïve and probably also the most common, was that the key obstacles related to the development of sufficiently efficient and reliable prime mover technologies. It was only as these technology issues were finally being resolved that the micro CHP developers were confronted with the inertia and vested interests of the DNO (Distribution Network Operators). These regulated utilities are rewarded and incentivised by a complex series of formulas, none of which relates to the connection of micro, or for that matter, any other generators. Their revenue is determined largely by the energy (kWh) they transport. The emergence of embedded generators connected to their networks, which both reduce their revenue and cause technical problems to network operation are therefore unlikely to be welcomed.

In the UK, where the government has identified micro CHP as a key element in its energy policy, great efforts have been expended in establishing a technical and commercial framework to incentivise DNOs and facilitate the connection and commercial operation of micro generators. The Regulator (OFGEM) has established a series of working groups with industry representation, to examine the complex issues relating to Distributed Generation[12] and to produce recommendations for issues such as:

- Metering and settlement
- Determining the value of micro CHP
- Determining the technical impact on networks
- Incentivisation mechanisms for DNOs
- Connection standards

Despite these efforts and the unprecedented rate of progress in several of these areas (the writing of engineering recommendations for connection of micro CHP to the network took less than 18 months), there remain a number of unresolved issues even as micro CHP products are beginning to be installed on a fully commercial basis.

Summary

It is clear that the market requirements in the USA differ significantly from State to State and certainly are not directly comparable with European conditions. However, the experience gained from introducing micro CHP to the European market can be of value to those who now seek to determine an appropriate route forward for the USA. A number of lessons have been learned, particularly with

respect to which challenges are likely to be most severe and what resources and time are likely to be required to meet them.

There is a clear need to identify and review the interests and potential conflicts of the various stakeholders, and to evaluate the commercial and environmental benefits which may accrue to the USA as a whole.

It should then be possible to identify potential prime mover technologies that may meet those market requirements and form the basis of a technology development programme.

However, last, but definitely not least, the concerns of the utilities and in particular the electricity distribution companies must be addressed at an early stage. Failure to do so will almost certainly hinder the progress of micro CHP and possibly damage the long term viability and benefits of this promising technology.

References and further information

[1] MICROMAP. European study of markets, applications and technologies for micro CHP. EU DGXVII report, 2000.

[2] Micro CHP European market study. EA Technology report, 2000.

[3] WhisperGen laboratory performance trials and evaluation. EA Technology report, 1998.

[4] PowerGen website. www.pgen.com/news/default.asp?display=detail&News_ID=486

[5] Senertec website. www.senertec.de

[6] BG Microgen website. www.microgen.com

[7] ENATEC website. www.enatec.com/EN01_ENG.htm

[8] Energetix Group website. www.energetixgroup.com

[9] Vaillant website. www.vaillant.com/

[10] Baxi website. www.baxi.com

[11] Tina Kaarsgard, US House of Representatives, Committee on Science; Steve Fischer, Oak Ridge National Laboratory

[12] DGCG website http://distributed-generation.org.uk/

Further information on EA Technology's micro CHP and Distributed Generation activities can be found at:

www.eatechnology.com

Additional useful links can be found at:

http://www.microchap.info/links.htm

Additional papers on micro CHP (including copies of this paper) can be found at:

http://www.microchap.info/micro_chp.htm