Potential for CHP in the UK

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Executive Summary

Introduction

The purpose of the Cogeneration Directive is to promote high efficiency Combined Heat and Power (CHP) where an economically justifiable demand for heat and cooling is identified in order to save energy and reduce CO_2 emissions. It does this by creating a framework which can support and facilitate the installation and proper functioning of CHP. Article 6 includes provisions obliging Member States (MS) to analyse national potentials for high efficiency cogeneration and barriers to their realisation.

An assessment of the economic potential for CHP in the UK was made during the development of the Government's draft cogeneration strategy to 2010. Here we provide an update of this assessment in the context of Article 6 of the Cogeneration Directive, drawing together analysis in three areas: industrial sectors, individual buildings and community heating. All three areas have been assessed using a bottom-up methodology, based on defined heat and power demands and costs and performance for CHP units.

The analysis presented below is an assessment of the costs and benefits of installing CHP in identified locations across the UK. The cost effective potential figure is from the investor point of view rather than the point of view of society. The societal perspective is the methodology used by the UK government[1] when appraising new policies or investments as it gives a more accurate picture of the welfare implications of any new policy or technology. For example, an investor would take into account subsidies when deciding whether it is worth investing in CHP. From an investor point of view, a subsidy is a benefit, but from a societal point of view the subsidy is simply a transfer from the government to the firm – the subsidy itself carries no benefit.

In this case it was judged that for the purposes of reporting to the Commission, an investor perspective would be more comparable across other Member States and therefore more in line with what the Commission requested. Please note this is not the UK Government’s view of the cost-effective potential, which may be smaller due a number of factors including discount rate and appropriate comparators. Incentivising the potential identified in the presented analysis may involve considerable effort and cost, possibly outweighing the benefits from lower energy use and carbon emissions from CHP.

[1] http://www.hm-treasury.gov.uk/economic_data_and_tools/greenbook/data_greenbook_index.cfm

The Analysis

In 2005, using the definitions in the Cogeneration Directive, there were 1,502 CHP units with a total electrical capacity of 5,440 MWe, generating 27TWh of electricity and 51 TWh of heat.

The latest energy projections for the UK by the end of 2010 are for 350 TWh of electricity supply with a projected contribution from CHP of 36 TWh (Cogeneration Directive basis). This projected contribution, of just over 10% of total electricity, is from the expected development of CHP and is not the economic potential.

The economic potential (at the market discount rate of 15% for industry and individual buildings and 9% for community heating) for additional CHP in 2010 and 2015 is shown in the table below.

In summary, by 2010, new (i.e. additional) generation of electricity is estimated to be around 61TWh, and by 2015 is likely to be abut 81 TWh, giving primary energy savings of about 44 TWh and 57TWh respectively. This generation potential is equivalent to about 17% of the projected total for electricity generation in 2010. In terms of additional capacity, this corresponds to about 8.2 GWe by 2010 and 10.6 GWe by 2015.

	Delivered Energy (TWh)		**Capacities (MW)**		**Energy Savings (TWh)**
	Heat	**Electricity**	**Heat**	**Electricity**	
2010	76	61	10,361	8,188	44
2015	94	81	12,529	10,567	57

This study uses bottom-up models of the potential for CHP and of necessity uses relatively simple cost effectiveness calculations. In practice, decisions on CHP will be influenced by a number of site-specific issues, which tend to reduce cost effectiveness and slow decision making on CHP development. This potential should therefore be regarded as an upper limit that will not be realised in full in practice.

The use of renewable-fired CHP and the inclusion of cooling demands would increase the potential, but it is not expected to be significant in the UK by 2010. This is also true of micro-CHP.

Barriers and support measures

The most significant barriers to the installation of CHP in the UK are a product of market conditions, mainly unfavourable electricity and gas prices and uncertainty over future market conditions and the continuity of Government fiscal benefits. Sources of significant uncertainty arise from the EU Emissions Trading Schemes and what will happen post 2012 and also from the longevity of industrial heat demands at particular sites.

Recognising the difficult market for CHP, the Government have put into place several support measures over the years including:

- Exemption from the Climate Change Levy of all Fuel inputs to and electricity outputs from Good Quality CHP.
- Eligibility for Enhanced Capital Allowances of Good Quality CHP
- Grants to support a Community Energy Programme, whereby the use of CHP in public sector lead district heating schemes is encouraged (now closed).
- Business Rates exemptions on rateable value for CHP power generation plant and machinery
- Favourable treatment for CHP in the second phase of the EU Emissions Trading Scheme
- Reduction in VAT on certain grant-funded domestic micro-CHP installations

The Government, in conjunction with the electricity and gas regulator Ofgem, are also addressing issues that more generally effect distributed generation such as the cost of grid reinforcement and the supply license for smaller suppliers.

Contents

Introduction

The Cogeneration Directive promotes high efficiency CHP, where there is an economically justifiable use of heat to save energy and reduce CO_2 emissions. It does this by creating a framework, which can support and facilitate the installation and proper functioning of CHP, for all existing or foreseen instances of demand for heat. Article 6 includes provisions obliging Member States to analyse national potentials for high efficiency CHP and barriers to their realisation. This is to allow the Commission to monitor Member States' progress towards realising their potentials.

This study draws together analysis in three areas: industrial sectors, individual buildings and community heating. All three areas have been assessed using a bottom-up methodology. However, the details of these assessments are different and the analyses are therefore described separately.

Section 2 of the report gives the current position of CHP in the market in the UK. Section 3 sets this in the context of projected energy supply and Section 4 details the barriers and policy drivers for CHP. An outline of the methodologies is given in Section 5, with details given in Appendices. The final sections give the results and conclusions.

Current position

In 2000, following an analysis of the potential published in 1997, the Government announced a target of achieving 10,000 MWe of CHP capacity by 2010. Fig. 1 illustrates the progress that has been made towards reaching this target, showing both the capacity and number of sites reported in the UK national statistics and, from 2003, the capacity and number calculated according to the Cogeneration Directive.

Figure 1 Installed CHP capacity by year

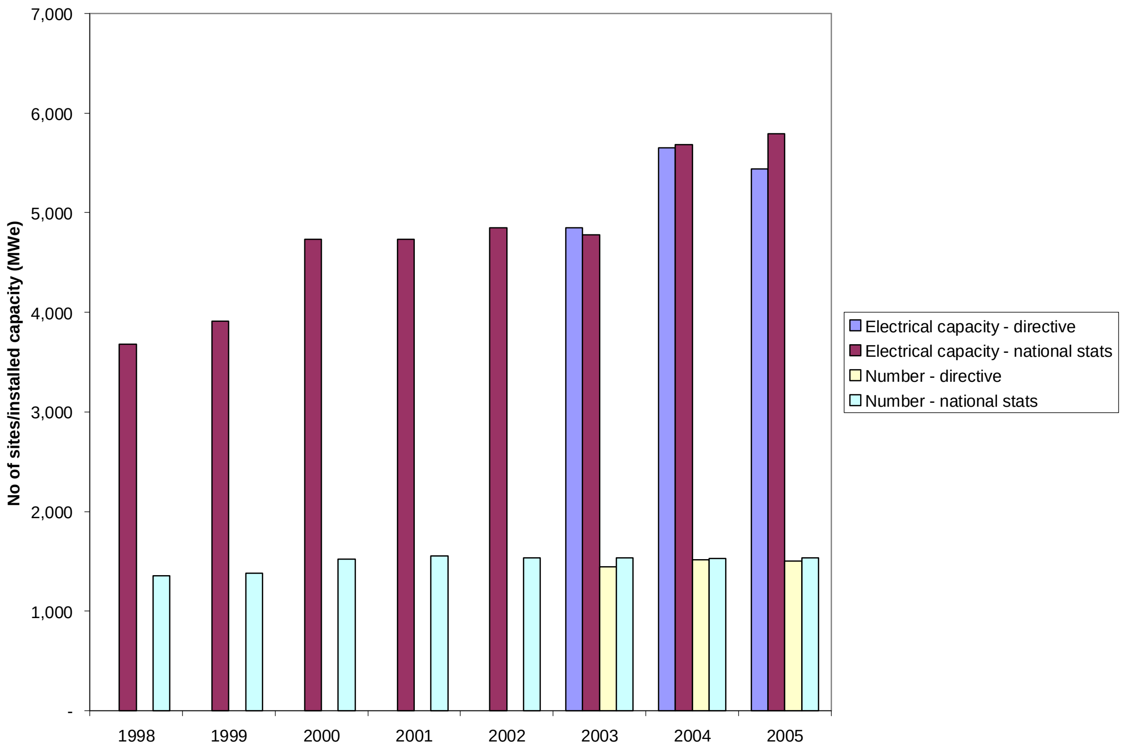


Table 1 shows the detail of how this has evolved since 2003.

Table 1 Evolution of CHP in the UK 2003-2005 (Cogeneration Directive definition)

	Unit	2003	2004	2005
Number of schemes		1,443	1,518	1,502
Total installed capacity	MWe	10,797	9,105	9,088
Good Quality Capacity (CHP)	MWe	4,848	5,653	5,440
Heat capacity	MWth	7,025	9,721	6,789
Fuel input (NCV)	GWh	98,499	99,352	95,376
Total electricity generation	GWh	48,729	51,634	53,122
High efficiency CHP electricity	GWh	22,950	26,337	27,237
Heat generation (CHP)	GWh	52,718	55,329	51,454

At the end of 2005 there were 1,502 CHP schemes installed in the UK with a total installed capacity of 9088 MWe of which 5440 MWe qualified as high efficiency CHP capacity. In 2005 some 27,237 GWh of electricity was generated by CHP in the UK (qualifying as high efficiency CHP electricity) which representing ~7 per cent of the total electricity generated in the UK by all methods. Across all commercial and industrial sectors (including fuel industries, but not including electricity generation) approximately 11.5% of electricity consumed was supplied by CHP.

Fig. 1 shows year on year growth in installed CHP capacity in the years 1998 to 2005. However, between 2000 and 2003 growth in installed capacity was muted, with the installed capacity in 2003 virtually unchanged from the 2000 figure. This is a reflection of the unfavourable energy market conditions for the operation of CHP that existed during this period. This is discussed in more detail in Section 4. Since 2003, there has been growth in capacity mainly due to the commissioning of large schemes that have taken a long time to develop.

Fuels Used in CHP in the UK

Figure 2 shows the use of fuels in CHP installations in 2004 and 2005 using the Cogeneration Directive definition. By far the most significant fuel used in CHP in the UK is natural gas. This fact tends to suppress the potential for CHP in geographical areas where there is no access to the natural gas grid (See Section 4).

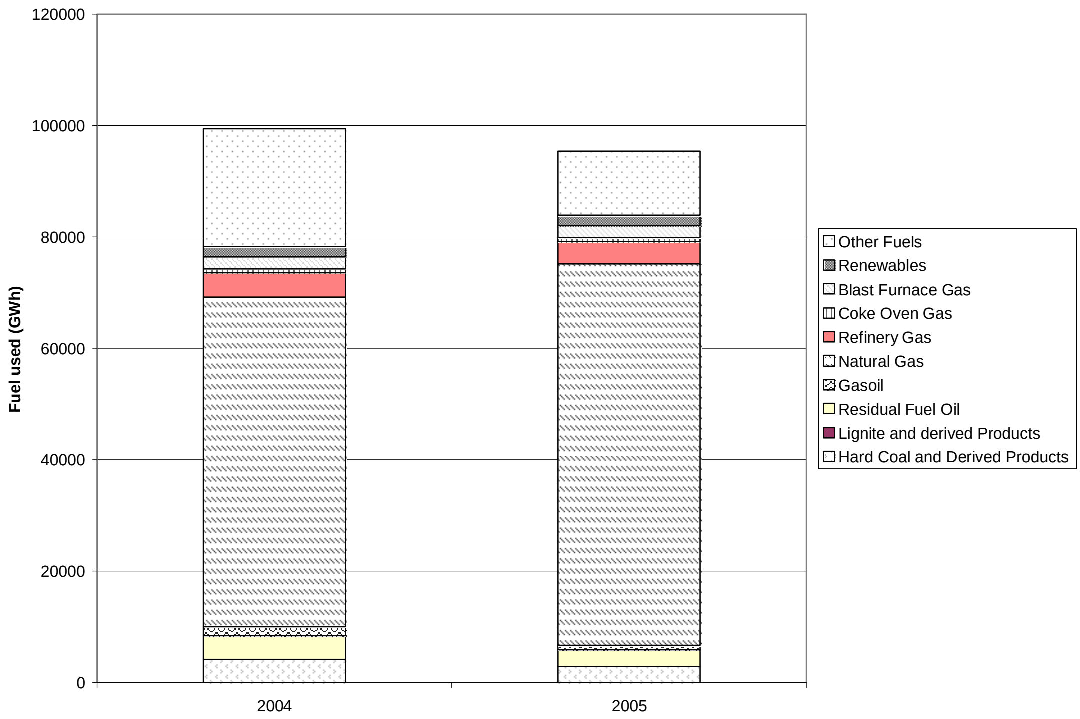


Figure 2 Fuel used in all CHP in 2004 and 2005

In 2005 approximately 20% of fuel used in CHP was classed as non-conventional fuel. Non-conventional fuels include solid, liquid or gaseous by-products or waste products from industrial processes and also include renewable fuels. The majority of these fuels are burned in external combustion engines, for example boilers used to raise steam for steam turbines. It is a characteristic of these fuels that the electrical generating efficiency will be lower than that achievable with conventional fuels. However, despite this lower efficiency there is a net environmental benefit, since these fuels displace conventional fossil fuels and must in any case be disposed of.

Projections of electricity supply

The projections presented in this section are from the updated projections for CO_2 prepared by the DTI and published in July 2006. They assume a CHP contribution determined by the projections of CHP capacity from Cambridge

Econometrics. The contribution from CHP is therefore a projection of what is expected to happen as a result of the policies in place not the economic potential for CHP.

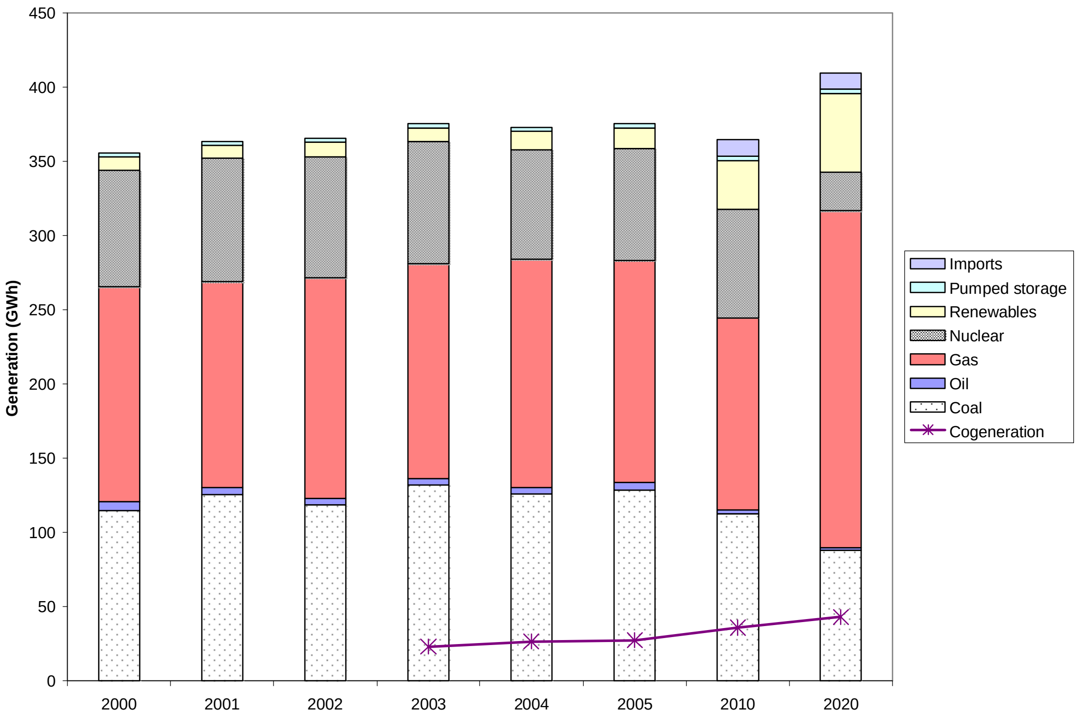


Figure 3. Actual and projected electricity generation mix

The projected generation mix beyond 2005 presented above in Fig. 3 is an average of two scenarios, both for a central fossil fuel price case. One of the scenarios assumes prices favourable for the generation of electricity using gas and the other scenario assumes prices favourable for the generation of electricity using coal. These scenarios are set by applying the same price for coal in both cases, but varying this price for different years, and then applying different gas prices for the two scenarios.

The proportion of electricity generated from CHP is not projected to grow significantly to 2010.

Barriers and measures to support CHP in the UK

Introduction

Investment in new CHP capacity has been limited in recent years and this has put into doubt the achievement of the UK Government's stated target of 10 GW of Good Quality CHP capacity by the end of 2010. Since 2000 the growth in new capacity installed has slowed significantly. This hiatus in progress towards meeting the Government's target has occurred at the same time as significant increases in fuel prices. At first sight this may seem paradoxical since the higher overall efficiencies associated with CHP of heat and power would be one way of reducing the financial impact of these fuel price rises. However, as will be shown below, the details of the fuel price and, in particular, the relative costs of electricity and gas are critical factors determining the cost effectiveness of running existing CHP installations and installing new CHP plant.

In recognition of this stagnated growth, the government has introduced a range of fiscal support measures designed to encourage the uptake of CHP. These support measures include:

- Exemption from the Climate Change Levy of all Fuel inputs to and electricity outputs from Good Quality CHP.
- Eligibility for Enhanced Capital Allowances of Good Quality CHP
- Grants to support a Community Energy Programme, whereby the use of CHP in public sector lead district heating schemes is encouraged.
- Business Rates exemption for CHP power generation plant and machinery
- Reduction in VAT on certain grant-funded domestic micro-CHP installations

Despite these current support mechanisms the projected installed capacity of Good Quality CHP for 2010 is now estimated to be 7500MWe, some way short of the target set by Government in 2000.

Below is a consideration of the obstacles and barriers to the installation of new CHP. Throughout this document a distinction is made between obstacles and barriers. The former tend to be unfavourable characteristics of the market that pertain at the present time, while the latter tend to be practical barriers or unwarranted disincentives to the operation and installation of CHP.

Obstacles to installation of CHP

Typical market obstacles faced by CHP are:

- unfavourable gas and electricity prices;
- volatile fuel prices and uncertainties;
- uncertainty about how a particular site’s heat demand will evolve over time; and
- the need for high initial capital investment.

Unfavourable gas and electricity prices reduce the return on the investment in CHP and erode the advantage over conventional generation. When combined with the increased risk from uncertainty regarding future fuel prices, this has the effect of either putting on hold investment decisions or encouraging the installation of conventional heat generating plant. Conventional heat generating plant is preferred as it requires lower capital investment and is seen as less risky.

The largest impact upon the attractiveness of investment in CHP is the relative price of fuel (mainly natural gas), used in CHP, and the financial value of the electricity generated by CHP. These relative prices are measured by the spark-gap, which is the difference between the price of electricity and gas. The larger the spark-gap (higher electricity price and lower gas price) the more favourable are the conditions for operating CHP. In the ten years between 1994 and 2004, both electricity and gas prices fell, with gas prices falling by 6% in real terms over this period. However, between 1999 and 2004 there was a 35% increase in gas price but no corresponding increase in electricity prices. During this period then, the economic conditions became more unfavourable to CHP.

CHP is an efficient way of using fuel when there is a real demand for the heat produced during generation. In situations (e.g. industrial settings) where there is a risk that there will be a smaller demand for heat over the medium to long term, there is a natural reluctance to commit to a technology that would become less efficient.

The capital costs associated with the installation of CHP are higher than those associated with using heat only boilers and importing electricity. If the relative fuel prices are favourable, savings associated with avoiding the purchase of electricity should off-set these additional capital costs in an acceptable period of time. However, because of the volatile fuel prices and uncertainties surrounding the size of the long term heat load of a site, investors take the view that CHP is a risky investment. Consequently, it is not uncommon for investors to demand a rate of return of 10-15% on CHP investment.

CHP also has higher associated operation and maintenance (O&M) costs than conventional generation. This is a consequence of the higher technical sophistication when compared with conventional methods of heat generation. The O&M costs of CHP range from 0.4-0.6 p/kWh and can be as high as 1 p/kWh for small capacity reciprocating engines. This compares with O&M costs of 0.05-0.1 p/kWh for heat only boilers.

The volatility in fuel prices, the relative prices of gas and electricity, uncertainties regarding the size of a particular site's heat demand into the future and the high investment risk attached to CHP installations are all considered obstacles to the installation of new CHP. Some of these are characteristic of CHP technology, while others are characteristics of the present state of the energy market.

Barriers to and support measures for CHP in the UK

While there are obstacles to the installation of CHP that either cannot be removed or for which it would be inappropriate to make interventions to remove, there are a number of barriers currently operating where action is possible through the regulatory framework. These are discussed below, together with the measures that either can be or are being adopted to overcome these barriers.

The distribution network in the UK was designed to take electricity from centralised power plants to consumers. This network will need reinforcing to move to a system where distributed generation, including CHP, can make a significant contribution, whilst maintaining the integrity and reliability of the network. This presents a barrier to CHP as developers wishing to export power to the distribution network would be charged for the necessary network reinforcement.

In response to this barrier, Ofgem is developing an incentive framework aimed at encouraging distribution network operators to connect and utilise distributed generation.

The need to obtain a license for the generation and supply of electricity can be a burdensome procedure for small-scale distribution.

However, in recognition of this the Government in 2001 relaxed the license requirements by raising the license exemption criteria. This means that a greater number of schemes can supply electricity directly without the need for the additional administrative burden associated with becoming a licensed supplier. This position is being kept under review.

The EU Emissions Trading Scheme is intended to encourage lower carbon technologies such as CHP. However, with the approach used in the Phase 1 allocation, CHP units do not seem to be able to realise the full value for their environmental benefits. For example, permits allocated for the same type of CHP plant in different sectors are not the same proportion of their baseline emissions.

These shortcomings were acknowledged by Defra when they consulted with CHP users in preparation for Phase II allocations to CHP sites. In the NAP for Phase II, CHP has been treated fairly and has more favourable allocation method

In most cases, the installation of CHP requires good, reliable access to the gas and electricity networks. Some parts of the UK, including parts of Scotland, Wales and Northern Ireland have little or no access to mains gas. In these situations potential CHP schemes would tend to rely on diesel as the fuel. However, the incentive to run CHP on diesel is not as strong as for running on natural gas, since there is no climate change levy on diesel and therefore no CCL rebate to enjoy when running CHP on this fuel. In short, using diesel in CHP would still incur the excise duty cost.

In recognition of this from 1st January 2006 diesel used in CHP has been treated as exempt from Hydrocarbon Oil Duty Rates. This provides a financial motivation for sites considering the use of CHP, who do not have access to the gas grid, to implement CHP at their sites.

Potential for CHP in the UK

Fuel price and growth assumptions

New fuel price scenarios have been developed based on the projections from the DTI in early 2006. The fuel prices and growth assumptions for the different models are discussed in Annex 1.

Industrial heat demands

The assessment of the potential in this sector builds on work done in 1997 for the UK Government on the potential for CHP. The model disaggregates heat and electricity demand by subsector and company size for key industries that use medium to low temperature heat. This facilitates a more accurate 'bottom-up' estimate of the potential, without having to consider a large number of individual sites. The model assesses the economic potential for CHP in these sectors, using defined characteristics and costs for different technology types, but also taking into account the interaction with energy efficiency measures. For high temperature industry (i.e. steel, glass, cement), special sectors (refineries, sugar processing) and large Utilities (Liquid Natural Gas (LNG) plants) separate assessments were carried out taking into account the specific circumstances in those industries.

For this study, the basic heat and electricity demand data in the model was up-dated using information available for sector energy demands. These data were checked for consistency with other data, such as emissions reported for the national allocation plan for the EU ETS and with data from the sector association. In addition, the data on energy efficiency opportunities were updated following recent work for Defra. To focus resources, it was assumed that the demand profiles and size distributions for different sectors have not changed significantly since the model was developed. Annex 2 gives details of the assumptions regarding sector heat and electricity demands and the costs and characteristics of CHP units.

The financial model used is a simple project costing assuming a fixed electricity and gas price and using an annualised capital cost. It does not include a cash flow calculation. The CHP unit is assumed to replace heat provided by a gas boiler of 75% efficiency and electricity imported from the grid. For the base case, it is assumed that climate change levy is paid on gas, with the reduction to 20% if the sector is generally in a climate change agreement. In practice, CHP should be able to obtain exemption on the levy for the fuel input but it is not clear of the status of the exemption in 2010 and anecdotal evidence suggests this benefit is heavily discounted. Sensitivity to this has been assessed. In addition, CHP is assumed to be eligible for enhanced capital allowance. The value of this is assumed to be 6% of the capital cost. The price for carbon is included in the electricity prices but it is assumed that CHP units are allocated sufficient allowances and need neither to buy nor sell them.

Various sizing strategies are tried out in the model, matching summer and winter heat and electricity demands in turn. The model selects the strategy with the highest potential capacity.

To obtain estimates for 2015, the results from 2010 were scaled by the expected growth rates for the different sectors. It was assumed that the structure of the industry and the relative costs would not change within that time.

Modelling the potential for CHP in individual buildings

The modelling presented here is based on an approach developed by the Building Research Establishment (BRE) to asses the potential for CHP in Northern Ireland and uses draft guidelines produced by the EU to assess the primary energy savings. The results are for all relevant types of commercial and public sector buildings, but not building-related energy use in industry as this is covered in the industry part. There is potential for overlap in the capacity identified in the present study and that identified in the Community Heating study. As this study is based on aggregate numbers of different building types and sizes, whilst the other is spatially based at the postcode sector level it is not possible to quantify the extent of this overlap without undertaking more detailed work.

This section describes how the potential for economically viable CHP was determined for individual buildings in Scotland, England and Wales

To establish the potential the main steps in the calculations were:

- Estimate the heat demands and electricity demands for a range of public and commercial building types
- Determine the size distribution for each building type in England and Wales.
- Determine the size of CHP plant that is appropriate for each combination of building size and type, based on their heat demand and by optimising the combined cost of heat and power supply.
- Assess the capital and service costs associated with operation of the CHP plant and assess the cost effectiveness based on the gas and electricity prices. The same price information was used in the industrial and community heating studies.
- Assess the potential income from exporting excess electricity produced to the grid.
- Determine the cost effective potential for CHP capacity across all building types for the base year (2002) and 2010, and for discount rates 3.5% and 15%.
- Calculate the Primary Energy Saving from the potential CHP capacity in accordance with the EU Guidelines[i]

More details of the modelling inputs and assumptions are given in Annex 3.

To obtain estimates for 2015, the results from 2010 were scaled up based on the difference in the expected sector heating demands between the two years. It therefore includes the impact of sectoral growth and the increased thermal efficiency of the building stock but not the effect of building size.

Community Heating

Community Heating (CH) can be defined as the supply of heat to a large number of buildings from a centralised heat production facility by means of a pipe network and is also known as District Heating. The technology has gained widespread acceptance in Scandinavia, the Netherlands and Germany. Whilst current CH/CHP capacity is small in the UK, notable examples exist in the major Community Heating schemes in Southampton, Sheffield, Nottingham, Lerwick and the City of London.

The Government previously commissioned a report into the UK Potential for CHP with CH that was prepared by PB Power. This report was subsequently published and is available from the Energy Savings Trust (www.est.org.uk).

This work has drawn on the previous study updating mainly with respect to energy prices and carried out to meet the requirements of the EU Cogeneration Directive. As a result, this report should be read in conjunction with the earlier report as it has not been the intention to repeat information that has not changed e.g. most of the modelling assumptions.

The CHP national potential and the primary energy savings have been estimated using the Guidelines issued by the EU.

To establish the potential the main steps in the calculations were:

- Estimating the heat demands per dwelling or per m^2 for domestic and non-domestic buildings in each postcode sector in the UK and, knowing the area of the postcode, calculate a heat density (in MW/km^2)
- Estimating the capital costs for the CH network and building connections based on a relationship with heat density
- Establishing assumptions for gas and electricity prices, using information provided by AEA Energy & Environment
- Estimating the capital costs of the centralised CHP and boiler plant and, by simulating the operation of CHP plant, optimise the CHP capacity and hence determine the costs of heat production
- Assessing the potential income from selling heat to customers on the heat network based on their avoided costs from using individual boilers
- Economic analysis to determine the potential capacity of CH/CHP for each postcode sector for a range of discount rates
- Calculation of the Primary Energy Saving from the potential CHP capacity in accordance with the EU Guidelines (2)

The potential heat demand that could be supplied from CH is very large. It is possible to transport heat over long distances and supply suburban areas. The main constraint is an economic one due to the higher cost of heat distribution networks in less built-up areas. More details of the methodology are given in Annex 4.

It is assumed for Community Heating that the potential in 2015 is the same as in 2010, because of the lead time for these types of projects.

Results

Industrial sector

Medium to low temperature industries

The cost effective potential in 2010 for CHP in the medium to low-temperature industrial sectors is shown in Table 2. This potential represents the additional capacity over the already installed CHP capacity. It can be seen that at the lower discount rate the cost effective additional potential is increased by about 13%.

Table 2 Summary of the UK (including Northern Ireland) additional potential by 2010 in the medium to low-temperature industrial sectors

Scenario	Delivered Energy (TWh)		Capacities (MW)		Energy Savings (TWh)
	Heat	Electricity	Heat	Electricity	
15% Discount rate	56	43	6898	5389	29
3.5% Discount rate	67	53	8339	6515	36

The different types of CHP units give savings of 14%-22%, with most units giving 20% or greater. The energy savings given have been calculated assuming an average of 20%.

The potential by sector in the base case is given in Annex 2. The cost effective potential in 2015 (

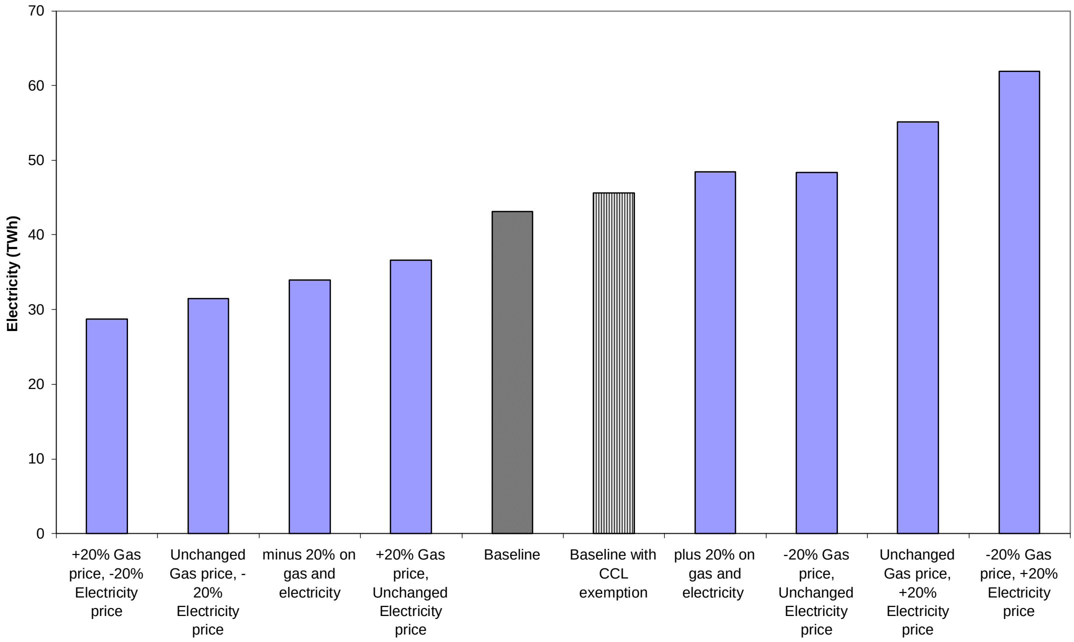
Table 3).

Table 3 Cost effective potential in the medium to low temperature industrial sectors by 2015 (15% discount rate)

Year	Delivered Energy		Capacities (MW)		Energy Savings (TWh)
	Heat (TWh)	Electricity (TWh)	Heat	Electricity	
2015	70	55	8646	6808	37

Sensitivity to the gas and electricity price and to the assumption regarding the exemption for CCL on input fuel is shown in Figure 4. The CCL exemption makes only a small difference to the potential, because of the discount for the climate change agreements. As shown in Figure 4, the lowest total potential is around 30 TWh, the highest 60 TWh.

Figure 4 Sensitivity to assumptions



High temperature industries

For high temperature industry (i.e. steel, glass, cement), special sectors (refineries, sugar processing) and large Utilities (Liquid Natural Gas (LNG) plants) separate assessments were carried out taking into account the specific circumstances in those industries. The potential for CHP lies in a small number of large opportunities. The potential developed in the original study looked at opportunities in specific process areas and extrapolated to other similar sites. In this study, we have used knowledge of developments to provide new estimates. However, this is based on expert judgement and is not modelled explicitly.

Steel Industry

Current capacity in steel is 68 MWe generating 269 GWh of power. It is estimated the remaining potential is approximately double this, giving 130 MWe, 530 GWh of electricity and 500 GWh of heat.

Glass and Cement Industries

The previous estimates were based on technical developments in these industries that have not occurred and no potential is currently identified.

Other specific sectors

This sub section covers those sectors that are not captured by the modelling for the lower temperature industries and contain a known, but small, number of sites, which can be assessed individually.

Refineries

The largest CHP unit to come into operation in recent years in the UK is located at a refinery, giving a total of 1540 MWe of capacity generating

8940 GWh of power in this sector. It is estimated that there is still a potential for upgrade of existing capacity and new installations of around about 1,400MWe. For the purposes of this report, it is estimated that about 400MWe additional capacity is cost effective in 2010 and a further 500MWe in the period 2015-2020.

Sugar processing

It is believed that there is the potential for an additional 200-250MWe of capacity in the sugar industry based mainly on upgrading existing systems. For the purposes of this study it is assumed that about 100MWe additional capacity is cost effective in 2010.

LNG plants

A number of opportunities (in order of 4) have been identified in the UK for these plants, which are users of low grade heat, however the potential has not yet been fully quantified as is site specific and would require a detailed analysis. However, we anticipate the potential Good Quality Capacity to be in the order of 1,600MWe. For the purpose of this report, it is estimated that about 800MWe is likely to be developed by 2010.

Summary of potential in 2010 in all Industrial Sectors

Sector	Electrical capacity MWe	Power generation TWh	Heat generation TWh
Low & Medium Temp Industries	5,389	43	56
High Temp Industries	130	0.53	0.48
Refineries	400	3.30	2.90
Sugar	100	0.60	0.55
LNG	800	6.80	2.80
Total	**6,819**	**54.23**	**62.73**

Individual buildings

The results that are presented in this section are based on modelling results for individual buildings scaled up to reflect the number of buildings of each type in each size band. Although this provides a more conservative estimate for the national potential, as described in the previous section, it is probably more realistic than that provided by the floor area approach, particularly given that no account of the practical space constraints associated with installing CHP has been taken.

The results presented in

Table 4 and show that, even at 2002 electricity and gas prices, there is significant additional potential for cost effective CHP installations, and if all the economic potential were taken up it would approximately double the current installed CHP capacity in pubic and commercial buildings. The majority of this potential is to be found in hospitals, hotels, further and higher education and in the leisure sector, which, unsurprisingly, are the main sectors where CHP is currently installed.

Table 4 - Economic potential for CHP in individual public and commercial buildings (GB) at 2002 prices

Scenario	Delivered Energy (TWh)	Electrical Capacities (MW)	Energy Savings (TWh)
15% Discount rate	7.1	761	4.9
3.5% Discount rate	12.4	1313	8.4

Table 5 - Economic potential for CHP in individual public and commercial buildings (GB) 2010

Scenario	Delivered Energy (TWh)	Electrical Capacities (MW)	Energy Savings (TWh)
15% Discount rate	11.9	1,268	8
3.5% Discount rate	12.5	1,319	8.5

At 2010, the potential is estimated to be about 1,268 MWe at 15% discount rate and only slightly higher at 3.5%. At 2010 prices, the price gap between gas and electricity is more favourable for CHP and most CHP plant above 40kWe should be economically viable at both discount rates. At less favourable 2002 prices the potential at 15% is approximately half that in 2010 and the effect of the discount rate is larger. Details of the results by sector are given in Annex 3.

Table 6 - Economic potential for CHP in individual public and commercial buildings (GB) 2015

Scenario	Delivered Energy (TWh)	Electrical Capacities (MW)	Energy Savings (TWh)
15% Discount rate	11.8	1228	8
3.5% Discount rate	12.3	1279	8.4

The calculations show that the potential primary energy savings that could be achieved from economically viable CHP plant is over 8,000GWh pa at 2010 fuel prices.

The potential for high efficiency CHP in buildings in Northern Ireland has been calculated separately (report available from Department of Enterprise, Trade & Investment, Northern Ireland, Belfast, BT4 2JP). For this study, we take their estimate of potential with a 4-year payback as being economic. This is the minimum payback with any potential identified. The potential at this payback is 45.5 MWe.

Community Heating

The CH/CHP potential for the UK has been assessed using the methodology given in Section 5.4 of the report and the results are summarised in Table 7. The CH/CHP Potential for Scotland and N Ireland was estimated by adding 10% to the estimate for England and Wales as the data on non-domestic buildings was not available for these countries. This shows the total CH/CHP potential that results in positive Net Present Values at each of three discount rates. There was no potential found for a 12% or 15% discount rate.

Table 7 - Summary of the UK potential for CH/CHP at discount rates

CH/CHP potential	Units	3.5%	6%	9%
Total net CH/CHP Potential for UK	MW_e	33,125	21,517	75
Number of postcode sectors	-	6,897	4,204	46
Total electricity produced	GWh p.a.	189,472	123,119	518
Total heat sold	GWh p.a.	230,358	149,686	630
Primary Energy Saving	GWh p.a.	159,881	103,890	437

The results exhibit a high sensitivity to discount rate; at 9% there is very little CHP/CH potential. It should be noted that the limitations of the modelling methodology are likely to be causing a distortion here. The model assesses the capital cost of district heating mains across an entire postcode sector - which is an arbitrarily defined boundary. In reality an area of high CHP/CH potential may straddle two postcodes, but in this analysis neither postcode, when taken as a whole, may be economic at 9%. The breakdown by postcode and a sensitivity study is shown in Annex 4.

Discussion

The study concentrated on those areas with the greatest potential in the period to 2010. In this section, we present a qualitative discussion of the potential for micro CHP, the use of renewable energy and waste to energy and the impact of meeting a cooling demand.

The potential for domestic micro-CHP in the UK

Background

This section examines the potential for micro-CHP within the domestic sector. Unlike the technologies discussed elsewhere in this report, micro-CHP is a new technology where the economic benefits and primary energy saving potential are unproven.

In 2001 there were 24.4m homes in Great Britain and around 17.6m of these had gas central heating systems. Micro-CHP is to be marketed as a direct replacement for the domestic boiler and this market equated to 1.19 million gas boilers in 2001. The Whispergen 0.8kWe stirling engine system is the only micro-CHP unit currently marketed in the UK domestic sector, although new products may emerge in the future with different characteristics and, possibly, using fuels other than gas.

Dwelling types suitable for micro-CHP

Dwellings in Great Britain are often classified in terms of detached, semi-detached, terraced and flats. Due to variations in the annual heat and power consumption of the different dwellings, certain types are likely to be more suited to micro-CHP than others. Those dwellings types with heat demands less than 9MWh per annum are considered to have little potential for micro-CHP (a similar assumption was also adopted in the MicroMap project in 2002) and these have been excluded from the analysis. Post 2000 terraced houses and flats built after 1990 fall into this category and they account for a combined total of 222,000 (around 1% of the GB housing stock). It should be noted that new products coming on to the market may open up areas of the market, particularly where use of heat storage is made.

New build dwellings tend to have much lower heating demands than older dwellings of the same type and, given the recent trend of progressively tightening building regulations, it is likely that heating demands will drop further in the future. Against this background, it appears unlikely that new build flats, with their small overall heating demands increasingly dominated by the remaining domestic hot water load, will be suitable candidates for micro-CHP unless heat storage is used.

Take up rates

Take up rates of technologies are driven by many factors, not least the underlying economics. There is no direct comparator for micro-CHP systems and there are a number of different approaches to estimating take up rates.

The 2003 SBGI study ("Micro-CHP – delivering a low carbon future"), which is currently being updated, varied the take-up rate based on a number of factors including payback, probability of purchase and market growth. As can be seen in the Figure 5, the base case (best outcome) scenario assumed unit sales of 65,000 per annum by 2010, rising to 120,000 per annum by 2020. **On a cumulative installed basis, the study predicted 160,000 in 2010, rising to 1,050,000 by 2020.**

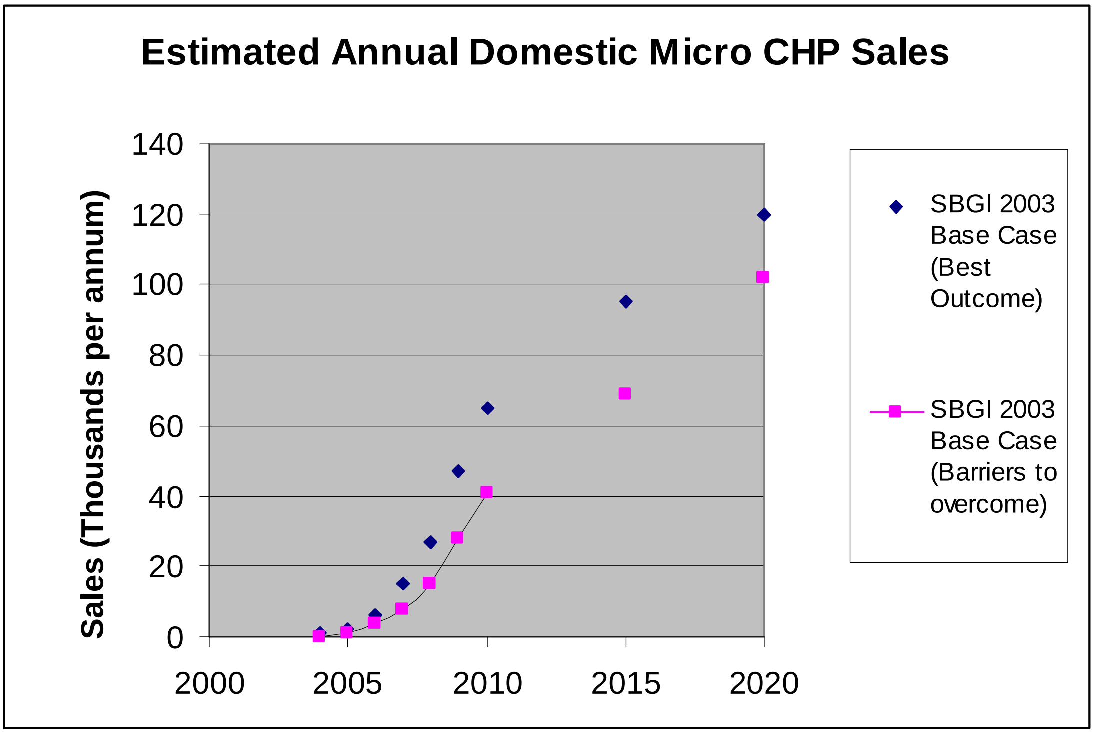


Figure 5 Estimate of annual domestic micro-CHP sales

Another scenario is to consider the take-up rates of condensing boilers prior to them being made compulsory under the Building Regulations. Condensing boilers were introduced in the 1980s. Take up was low in the initial years e.g. by 1995 they still accounted for less than 3% of total gas boiler sales. By 2001, sales of condensing boilers had increased (in part due to grant funding) to account for around 9% of total gas boiler sales (Table 23 BRE Domestic Energy Factfile 2003) . Following the 2006 amendments to part L1 of the building regulations condensing boilers became compulsory except in certain circumstances and, hence, now account for 85% of the market.

If micro-CHP follows a similar build up pattern to that of condensing boilers, it is likely to account for less than 1% of total domestic gas boiler sales by 2010, equivalent to around 3,000 unit sales per annum (**a cumulative stock of 7000 in 2010**). Sales may reach around 50,000 per annum **by 2020, equating to a cumulative installed stock of 230,000** (as shown in the Figure 6).

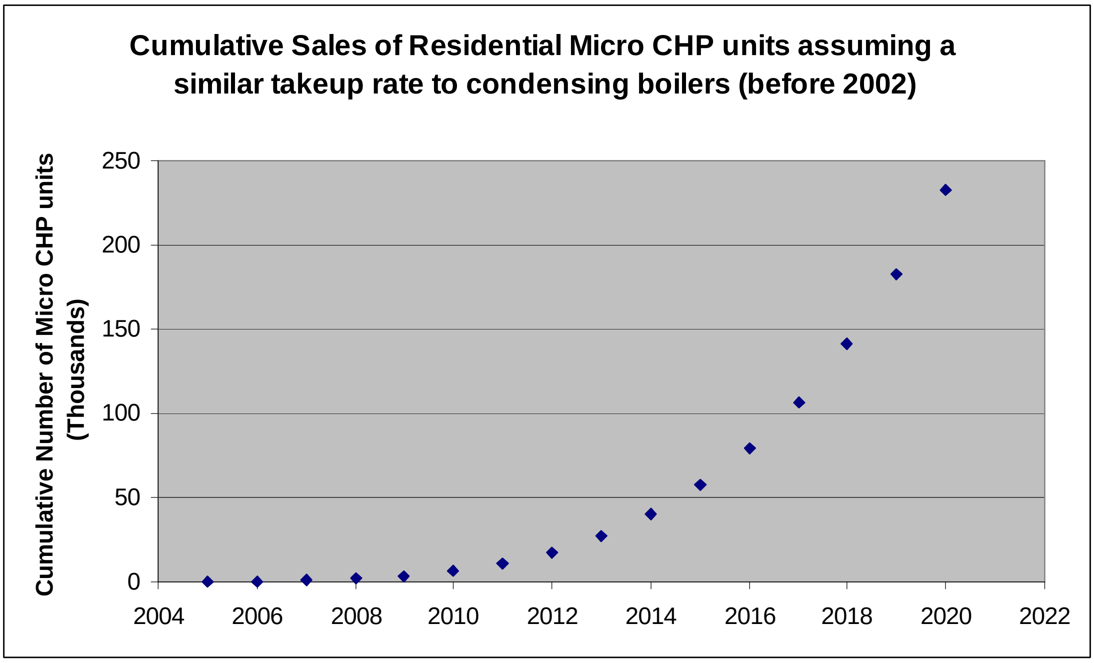


Figure 6 Cumulative sales of residential micro-CHP units

Note: the tenure of the properties may also have some impact on take up rates in different categories, but it has not been possible to examine this issue within the timeframes for this work.

Potential over time

The potential for CHP is commonly expressed in terms of the installed electrical capacity. In the case of micro-CHP, it is worth noting that the installed electrical capacity will operate for significantly less operating hours than conventional CHP and hence generate less electricity relative to capacity.

If domestic micro-CHP follows a similar build up pattern to that of condensing boilers, it is likely to make a very small contribution to installed CHP capacity by 2010 e.g. around 5MWe by 2010, particularly as early trials in the UK have been unsuccessful. Under the same scenario, installed capacity may rise to around 200MWe by 2020. Government intervention, for example through the building regulations, to require micro-CHP to be installed as a direct replacement for existing and new boilers would, of course, cause the installed capacity to increase at a much faster rate.

Primary energy saving

The primary energy savings from micro-CHP are, as yet, unproven in real operation. The Energy Saving Trust (EST) in conjunction with the British Standards Institute (BSI) are developing a procedure (PAS 67) to test the performance of micro-CHP systems under laboratory conditions. The Building Research Establishment (BRE) is developing a methodology that will make use of the laboratory test results to evaluate the energy benefits of micro-CHP heating systems in houses. Both the laboratory test procedure and methodology were issued for industry consultation in January 2006. The Carbon Trust are also undertaking field trials of micro-CHP installations and the results from the exercise are now planned to be available in 2007.

Micro-CHP suppliers have, however, made estimates of the savings achievable from their systems. For example, primary energy savings equivalent to a 20% reduction are suggested.

Renewable energy and waste to energy

The main renewable energy used for Community Heating and CHP is biomass in the form of energy crops or wood chips from forestry or industry. This is a very appropriate fuel for use with larger-scale CH/CHP systems and for some individual buildings and industry sectors. It is possible that the incentives available through the Renewable Obligation Certificate will mean that more biomass electricity generating plants will be constructed. The greatest primary energy saving will be obtained when these plants are constructed to also supply heat. Given the right fuel supply it could be the case that biomass CHP is more economic than gas-engine CHP and inclusion of biomass in this potential study would mean that the economic CH/CHP potential could be greater than estimated from the use of gas-engines alone. Similar arguments apply to waste to energy projects except that as the waste is generated within an urban environment there is potentially a greater opportunity to develop a CH/CHP system from an energy from waste plant.

The recent announcement that waste to energy CHP plants would be eligible for ROCs, albeit partially, would be expected to stimulate an interest in CH. It is interesting to note that a number of other major CH systems in the UK (Sheffield, Nottingham and Lerwick) have energy from waste as the heat source. The newer technologies for energy from waste will generally be at a smaller scale than mass incineration and therefore potentially more suitable for construction in an urban environment as CHP plant.

Cooling demand

Meeting a cooling demand using heat from a CHP unit to supply an absorption chiller is technically viable and can be economic in the right conditions, particularly for larger projects. Generally however the economics are marginal and are normally based on making use of heat from a CHP plant that is already justified on the supply of heat. For this study, it has not been possible to undertake detailed modelling of the potential for cooling from CHP as cooling demand profiles for the various building types are not available.

Electricity consumption for cooling in public and commercial buildings in 2002 is estimated at 9,000GWh pa compared to 111,000GWh pa for heating. On this basis alone the potential for cooling from CHP is likely to be an order of magnitude lower than for heating. Furthermore, energy use for chillers is frequently less than half of that of the total electricity demand for cooling - the remainder is for fans and pumps, which usually have run hours which are significantly longer than the chiller run hours (and which would still be required with absorption chillers). (Ventilation is usually required throughout occupancy, while cooling is only needed at time of high heat gain). In principle, absorption chillers that use heat to drive the refrigeration cycle can replace the electrical energy used with conventional compression refrigeration with the heat being provided by the CHP unit. By providing a summer demand for heat and therefore longer hours of heat demand, the viability of CHP is improved. However, absorption chillers are relatively expensive (and less efficient than conventional chillers) As a result, the use of waste heat from CHP for cooling rarely makes CHP a cost effective option. In practice absorption chillers are most economic where chiller run hours are significantly higher than for most building application. Possible building types where they could prove cost effective are warehouses and distribution centres with both refrigerated and ambient storage requirements.

Because the demand for cooling is small relative to the heat demand for most buildings, in most instances the use of waste CHP heat to power absorption chillers is unlikely result in a larger size of CHP unit than would be required for heating alone. So using waste CHP heat for cooling is unlikely to make a significant impact on the potential for installed capacity although clearly, if economic, it could result in additional carbon and energy savings. Another potential option for CHP would be to use CHP for cooling alone. Here CHP heat is used to power absorption chillers whilst the electricity generated is used to power a conventional chiller, with the conventional chiller taking care of load variations with surplus electricity being available for other uses. This option will only be viable where there is a suitably high and relatively constant refrigeration demand.

Further work will be required to identify building types where absorption chillers with waste CHP would be an economically viable option and the extent to which these would increase the potential for installed capacity and the primary energy and carbon savings that they might realise.

The inclusion of cooling in the analysis could in principle also increase the CH/CHP potential in the non-domestic sector and in some industry however as discussed above it would be expected that the impact would be relatively small.

Data limitations and additional considerations

All the models rely on heat and electricity demand profiles. Data on these, particularly at the detailed level used are sparse and in some cases have to be based on relatively old (1990s) data. For all the models these data have been checked against alternative sources of information from for example sector associations and the national allocation plan in the industry sector. However, it is difficult to obtain consistent data.

The current model for individual buildings considers only schemes larger than 40kWe as these reflect the lower limit currently installed. Although the requirement of many buildings would be for schemes that fall below this size, in practice not many have the constant heat load necessary to justify CHP and the higher cost per kWe installed associated with smaller CHP systems which usually means that it would not be economically viable to install. Nevertheless at a later stage it may be valuable to extend this analysis to smaller plant sizes to confirm these expectations.

The Community Heating study has been based on the development of gas-engine schemes as this has been the focus of development to date. In many cases the high heat density sectors are contiguous such that the total heat demand of an area could be large enough to justify a Combined Cycle Gas Turbine plant. If a CCGT CHP plant was constructed to supply the CH schemes then the primary energy savings and CO_2 savings would be greater and the CHP capacity also larger than that estimated here. It is also likely that the economics would be improved due to the higher efficiency of a CCGT CHP plant. A separate study would be required to evaluate this option.

Conclusion and Recommendations

This study has modelled the additional economic potential for CHP in UK in 2010 (Table 8) and 2015 (Table 9).

At the market discount rate (15% for industry and individual buildings and 9% for community heating), the additional potential for new generation of electricity is 61TWh, with energy savings of 44 TWh at 2010. At 2015, this increases to 81 TWh of electricity and 57 TWh of energy savings. This generation potential is around 17% of the projected total for electricity generation in 2010.

Table 8 – Additional potential for cost effective CHP at 2010 at market discount rate

Scenario	Delivered Energy (TWh)		Capacities (MW)		Energy Savings (TWh)
	Heat	Electricity	Heat	Electricity	
Medium to low temperature industry	56	43	6,898	5,389	29
High temperature industry	0.48	0.53	120	130	0.5
Other industries (Refineries & LNG)	6.25	10.70	650	1,300	5.9
Buildings (GB only)	12	6	2,536	1,268	8
CH (9% DR)	0.6	0.5	67	56	0.4
Buildings (NI)	*0.4*	*0.2*	*90*	*45*	*0.3*
Total*	**75.73**	**60.93**	**10,361**	**8,188**	**44.1**

The figures in italics are calculated assuming that buildings in Northern Ireland (NI) have similar characteristics to Great Britain.

* It should be noted that there could be overlap between the potential in medium to low temperature and high temperature industry and between buildings and community heating. This overlap has not been quantified, so the total should be taken as an upper limit.

Table 9 – Additional potential for cost effective CHP at 2015 at market discount rate

Scenario	Delivered Energy (TWh)		Capacities (MW)		Energy Savings (TWh)
	Heat	Electricity	Heat	Electricity	
Low temperature industry	70	55	8646	6808	37
High temperature industry	0.48	0.53	120	130	0.5
Other industries (Refineries & LNG)	11.0	19.2	1150	2300	10.4
Buildings (GB only)	11.8	*6*	*2456*	1228	8
CH (9% DR)	0.6	0.5	67	56	0.4
Buildings NI	*0.4*	*0.2*	*90*	45	*0.3*
Total*	**94.28**	**81.43**	**12,529**	**10,567**	**56.6**

* It should be noted that there could be overlap between the potential in low temperature and high temperature industry and between buildings and community heating. This overlap has not been quantified, so the total should be taken as an upper limit.

The study uses bottom-up models of the potential for CHP and of necessity relatively simple cost effectiveness calculations. In practice, decisions on CHP will be influenced by a number of site-specific issues, which tend to reduce cost effectiveness. This potential should therefore be regarded as an upper limit and unlikely to be realised in full in practice.

Annex 1 Fuel price and growth assumptions

Industrial fuel prices

Table A1.1 gives the energy prices for the industrial sector. Fossil fuel (gas and diesel and top-up heat) prices are based on delivered prices extrapolated from the latest DTI central price projections. Top-up power is also based on delivered cost estimates. Power export value is taken as the same for each size tranche and is equivalent to the wholesale price plus embedded benefits minus the DUoS cost. We have used 2004 values at 2002 prices. This is equivalent to £2.8/MWe (embedded benefit) minus a £3/MWe discount, equivalent to a net effect of -(minus) £0.20/MWe on the wholesale electricity price.

Delivered fuel prices have been determined according to purchase size tranche from the historic splits published in the DTI's fuel price statistics. Depending upon the fuels, these are split into differing ranges of small, medium and large delivery size tranches; these have been aligned with the CHP sites sizes according to power capacity splits of < 2 MWe, 2 to 6 MWe and > 6 MWe. For the larger CHP sites, we have used the wholesale price for gas as equivalent to the delivered fuel price; for diesel, we assume a price consistent with larger sites (equivalent to > 2,200 MWh pa) for all sites.

Table A1.1. Industrial energy prices (2002 prices)

Prices in 2005 (real 2002)			**Prices in 2010 (real 2002)**		
Tranche 1: <2MWe	£/GJ	£/MWh	**Tranche 1: <2MWe**	£/GJ	£/MWh
Gas	3.58	12.89	Gas	2.86	10.30
Diesel	8.85	31.86	Diesel	5.63	20.27
Top up heat	4.48	16.13	Top up heat	3.58	12.89
Top up power	16.55	59.58	Top up power	14.82	53.35
Heat export	-	-	Heat export	-	-
Power export	9.73	35.03	Power export	7.12	25.63

Tranche 2: 2-6MWe	£/GJ	£/MWh	**Tranche 2: 2-6MWe**	£/GJ	£/MWh
Gas	3.58	12.89	Gas	2.86	10.30
Diesel	8.85	31.86	Diesel	5.63	20.27
Top up heat	4.48	16.13	Top up heat	3.58	12.89
Top up power	13.28	47.81	Top up power	11.89	42.80
Heat export	-	-	Heat export	-	-
Power export	9.73	35.03	Power export	7.12	25.63

Tranche 3: >6MWe	£/GJ	£/MWh	**Tranche 3: >6MWe**	£/GJ	£/MWh
Gas	3.38	12.17	Gas	2.63	9.47
Diesel	8.85	31.86	Diesel	5.63	20.27
Top up heat	4.23	15.23	Top up heat	3.29	11.84
Top up power	13.28	47.81	Top up power	11.89	42.80
Heat export	-	-	Heat export	-	-
Power export	9.73	35.03	Power export	7.12	25.63

The relationship between DTI price projections, which are for wholesale prices, and delivered prices, uses the historic relationships between wholesale and delivered prices by tranche size, and extrapolates this forward for each delivered fuel price.

We also allow for the effect of a medium value for allowance prices in the EUETS, and a 50% pass-through to electricity prices.

Recent price projections from the DTI have changed significantly compared with previous 2004 projections (as defined for the NAP 1 emissions projections in Oct 2004). This has a significant effect on the economics of CHP particularly in 2005. The spark gap between gas and power prices in 2005 is higher than that projected for 2010, and is very much higher than those at 2004, giving more favourable economics for CHP in 2005.

Fuel prices for Community Heating

Energy prices assumed were as follows:

- Gas price to the CHP and boilers was taken to be as the mid-range tranche of 0.824p/kWh in 2010 (at 2002 price level) (excluding CCL).

It was calculated that the full benefit of exemption from the Climate Change Levy (CCL) would be received given that the CHP and boiler energy utilisation meet the criteria for Good Quality CHP. Hence CCL has not been added to the fuel price for CHP and boilers.

Electricity revenues have been based on the export price provided by AEA Energy & Environment for the mid-tranche CHP size. This price is 2.56p/kWh in 2010 (at 2002 price levels), which is 40% below the corresponding import price of 4.28p/kWh. The export price reflects the typical situation for CHP on a host site where the amount of electricity exported is small and variable and consequently a relatively low price is obtained in the market. There are a number of reasons why this is a lower price than would be achieved in practice if CH/CHP became established more widely:

- the electricity output from a number of CHP systems supplying CH would be more predictable and the costs of the balancing mechanism would be reduced
- the role of consolidators in the market would be much more common and it would be possible to co-ordinate the output of the CHP plants to maintain more constant supplies from the whole group of generators
- the use of a thermal store with CHP could enable the CHP generators to offer ancillary services to the market such as reserve power capacity
- the benefits of embedded generation would be reflected more closely including the saving of the national grid triad charges, the reduction in local network losses and the reduced expenditure for capacity on the distribution system
- the potential that some CHP installations will be located on a large customer's site e.g. a hospital and will supply part of the electricity generated directly to this customer and export both heat and power
- the potential that some CHP installations will supply power directly to customers through a private wire network

In the light of the above we consider that a 10% uplift can be justified and is still likely to underestimate the value of locally generated electricity. This brings the base price up to 2.82 p/kWh. This is still 34% below the cost of imported power for commercial customers of 4.28 p/kWh; this difference reflects the cost of maintaining the distribution network over which the CHP generated electricity would reach the final customers.

To this price has been added the CCL of 0.43p/kWh as exemption would be available for CHP generated electricity. This brings the price up to 3.25p/kWh.

Heat selling price

The heat selling price was determined for each customer type by calculating the costs that would have been incurred for a conventional heating system over the lifetime of the scheme.

The gas prices assumed were provided by AEA Energy & Environment for 2010 (but on a 2002 price basis) as follows:

Domestic gas price: 1.29p/kWh

Commercial gas price: 1.03p/kWh

A domestic standing charge of £36 p.a. was added and CCL of 0.15p/kWh was added to the non-domestic price.

In the domestic heat market a further important factor in the determination of the heat selling price is the maintenance costs of individual boilers, particularly for social housing landlords where the annual inspection and the need for proper records is a legal requirement. Although CH systems benefit from an annual maintenance visit to the dwelling, the work is minimal and not essential. The costs included are £150 per dwelling for individual boiler maintenance and £53 per dwelling for CH maintenance.

An uplift was also added to the heat price to commercial customers to reflect avoided maintenance and boiler capital costs in line with the experience of operators of CH schemes in the UK.

Annex 2. Assumptions in and results from the industrial sector model

Steam and power demands

The model needs steam and power demands for industrial sectors and sub-sectors. We have chosen a base year of 2002, as this is the latest year for which detailed analysis has been carried out in both the industrial and buildings sector. The information on industrial heat and power demands is based on two sets of analysis carried out for Defra during 2005. The first study, the industrial indicators work, looked at trends in energy use and production, in the industrial sub-sectors using information from DUKES and disaggregated energy data published by the DTI. For some sectors CCA data, where available, was used to refine these estimates. The second study was on the potential for CO_2 savings in industry and comments were received on the assumptions from the sector associations. However, there is no data on steam demands for industry, these were established using available data on fossil fuel consumptions and assumptions on the proportion of that fuel used to produce steam and the conversion efficiency. These assumptions are based on the ENUSIM model used in the industrial CO_2 project.

The preliminary estimates for electricity and steam demand in industry are give in Table A2.1. In general compared to 1997, the electricity to steam ratio has increased in most industrial sectors. The engineering sectors are significantly different; information has been received recently from the vehicles sector to suggest previous estimates did not reflect current energy use.

Table A2.1 Electricity and steam demand in industry

	Electricity (1997)	Steam (1997)	Electricity (2002)	Steam (2002)
Food				
Creameries	1.3	7.9	1.5	4.0
Liquid Milk	1.8	4.7	2.1	2.4
Distilling	0.7	8.9	0.7	2.4
Meat	0.5	0.9	1.5	0.8
Baking	5.3	16.2	6.3	4.2
Brewing and malting	4.1	15.3	3.0	7.8
Rest of food (excl sugar)	27.1	37.8	24.9	37.0
Chemicals				
Dyes and pigments	2.1	7.3	2.6	13.8
General inorganics	4.9	10.7	11.6	17.3
Miscellaneous	1.9	23.2	5.5	7.1
Basic organics	41.6	77.7	13.5	39.6
Paint and inks	1.8	5	1.7	1.8
Pharmaceuticals	6.2	8.7	10.2	19.3

	Electricity (1997)	Steam (1997)	Electricity (2002)	Steam (2002)
Resins and plastics	5.9	10.3	13.9	19.5
Rubber polymers	0.7	2.8	0.6	1.7
Soap and detergents	1.8	3.7	2.7	1.4
Synthetic fibres	2.1	8.4	1.8	1.6
Paper				
Paper and Board	15.9	41.5	16.4	32.4
Printing	24.3	23.8	20.6	20.6
Textiles				
Carpet	1.2	3.3	0.8	2.1
Dyeing and finishing	3.1	10.9	1.3	7.9
Spinning, weaving and knitting	4.3	9.9	2.6	3.7
Woollen and worsted	3.9	10	1.3	1.7
Others				
Rubber processing	3.7	7	7.1	6.5
Plastics processing	12.6	5.5	29.6	12.9
Wood products	5.8	15	7.1	18.3
Engineering				
Electrical engineering	19.6	21.1	20.8	2.5
Mechanical engineering	40.9	55.6	37.2	7.8
Vehicle engineering	24.4	36.7	7.2	9.2

CHP characteristics and costs

The performance characteristics of different CHP technologies, originally provided in the 1997 study, have been reviewed for different operating scenarios. The administration of the CHPQA programme and the compilation of performance statistics necessary for the EU Directive made available comprehensive real performance data for a range of different CHP technologies in different operating scenarios and configurations. Table A2.2 shows the updated performance characteristics. Efficiencies are shown as higher heating values.

Table A2.2 CHP characteristics

	Gas Engine (Small)	Gas Engine (Large)	Dual Fuel Diesel	GT	Large GT	CCGT (Small)	CCGT (Large)
Minimum Unit Size (MW)	0.04	0.8	0.5	1	12	16	>100
Maximum Unit Size (MW)	0.5	3.7	20	7	40	<100	700
Low temp (80oC) heat %	50%	50%	50%	0%	0%	0%	0%

	Gas Engine (Small)	Gas Engine (Large)	Dual Fuel Diesel	GT	Large GT	CCGT (Small)	CCGT (Large)
High temp heat %	50%	50%	50%	100%	100%	100%	100%
Unfired H:P ratio	1.6:1	1.2:1	1:1	1.6:1	1.2:1	1:1	0.9:1
Unfired overall efficiency %	79%	75%	70%	78%	77%	78%	80%
Unfired electrical efficiency %	30%	34%	35%	30%	35%	39%	42%
After-fired potential H:P ratio	2.9:1	2.6:1	2:1	2.2:1	2:1	1.5:1	1.5:1
After-fired overall efficiency %	75%	80%	75%	80%	72%	80%	80%
Afterfired electrical efficiency %	19%	22%	25%	25%	25%	32%	32%
Maximum turndown %	50%	50%	50%	25%	25%	50%	50%
Unfired turned down H:P	1.9:1	1.5:1	1:1	2:1	1.2:1	1:1	0.9:1
Unfired turned down efficiency %	25%	32%	34%	25%	35%	39%	42%

Detailed results

The detailed results for 2010 at 15% discount rate is shown in Table A2.3.

Table A2.3 Base case potential at 15% discount rate in the different industrial sectors

Sector	**Delivered Energy**		**Capacities (MW)**	
	Heat (TWh)	**Electricity (TWh)**	**Heat**	**Electricity**
Chemicals	23	18	2,842	2,220
Engineering	13	10	1,613	1,260
Food	11	8	1,322	1,033
Paper	5	4	661	516
Textiles	2	1	224	175
Other	2	1	237	185
Total	**56**	**43**	**6,898**	**5,389**

The largest potential is in chemicals and there are also significant potentials in engineering and food. This reflects a relatively low installed capacity in both these sectors.

The potential is projected to increase with time, mainly due to growth in industrial sectors.

Annex 3: Individual buildings methodology

This Annex describes in more detail assumptions used in the individual buildings methodology.

Public and commercial buildings sectors

When analysing energy use within buildings the emphasis is generally on a small number of major sectors, which are made up of sub-sectors with similar generic building use (e.g. the major sector of “retail” covers both supermarkets and corner shops). However, for the purposes of this modelling exercise it was necessary to identify and pull out a number of more specific building types, which have heat and power demand profiles that are likely to make CHP a desirable option.

The sectors that have been defined will cover the majority of building types and certainly the vast majority with significant CHP potential.

Heat and power demand profiles for public and commercial buildings

The heat and power demands for the relevant sectors of the public and commercial building stock are shown below. The building sectors to be considered account for the majority of the heat and power demand arising from public and commercial buildings in Great Britain.

Heat and electricity demand profiles have been generated for the above building types, with typical diurnal demand patterns for each season, and for both working days and other (off peak/weekend) periods. The proportion of working and other days may vary considerably from building sector to building sector. In addition, for each sector there is number of total operational days, which excludes additional days when the building is expected to be not operating (i.e., bank holidays). The demand profiles are based on a combination of monitoring data and/or expected occupancy and equipment demand patterns. A validation exercise was carried out by checking that the annual energy consumption that the demand profiles generate is consistent with both sectoral consumption estimates and appropriate benchmarks.

Building stock profiles

In addition to the heat and demand profile, the size of a building will have a significant effect on the economics of CHP. The building size profile information used here has been derived from BRE’s N-DEEM model, which is a technically disaggregated model of energy use in the UK non-domestic buildings. For some sectors we hold actual size distribution data, whereas for other sectors estimates had to be derived from more limited information, and for a few sectors the size distribution was estimated based on the typical and total floor area or numbers. To ensure complete coverage and to avoid double counting the total floor area and number of commercial and public premises was checked to ensure consistency with other appropriate data sources.

Operational assumptions

For all CHP plant types the modelling assumption is that the plant will run at times where the heat demand is above 50% of the maximum heat output. Further, it is assumed that, where possible, the plant output will be modulated to meet this reduced demand. This assumption is deemed to be the most appropriate for individual buildings situations where there will be no existing provision for exporting excess heat. For gas turbines, no modulation capability is assumed, hence where heat demand is between 50% and 100% of the maximum CHP heat output it is assumed that the plant will run at 100% and any excess heat production is waste. The complimentary district heating modelling work presented in this report effectively assesses the potential for CHP if heat networks were also developed to allow heat export.

Having established the plant run profile the procedure then calculates the extent to which the CHP outputs meet the building heat and power demands. Where the heat output from the CHP is insufficient to meet the heat demand for the building, the model assesses the amount of additional heat will be required to make up the shortfall. Similarly where the electricity output is insufficient for the building demand the additional grid electricity requirement is calculated. In instances where the CHP electricity output is greater than the building demand it is assumed that this additional electricity will be exported to the grid.

CHP characteristics

Four types of CHP plant were considered suitable for individual buildings, small gas engines, large gas engines, gas turbines and dual fuel diesel plant. The overall efficiency, HPRs and modulation characteristics used in the modelling were the same as those for the industrial sector and are shown in Annex 2.

The typical capital (£/kWe installed) and servicing (£/kWh electricity generated) costs were based on information provided in Carbon Trust publications.

A lifetime of 15 years was assumed for CHP plant in individual buildings which represents an appropriate lifespan for considering capital investments for most building applications

Other Assumptions

Assumptions relating to the price of fuels are shown in Annex 1.

Assumptions about the efficiency of generation for alternative heat and power, including grid losses were taken from the EU guidelines. In instances where more than one type of CHP plant was calculated to be cost effective the capacity and savings associated with the most cost effective option was assumed.

Scale-up

Two methods of scaling up results for individual building sizes and types to the national level are possible. Capacity and energy savings data can be scaled up based on the number of buildings within each size band or on the total floor area within each size band. The former might underestimate the capacity as it assumes that plant is only available in the specific plant sizes modelled (See Table A3.1). And hence a plant may be undersized. Alternatively, scaling up based on floor area can overestimate the potential by assuming that CHP plant is available in an infinite variety of sizes. In general the floor area scale up gave results that were around 20% higher than the numbers based approach.

Table A3.1 Plant Sizes Explicitly Modelled

CHP plant type	MWe	MWe	MWe	MWe	MWe	MWe	MWe
small gas engine	0.04	0.08	0.12	0.20	0.32	0.52	1.00
large gas engine	0.55	1.07	1.62	2.69	4.31	7.00	13.99
dual fuel diesel	0.83	1.60	2.43	4.03	6.46	10.50	20.99
gas turbine		0.80	1.22	2.02	3.23	5.25	10.50

Those sectors that are explicitly excluded are listed below:

- Boarding Houses
- Car Parks
- Churches
- Halls
- Petrol Flling
- Holiday Centre
- Road Haulage
- Holiday Flats
- Other Teaching

These are generally expected to be unsuitable for CHP due to their size and/or heat and power demand profiles.

Due to their higher demand for heat, premises with swimming pools can often be good candidates for CHP. With this in mind, sectors which are most likely to have swimming pools have been split into premises with and without pools. This is the case for leisure centres, education, and hotels.

Where a building has consistently longer opening hours than average, this could influence the potential for CHP. The retail and warehouses sectors are likely to be most affected by this and therefore an additional “retail warehouses” sector which assumes longer operational hours is considered. Similarly there are an increasing number of call centres in the UK which have essentially office type heat and power loads, but with longer operating hours.

Another complication with public and commercial buildings is the estimation of the number of individual buildings from "premises" records. For most sectors, "premises" generally relates to an individual site with a single occupant, be it a single building or a group of closely related buildings, like a school. In some instances a number of premises are found under one roof, for example a shopping centre or an office block. Due to the greater energy demand of the whole building as opposed to the individual premises, this could make CHP more viable. We therefore propose to carry out additional analyses for the retail and offices sector which consider the size breakdown based on an "under one roof" as well as on an individual premise basis.

There is potentially some overlap with industrial buildings, particularly for workshops and warehouse premises. This would only be an important issue if significant potential for CHP capacity were identified in these building types. However, as the heat and energy demand profiles have been reconciled to agree with DUKES[1] energy use for the commercial, public and miscellaneous sectors and similarly the industrial sector modelling considers only reported industrial energy use.

Table A3.2 Heat and Power Demands for Public and Commercial Buildings GB 2002

SECTOR	Heat GWh pa	Electricity Gwh pa
AIRPORT TERMINALS	221	452
BUS STATION/TRAIN STATION/SEAPORT TERMINAL	41	528
CALL CENTRES	18,787	6,453
COMMUNITY/DAY CENTRE	1,822	284
CROWN AND COUNTY COURTS	551	95
EMERGENCY SERVICES	785	481
FUTHER AND HIGHER EDUCATION	1,247	1,840
FUTHER AND HIGHER EDUCATION WITH POOL	798	368
HOSPITAL	6,507	8,740
HOTEL	6,755	3,268
HOTELS WITH POOLS	1,862	783
LAUNDRETTE	2	54
LEISURE CENTRE NO POOL	111	137
LEISURE CENTRE WITH POOL	443	137
LIBRARIES/MUSEUMS/GALLERIES	383	117
NURSING RESIDENTIAL HOMES AND HOSTELS	2,391	726
OFFICE BUILDINGS	18,787	6,453
POOL ONLY	860	388
PRIMARY HELATH CARE BUILDINGS	798	122
PRIMARY SCHOOL	1,874	467
PRIMARY SCHOOLS WITH POOLS	160	37
PRISONS	1,287	372
RESTAURANT/PUBLIC HOUSE	2,890	4,245
RETAIL WAREHOUSE AND LARGE SUPERMARKETS	334	916
SECONDARY SCHOOL	3,810	1,231
SECONDARY SCHOOLS WITH POOLS	797	243
SHOPPING MALLS	778	2,249
SHOPS	2,950	8,525
SOCIAL CLUBS	1,086	605
SPORTS GROUND ARENA	11	12
TELEPHONE EXCHANGES	552	621
THEATRES/CINEMAS/MUSIC HALLS AND AUDITORIA	1,233	693
WAREHOUSE AND STORAGE	8,034	8,506
WORKSHOPS/MAINTENANCE DEPOT	411	2,753
MOD*	7,678	3,105
Total Sectors Modelled	97,036	66,003
Total Service Sector	132,320	93,633

Results

In this section, the results for individual building types are presented (Table A3.3). It is noticeable that even with more CHP-favourable prices and lower discount rate (e.g. 2010 prices and 3.5% discount rate) there are no additional sectors identified where there is significant potential for economically viable CHP. This is because, even where there are sectors with an appropriate heat and electricity demand profiles, most of the individual buildings are well below the floor area appropriate for the minimum plant size considered here. However, sensitivity analyses did indicate that, there were a few additional sectors, such as call centres, warehouses and shopping malls where CHP installations might become economically viable in some circumstances. .

Table A3.3 Economic Potential for CHP in Individual Public and Commercial Buildings by installed electrical capacity (GB)

YEAR	2002	2002	2010	2010
DISCOUNT RATE	15%	4%	15%	4%
SECTOR	**MWe**	**MWe**	**MWe**	**MWe**
AIRPORT TERMINALS	4	8	8	8
BUS STATION/TRAIN STATION/SEAPORT TERMINAL	-	-	-	-
CALL CENTRES	-	-	-	-
COMMUNITY/DAY CENTRE	-	-	-	-
CROWN AND COUNTY COURTS	-	-	-	-
EMERGENCY SERVICES	17	22	22	22
FUTHER AND HIGHER EDUCATION	41	86	86	86
FUTHER AND HIGHER EDUCATION WITH POOL	58	144	104	144
HOSPITAL	254	576	571	576
HOTEL	218	257	257	257
HOTELS WITH POOLS	59	74	74	74
LAUNDRETTE	-	-	-	-
LEISURE CENTRE NO POOL	1	1	1	1
LEISURE CENTRE WITH POOL	5	6	6	6
LIBRARIES/MUSEUMS/GALLERIES	-	-	-	-
NURSING RESIDENTIAL HOMES AND HOSTELS	9	9	9	9
OFFICE BUILDINGS	7	7	7	7
OFFICE PREMISES	-	-	-	-
POOL ONLY	30	52	52	52
PRIMARY HELATH CARE BUILDINGS	-	-	-	-
PRIMARY SCHOOL	-	-	-	-
PRIMARY SCHOOLS WITH POOLS	-	-	-	-
PRISONS	18	23	23	29
RESTAURANT/PUBLIC HOUSE	-	-	-	-
RETAIL WAREHOUSE AND LARGE SUPERMARKETS	10	14	14	14
SECONDARY SCHOOL	-	-	-	-
SECONDARY SCHOOLS WITH POOLS	-	-	-	-
SHOPPING MALLS	-	-	-	-
SHOPS	-	-	-	-
SOCIAL CLUBS	-	-	-	-
SPORTS GROUND ARENA	-	-	-	-
TELEPHONE EXCHANGES	10	14	14	14
THEATRES/CINEMAS/MUSIC HALLS AND AUDITORIA	-	-	-	-
WAREHOUSE AND STORAGE	-	-	-	-
WORKSHOPS/MAINTENANCE DEPOT	-	-	-	-
MOD*	20	20	20	20
Total Capacity	761	1,313	1,268	1,319

* Ministry of Defence potential presented here is preliminary and is based on a separate analysis carried out for the Carbon Trust, which may not have used the same cost assumption, lifetime and discount rates as this study.

Table A3.4 shows the annual useful heat output that would be provided from the installed capacities shown in Table A3.3. The potential heat output calculated at 2002 fuel prices with a discount rate of 15% amounted to 11,943 GWh pa.

Table A3.4 Economic Potential for CHP in Individual Public and Commercial Buildings by useful heat output (GB)

YEAR	2002	2002	2010	2010
DISCOUNT RATE	15%	3.5%	15%	3.5%
SECTOR	**MWh heat**	**MWh heat**	**MWh heat**	**MWh heat**
AIRPORT TERMINALS	29,131	61,980	61,980	61,980
BUS STATION/TRAIN STATION/SEAPORT TERMINAL	-	-	-	-
CALL CENTRES	-	-	-	-
COMMUNITY/DAY CENTRE	-	-	-	-
CROWN AND COUNTY COURTS	-	-	-	-
EMERGENCY SERVICES	156,311	203,723	203,723	203,723
FUTHER AND HIGHER EDUCATION	332,895	695,552	695,552	695,552
FUTHER AND HIGHER EDUCATION WITH POOL	553,417	1,384,184	999,688	1,384,184
HOSPITAL	2,433,438	5,507,536	5,459,727	5,507,536
HOTEL	2,039,413	2,408,682	2,408,682	2,408,682
HOTELS WITH POOLS	651,918	812,701	812,701	812,701
LAUNDRETTE	-	-	-	-
LEISURE CENTRE NO POOL	3,558	3,558	3,558	3,558
LEISURE CENTRE WITH POOL	61,572	68,413	68,413	68,413
LIBRARIES/MUSEUMS/GALLERIES	-	-	-	-
NURSING RESIDENTIAL HOMES AND HOSTELS	101,189	101,189	101,189	101,189
OFFICE BUILDINGS	26,254	26,254	26,254	26,254
OFFICE PREMISES	-	-	-	-
POOL ONLY	318,360	546,000	546,000	546,000
PRIMARY HELATH CARE BUILDINGS	-	-	-	-
PRIMARY SCHOOL	-	-	-	-
PRIMARY SCHOOLS WITH POOLS	-	-	-	-
PRISONS	275,348	351,833	351,833	449,734
RESTAURANT/PUBLIC HOUSE	-	-	-	-
RETAIL WAREHOUSE AND LARGE SUPERMARKETS	96,729	135,420	135,420	135,420
SECONDARY SCHOOL	-	-	-	-
SECONDARY SCHOOLS WITH POOLS	-	-	-	-
SHOPPING MALLS	-	-	-	-
SHOPS	-	-	-	-
SOCIAL CLUBS	-	-	-	-
SPORTS GROUND ARENA	-	-	-	-
TELEPHONE EXCHANGES	48,890	68,446	68,446	68,446
THEATRES/CINEMAS/MUSIC HALLS AND AUDITORIA	-	-	-	-
WAREHOUSE AND STORAGE	-	-	-	-
WORKSHOPS/MAINTENANCE DEPOT	-	-	-	-
MOD*	NA	NA	NA	NA
Total MWh useful heat	7,128,423	12,375,472	11,943,168	12,473,374

Table A3.5 shows, for the individual sectors, that the percentage of the total heat demand that could be met by CHP varies between 3% or 4% up to 40% for swimming pools, with correspondingly higher percentages in 2010 and for the lower discount rate.

Table A3.5 Percentage of Annual Heat Demand Met by CHP Heat

YEAR	2002	2002	2010	2010
DISCOUNT RATE	15%	3.5%	15%	3.5%
	% heat demand met by CHP			
AIRPORT TERMINALS	13%	28%	28%	28%
EMERGENCY SERVICES	20%	26%	26%	26%
FUTHER AND HIGHER EDUCATION	15%	31%	31%	31%
FUTHER AND HIGHER EDUCATION WITH POOL	39%	96%	70%	96%
HOSPITAL	37%	85%	84%	85%
HOTEL	30%	36%	36%	36%
HOTELS WITH POOLS	35%	44%	44%	44%
LEISURE CENTRE NO POOL	3%	3%	3%	3%
LEISURE CENTRE WITH POOL	14%	15%	15%	15%
NURSING RESIDENTIAL HOMES AND HOSTELS	4%	4%	4%	4%
OFFICE BUILDINGS	0%	0%	0%	0%
POOL ONLY	40%	68%	68%	68%
PRISONS	10%	12%	12%	16%
RETAIL WAREHOUSE AND LARGE SUPERMARKETS	3%	4%	4%	4%
TELEPHONE EXCHANGES	4%	6%	6%	6%

Table A3.6 shows the total primary energy savings that the CHP potential identified could realise in individual public and commercial buildings. In this study, although dual fuel diesel was identified as an economically viable option in some instances, in all cases gas fired plant was more cost effective and hence it was assumed in the modelling that the gas option would be implemented. In practice dual fuel diesel is only likely to be chosen in instances where grid gas is unavailable. Whilst a very small percentage of buildings in Great Britain are not connected to the gas grid, these tend to be isolated areas where the building types that were identified as having significant CHP potential are unlikely be sited. Hence it was reasonable to assume that all the CHP potential identified could be gas fired. Clearly the situation for Northern Ireland, where the gas network is less extensive, would be different.

Table A3.6 Potential primary energy savings from economically viable CHP in individual public and commercial buildings (GB)

YEAR	2002	2002	2010	2010
DISCOUNT RATE	15%	3.5%	15%	3.5%
SECTOR	**MWh primary**	**MWh primary**	**MWh primary**	**MWh primary**
AIRPORT TERMINALS	18,428	39,208	39,208	39,208
BUS STATION/TRAIN STATION/SEAPORT TERMINAL	-	-	-	-
CALL CENTRES	-	-	-	-
COMMUNITY/DAY CENTRE	-	-	-	-
CROWN AND COUNTY COURTS	-	-	-	-
EMERGENCY SERVICES	113,872	148,411	148,411	148,411
FUTHER AND HIGHER EDUCATION	185,311	387,190	387,190	387,190
FUTHER AND HIGHER EDUCATION WITH POOL	434,678	1,087,199	785,200	1,087,199
HOSPITAL	1,520,804	3,441,995	3,412,117	3,441,995
HOTEL	1,489,055	1,758,673	1,758,673	1,758,673
HOTELS WITH POOLS	471,387	587,645	587,645	587,645
LAUNDRETTE	-	-	-	-
LEISURE CENTRE NO POOL	2,536	2,536	2,536	2,536
LEISURE CENTRE WITH POOL	45,734	50,816	50,816	50,816
LIBRARIES/MUSEUMS/GALLERIES	-	-	-	-
NURSING RESIDENTIAL HOMES AND HOSTELS	71,806	71,806	71,806	71,806
OFFICE BUILDINGS	10,257	10,257	10,257	10,257
OFFICE PREMISES	-	-	-	-
POOL ONLY	245,174	420,483	420,483	420,483
PRIMARY HELATH CARE BUILDINGS	-	-	-	-
PRIMARY SCHOOL	-	-	-	-
PRIMARY SCHOOLS WITH POOLS	-	-	-	-
PRISONS	210,559	269,048	269,048	343,914
RESTAURANT/PUBLIC HOUSE	-	-	-	-
RETAIL WAREHOUSE AND LARGE SUPERMARKETS	75,062	105,086	105,086	105,086
SECONDARY SCHOOL	-	-	-	-
SECONDARY SCHOOLS WITH POOLS	-	-	-	-
SHOPPING MALLS	-	-	-	-
SHOPS	-	-	-	-
SOCIAL CLUBS	-	-	-	-
SPORTS GROUND ARENA	-	-	-	-
TELEPHONE EXCHANGES	36,041	50,458	50,458	50,458
THEATRES/CINEMAS/MUSIC HALLS AND AUDITORIA	-	-	-	-
WAREHOUSE AND STORAGE	-	-	-	-
WORKSHOPS/MAINTENANCE DEPOT	-	-	-	-
MOD*	NA	NA	NA	NA
Total MWh primary energy saving	4,930,704	8,430,811	8,098,933	8,505,677

Annex 4 Community heating methodology

This Annex describes the methodology for determining the economic viability of Community heating (CH)/CHP in each postcode sector and the economic models developed for estimating the costs of the heat network, the building connections and the heat sales from the network.

Heat demand

The starting point for the analysis was an estimate of the heat demand in each postcode sector in the UK. There are approximately 8,900 postcode sectors in the UK with typically 2000 addresses in each.

The number, type and tenure of dwellings was obtained from the 1991 census, as used for the earlier UK potential report (1). Floor areas for various types of non-domestic buildings were obtained from the Business Rates database (available for England and Wales only). This was supplemented by information obtained on hospitals, universities and the Government Estate.

The number of domestic and non domestic buildings in each postcode sector and average energy indices were used to calculate the heat demand. The heat density was calculated as the average heat demand in the postcode sector divided by the area of the sector. These heat demand densities were plotted on maps for the major UK cities and are available via the Energy Saving Trust (EST) web site (www.est.org.uk).

Heat network costs by postcode sector

From the heat density, cost relationships were derived which enabled the capital and operating costs (pumping and heat losses) of the heat network to be estimated for each postcode sector.

CHP sizing and the cost of heat production from CHP

For a given annual heat demand profile, there will be a range of CHP sizes over which a net carbon saving would be realised in comparison to an alternative scenario of central boiler plant. A model of the CHP operation was used to determine for each of the discount rates the optimum ratio of CHP electrical output to peak heat demand for domestic and non-domestic load profiles. The model then enabled the cost of heat production to be calculated taking account of capital, fuel and maintenance costs and electricity revenues. Gas-fired boilers were included for peak and standby use and a thermal store was also modelled.

The CHP efficiencies assumed to be a typical gas-engine CHP system for this application (electrical efficiency 42% and heat efficiency 46%-both based on net calorific value) in the range 1MWe to 5MWe.

Market penetration

The model assumes an initial market penetration of 40% rising to 80% over 8 years. The capital expenditure of the CH network is linked to this growth in demand but weighted towards the initial investment to reflect the fact that the main distribution system will have to be installed initially.

Existing infrastructure

Data was obtained on the number of dwellings supplied by existing Community Heating. The capital cost for the network and dwelling connections was reduced for these dwellings to take account of this existing infrastructure.

Net Present Value (NPV) Analysis

Once the cost of heat production from CHP and boilers, the CH network costs and the revenue from heat sales has been determined for each postcode sector, the Net Present Value (NPV) of the scheme over a 25 year period can be established.

The NPV is calculated as:

> Present value (PV) of heat sales less PV of CH network cost less PV of cost of heat production.
>
> The optimum CHP capacity for each postcode sector is determined from the average heat demand in the sector, the split between the domestic and non-domestic sectors and the ratio of CHP output to heat demand derived from the simulation models. This ratio varies for the different discount rates used for the optimisation.
>
> The summation of this CHP capacity for all the sectors where the NPV is positive results in the total UK potential. Finally, the CHP capacity that already exists in buildings in the viable postcode sectors was obtained from the OFGEM database and subtracted from the total to give the new net CHP potential.
>
> From the above it can be seen that the discount rate selected is a limiting value and not that the overall rate of return for all of the schemes included is equal to the discount rate i.e. the average rate of return of the schemes will be higher than the discount rate used in the analysis. We have taken a range of discount rates between 3.5% and 15% to show how the potential varies with the cost of capital. A lower discount rate has two effects, reducing the importance of capital costs in the NPV calculation and increasing the capacity of the CHP plant that can be justified for a given heat demand.

The methodology for assessing the economic viability of CH/CHP in each postcode sector was as follows:

Cost data is related to 2002 price levels unless otherwise stated. For each postcode sector the Net Present Value is estimated over 25 years and at a given discount rate (3.5%, 6%, 9%, 12% and 15%) for the following cost and revenue components:

- Cost of Heat Production - from generic CHP simulation models
- Cost of Heat Distribution - capital cost of network, pumping energy and heat losses
- Cost of building heating system modifications

- Revenues from heat sales based on customer's avoided costs.
- Administration, network maintenance and other costs.

The sum of these NPVs gives the NPV for the scheme. If this is positive the associated CHP capacity is counted towards the UK potential.

The postcode sectors are ranked by sorting on the NPV divided by the heat sold p.a. in MWh.

The cost of heat production by CHP and the ratio of an optimum sized CHP plant to the average heat demand were determined from the generic CHP models.

The approach taken to estimate heat network costs, building heating system costs and heat sales is described here.

Other assumptions included in the analysis are:

- Heat network maintenance costs at 1% of capital costs p.a.
- Dwelling maintenance cost for CH systems at £55 p.a. per dwelling
- Administration costs at 10% of heat sales revenue p.a.

Methodology for estimating costs of heat networks

As CH is not well established in the UK information on the costs of installing heat mains on a large scale is limited. A three-fold approach was used:

- development of a cost model using sample designs of heat networks
- correlation of the model with cost estimates made in feasibility studies for specific areas.
- comparison of results with those that would be predicted in Denmark

The heat mains costs are assumed to be those of the buried heat mains between the CHP/Boiler plant and the perimeter of the buildings. The cost of additional pipework within the buildings (such as internal risers in a block of flats) is included in the building heating systems costs.

The cost model for heat networks

The cost of installing heat mains in a given area depends on four factors:

1. The design operating temperatures: The influence of operating temperatures on the design of CH/CHP systems is complex and the following assumptions have been made in order to allow evaluation of the costs of heat mains for a range of actual operating temperatures without significant variations. The DH networks will be designed as low temperature systems with flow and return temperatures of 95ºC flow 65ºC return. A wider temperature difference would be preferable however the return temperature will be limited by the temperatures of existing heating systems, which typically will be 80ºC flow 60ºC return unless designed specifically for DH. Higher flow temperatures than 95ºC are not achievable from spark-ignition gas-engine CHP plant without either additional costs or loss of efficiency

2. The complexity of existing services: The impact of the complexity of existing services is difficult to quantify but it is clear that the same length of pipe installed in city centre locations will be more expensive than in less congested areas partly because of the difficulty of finding routes around existing services and partly because of the need for traffic management and related safety requirements. The speed of excavating trenches is often a determining factor in the total price of the project. The following weighting assumptions on capital cost have been made:

outer London and average heat density areas less than 8MW/km^2	0.95
inner London and average heat density areas more than 8MW/km^2 and less than 12 MW/km^2	1.0
inner London and average heat density areas more than 12 MW/km^2	1.3

3. The length of the heat mains; this is assumed to equal the total length of the streets in the area.
4. The peak heat demand; if more heat is to be delivered the pipe sizes will be larger. In this case the heat density is calculated using the peak heat demand.

Network Costs as a function of postcode area and road density

Geometry

The heat mains are the pipes that supply heat to individual buildings and dwellings. In practice the pattern of heat mains serving a given area will be unique; the actual lengths and layout of the pipes depend on the distribution of the supply points, the diameter of the pipes would be designed to supply sufficient load to each connection whilst optimising pumping costs, and branch and bend fittings would be specified as appropriate to the particular application. Typically many different loads would be connected to a DH system, ranging in capacity from a few kilowatts for an individual dwelling, to several hundred kilowatts for a large office or school.

In order to estimate the cost of the network over the extent of the UK, a model was developed to create a single local DH mains structure for each postcode sector area. The design of each network is based on a notional supply grid, as shown in Figure A4.1, employing branches to link every load within an equivalent square area to the postcode sector area to a single supply point. It is assumed that the geographical distribution of loads (heat load density) within a postcode sector area is homogeneous.

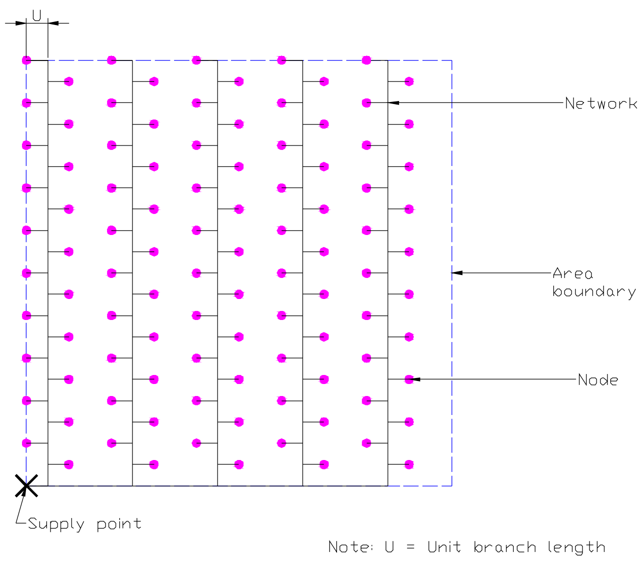


Figure A4.1 Notional grid geometry (100 equispaced nodes)

The capital cost of each postcode sector area network is a function of its land area and the number of nodes it contains (which affect the total length of the pipes) and the load at each node (which affects the diameter of the pipes).

The peak heat load for each postcode sector area was assessed from benchmark data, but there is no statistical breakdown available of the number or size of building connections. It was assumed that each postcode sector grid would contain 100 supply nodes and that all of the 100 nodes would be of equal capacity, i.e. that the total peak load for that postcode sector area is divided equally between 100 nodes. This was considered a reasonable assumption as variations in pipe sizes about the mean due to larger or smaller actual connections will tend to cancel out.

The number of nodes per grid was selected after studying the frequency distribution of the peak heat loads of 132 postcode sector areas in UK cities in a previous study [A comparison of distributed CHP/DH with large scale CHP/DH, Report 8DHC-05.01, IEA District Heating & Cooling Project Annex VII].

Thus the capital cost of each postcode sector area network is a function of the load at each node and the length of pipes in the network, which is approximately proportional to the sector area.

Network optimisation

The actual optimisation of design of the notional grids was performed using a suite of hydraulic analysis software called System RØRNET developed by Ramboll. Given a set of parameters defining the network geometry and operational constraints, the software calculates the economic optimum sizes of the pipes, taking account of pumping energy, heat losses and capital costs. For the postcode based grids, the following design criteria are assumed:

- a static head of 3bar

- a factor of 1.1 on pressure drop through the network over and above pressure losses resulting from the roughness of pipes, to account for bends, branches and valves
- a 1bar differential pressure allowance at each customer connection to allow for the hydraulic interface heat exchangers and control valves
- maximum system working pressure of 10bar based on an analysis of a range of working pressures from 6bar to 16bar and the effect on network design and cost implications.
- primary DH flow temperatures of 95°C and an average return temperature of 65°C, giving a 30°C temperature difference across the network.

Capital cost

It was not feasible to perform a design optimisation analysis on every one of the notional grids created for the postcode sector areas, each having different geometry and peak load requirements. Instead, 10 networks were analysed, with combinations of loading and total pipe lengths to cover at intervals the range of loads and sector areas in the data. The unit used to express the length of pipe in a network is "unit branch length", as shown in Figure , a fixed fraction of the total pipe length which is derived from the land area of the postcode. The results are expressed in Figure A4.2 as an average specific pipe cost for a given network e.g. if the total length of piping in a given network is 100m and the combined capital cost of the pipes required is £91,000 then the average pipe cost is £910/m. The schedule of pipe costs used is typical of those experienced in the UK for similar projects, and is shown in Figure A4.3.

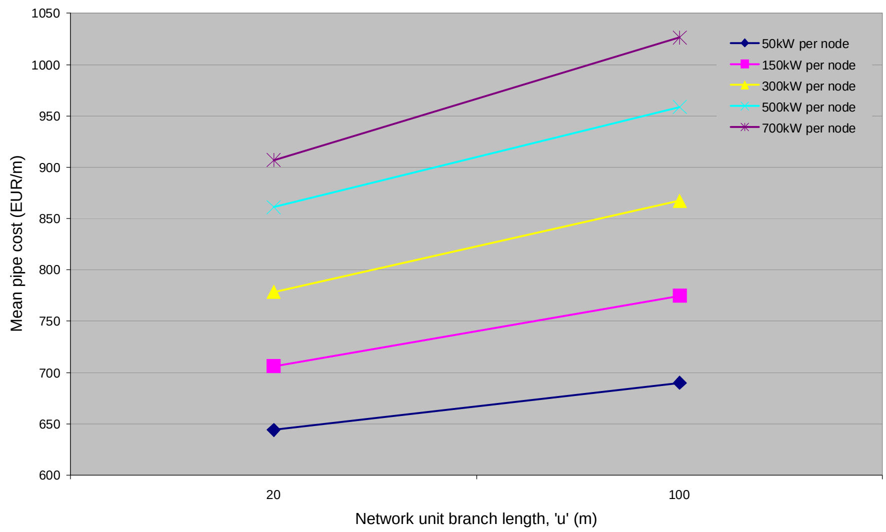


Figure A4.2 Variation in average pipe capital cost with loading and network size for the notional grid network

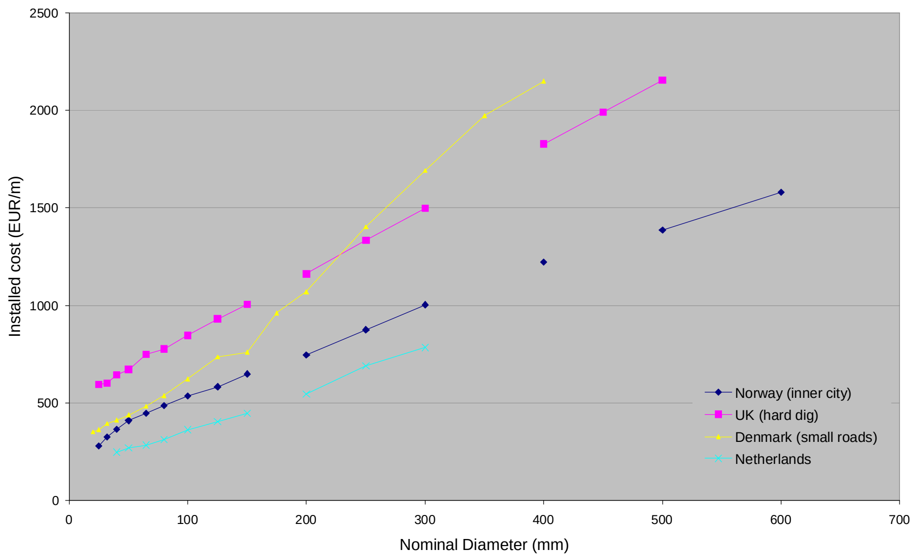


Figure A4.3 Cost of DH mains

The results show the expected increase in costs as the loading on the network increases, caused by the requirement for larger diameter pipes. There is also an increase in average pipe cost per m with increasing network length for a given load, which is approximately linear and has been shown as such on Figure . This is caused because larger pipe diameters within the longer pipes are needed to avoid high pressure drops, increasing the overall average cost.

The peak heat load and land area of each postcode sector were used to derive values for load per node and unit branch length. These values were used to find an average cost per metre of pipe based on the relationships shown in Figure A4.2, interpolating as required. By multiplying this value by the total theoretical network length a capital cost for the network was produced.

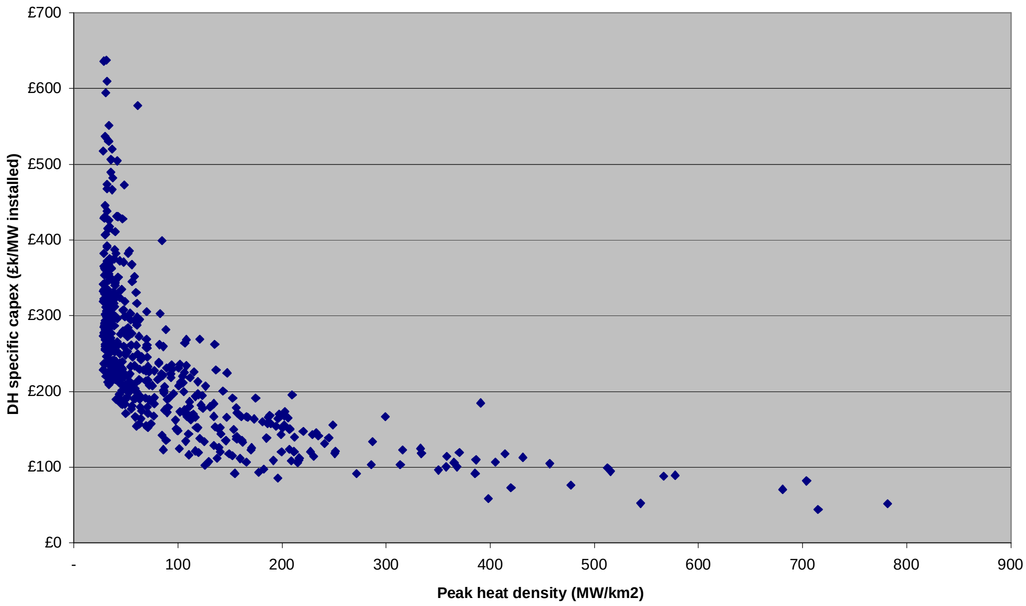


Figure A4.4 Postcode sector DH mains specific cost versus heat density for 500 postcodes of greatest heat density

Local connections

The approach described above provides cost estimates for the heat mains in the streets within a single postcode sector. There will be additional costs for connecting each of the buildings to the heat mains in the street.

Residential Buildings

The connecting heat mains from the street mains to the building are of significance for the housing sector where small buildings are connected with buried pipe. The costs are not directly related to the distance of the building from the street as the costs include for the branch connection to the street mains, the building entry and the supply of isolating valves within the building. Cost estimates have been prepared after discussions with Contractors experienced in the field and taking account of the potential benefits of using pre-insulated cross-linked polyethylene pipes. These costs are expressed as a cost per dwelling for the different dwelling types. (For the purpose built flats the heat distribution pipework within the building is discussed under the section on building heating system costs.)

As discussed above, the notional grid model does not make provision for the branches that will serve domestic consumers. A single dwelling branch has been sized with the following assumptions:

- 50kW maximum peak instantaneous hot water demand
- 10m typical branch length (from street to dwelling)

- 95/65 DH flow/return temperatures
- Pipe of nominal diameter 25mm supplies heat peak with flow velocity of 0.8ms-1, pressure drop of 23mm/m.

For each postcode sector the cost for a single 10m long DN25 branch was multiplied by the number of dwellings in each category, with the following factors to account for multiple dwellings per connection for certain build types and for proximity to the street main, which are estimates based on typical UK experience:

- Detached houses 1.0
- Semi-detached houses 0.6
- Terraces 0.4

Communal housing (e.g. purpose-built flats) was not included in this analysis as the typical connection size is larger and falls into the range already accounted for by the notional grid model. The dwelling connection costs were added to the notional grid costs resulting in a total cost for the heat mains for each postcode sector, which are displayed in Figure A4.4.

Non- Domestic Buildings

The cost of connection for non-domestic buildings is difficult to estimate as the number of individual premises for each sector, and therefore the number of connections is unknown. The database only contains total floor space data. The cost will however be very small in comparison with the total cost and will not affect the results significantly.

Dwellings Heating System Costs

Installations within the dwellings

Capital cost estimates for new heating systems within dwellings suitable for connection to CH have been estimated using the tenders received for recent CH refurbishment contracts in the UK which have been designed by PB Power. The largest of these projects was for more than 4300 dwellings; this was used as the main source of data as it represented the economies of scale that would result from large scale implementation of CH/CHP. The costs can be related to three main variables:

- the peak space heating demand
- the number of radiators
- the number of occupants (to determine hot water service requirements).

Although a heating system for CH is similar to an individual gas-fired boiler system there are important differences, which are reflected in the cost:

- the boiler is replaced with a prefabricated control unit which will typically contain a differential pressure control valve, on/off control valve for the heating circuit and a variable orifice double regulating valve to enable flow rates to be measured

- the radiators are sized for a lower mean temperature e.g. 65°C compared to the normal standard of 76.5°C. This enables the differential temperature to be increased
- the radiators are suitable for a working pressure of at least 7 bar instead of the more usual 4.4 bar
- the pre-insulated cylinder will have its own direct acting control valve and additional coil surface to increase the design temperature difference
- a strainer is installed to protect the control valves from debris in the CH circuit
- the thermostatic radiator valves should be suitable for low flow rates and incorporate pre-setting to give accurate balancing between radiators
- quarter turn ball valves are installed in a prominent position to enable a quick shut off of the CH system in the event of a leak.

Other components such as programmer, lockshield valves, drain points, air vents, pipework are similar to an individual system. Items not required are the circulating pump, gas pipework and boiler flue. This design is for a direct connection system which is appropriate for smaller projects and when connecting small buildings such as flats. An indirect system is more complex with the following additional equipment:

- heat exchanger
- primary control valve
- circulating pump
- secondary side F and E tank or pressurisation system.

Again this equipment is normally supplied as a prefabricated control unit.

Hot Water Service Provision

An alternative to the hot water cylinder is a plate heat exchanger which provides instantaneous hot water in a similar way to a combination boiler. This is now the most popular choice for many continental schemes and has the following advantages:

- eliminates standing heat losses from the hot water cylinder
- provides low return temperatures in the network
- uses less space in the dwelling
- enables mains pressure hot water to be provided for showers.

The disadvantages are:

- additional cost

- higher primary peak flow rates in the local pipework
- risk of scaling in the heat exchanger
- no toleration of short interruptions in community heating supply.

Heat Meters

It is likely that in some sectors market acceptance will only be achieved if heat meters in individual dwellings are offered. The additional costs are:

- the supply of the heat meter
- installing the heat meter within the prefabricated control unit
- commissioning
- meter reading and billing
- maintenance and battery replacement.

The cost of the variable orifice double regulating valve can be avoided if a heat meter is installed (as the heat meter can provide instantaneous flow rate measurement).

Additional options that are often considered with heat meters are:

- prepayment equipment to eliminate bad debt and reduce billing costs
- remote meter reading to reduce meter reading costs

For the purposes of assessing the potential for CH/CHP it has been assumed that:

- all dwellings have radiators with hot water cylinder and indirect primary heating coil (where dwellings do not have this system the costs of installing a new heating system will be borne by the building owner and not the CHP scheme)
- heat meters will be installed in all dwellings
- pre-payment devices will not be installed - if these are required the additional costs will be recovered in the form of higher standing charges.

Whilst there will be cases where these assumptions underestimate the cost of connecting to CH (e.g. where recent combination boilers have been installed), there will be other cases where the cost of new CH internals will be lower than a gas-fired installation e.g. multi-storey blocks without an existing gas infrastructure.

Included in the economic model is a connection cost to dwellings of £950, which comprises:

- prefabricated control unit (£350)
- heat meter - ultrasonic type (£250)
- installation (£250)
- survey, design and commissioning (£100).

Local pipework for purpose-built flats

In blocks of flats there is an additional cost for internal pipe distribution systems within the block. There may also be a heat exchanger substation at the base of the block to enable direct connection to be achieved to individual flats. An average cost of £510 per dwelling has been estimated from recent tenders received for Community Heating installations, to cover this element of the capital cost.

Non-residential buildings system costs

It is assumed throughout that the existing heating systems within non-residential buildings will be retained and a connection to the existing heating system made either directly or indirectly depending on the temperature and pressure compatibility of the systems. The customer will benefit from the avoided costs for replacement of boilers but as commercial boilers have a longer life than domestic boilers this cost benefit is small and has been neglected. Using cost estimates from other work by PB Power for the International Energy Agency, together with example UK scheme costs in the UK, an average cost of £10/kW_{th} was assumed in the economic model for non-domestic properties. Larger properties will have lower costs and smaller properties higher costs but the database information only provides the total of non-domestic floor space not a breakdown of the number of buildings.

CHP sizing

For a given annual heat demand profile, there will be a range of CHP sizes over which a net carbon saving would be realised in comparison to an alternative scenario of central boiler plant. An analysis has been performed using a whole life comparison of capital and operational costs to determine the optimum CHP size. The result will vary according to the discount rate, lower discount rates favouring larger CHP sizes. The results are shown in Figures A4.5 and A4.6.

The variables P_d and P_{nd} were established, being the ratios of CHP electrical output to the domestic and non domestic components of average heat demand respectively. Using a representative heat demand profile P_d and P_{nd} were optimised on a whole life basis over a range of discount rates from 3.5% to 15%. Thus for each postcode an optimum CHP was determined based on average domestic and non- domestic heat demand, and discount rate.

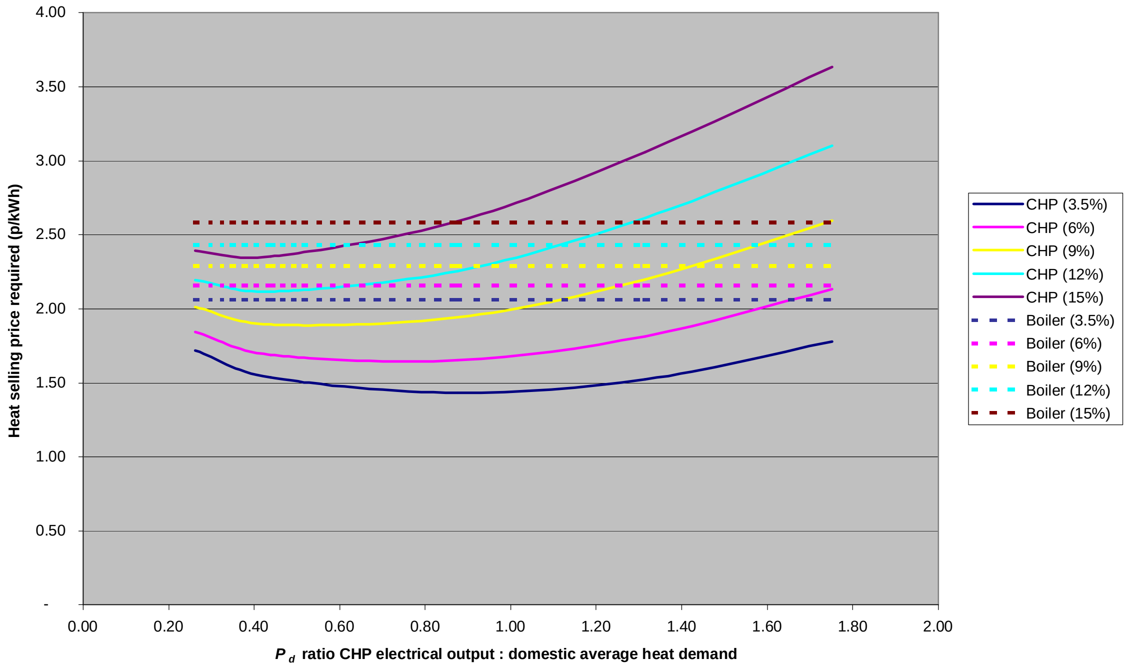


Figure A4.5 Optimisation of CHP sizing for domestic heat load profile

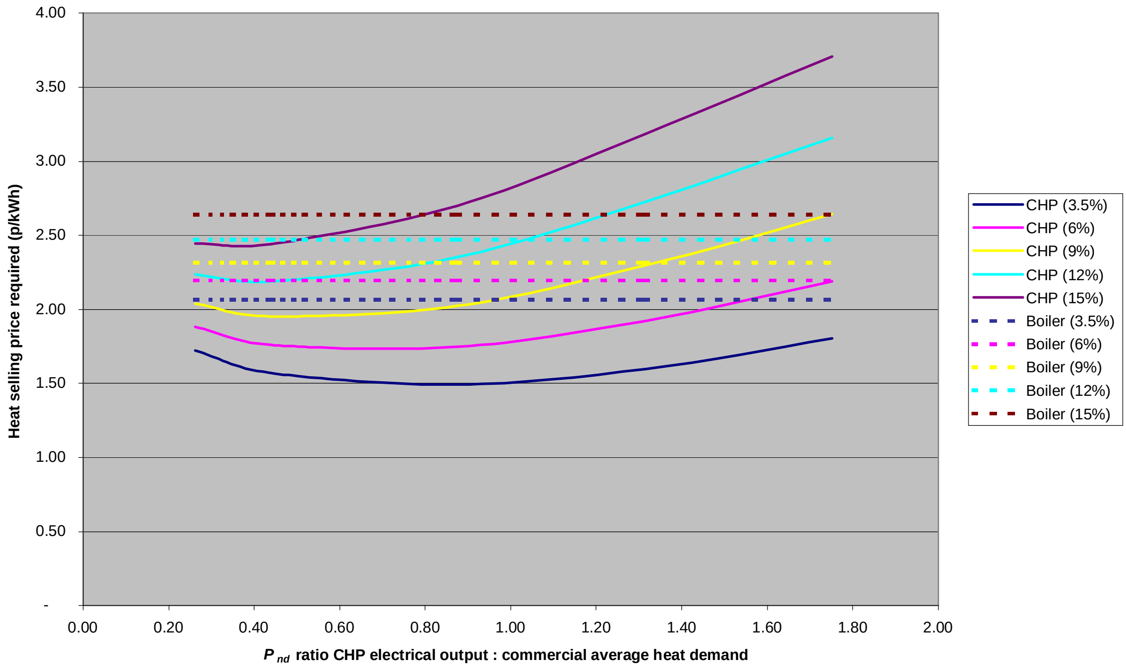


Figure A4.6 Optimisation of CHP sizing for non-domestic heat load profile

Heat Sales Revenues

General

The final element in the economic analysis is the calculation of the revenues from heat sales. In general, if this revenue, less the cost of heat production, is sufficient to finance the cost of the heat distribution system then the scheme will be viable.

In calculating the 'technical potential' for CH/CHP it is assumed that heat is sold at a price equal to that which customers would be paying without CH/CHP.

Domestic Heat Demand

The predominant heating system for individual dwellings is assumed to be conventional boilers supplying a radiator heating system with natural gas as the fuel.

The cost of running such a system has been estimated using the following assumptions: All costs are 2002 costs.

- Existing Seasonal boiler efficiency 65% (as assumed by NHER Evaluator software)
- Replacement of boiler in Year 8 at a cost of £1061
- Future Seasonal boiler efficiency 86% (subsequent to year 8)
- Annual maintenance cost for the heating system including gas safety check £150 p.a. including an allowance for parts and labour over 15 year boiler life
- Standing charge for gas supply £36 p.a.
- Electricity for circulating pump and boiler £8 p.a.

The boiler replacement is judged to occur in Year 8 as a significant expansion in individual gas-fired central heating occurred in the 1980s and replacement of these boiler systems is likely within 8 years of any CHP project.

From the above costs a levelled heat price is calculated as shown in Table A4.1.

Table A4.1 – Total heating costs expressed as levelled heat price for individual dwelling gas-fired heating systems at 9% IRR

House Type	**Levelised heat price**
	p/kWh
Detached	3.45
Semi-detached	3.67
Terrace	5.27
Purpose-built flat	4.91
Converted flat	3.45

The technical potential has been calculated assuming a heat sales income based on these levelised p/kWh prices.

Non-domestic heat demand

The same principles apply to the non-domestic sector but the assumptions are harder to make given the range of buildings that might be connected. The variables are:

- type of fuel, predominantly gas but some oil is also likely
- boiler efficiency
- age of boiler plant and likely replacement programme
- cost of capital
- maintenance costs
- value of the space occupied
- size of the building
- fuel price payable

It has not been considered practical to estimate these factors from the limited information in the database particularly with regard to the size of the connection. Taking a typical 2000m^2 commercial office building the delivered gas price would be about 1.03p/kWh. Taking a boiler efficiency of 75% results in a fuel related heat price of 1.37p/kWh. This may well be the starting point for negotiations with customers but experience from Sheffield, Nottingham and Southampton indicates that the following benefits of CH/CHP are recognised by potential customers:

- lower staff costs
- lower maintenance costs
- improved reliability
- release of space
- avoidance of future boiler replacement costs

An evaluation of all of the above factors is not feasible without detailed information from a customer survey. We have therefore relied on advice from operators of existing CH schemes in the UK who have been marketing CH to non-domestic customers for a number of years. From our discussions with the CH companies in Sheffield, Nottingham and Southampton, it is reasonable to assume that the heat selling price could be increased by about 50% and still remain competitive once the above factors have been considered. In addition to this an additional charge 0.2p/kWh can be added as this would be incurred with individual boilers due to the Climate Change Levy of 0.15p/kWh and a 75% boiler efficiency. Hence a current charge of 2.09p/kWh has been assumed.

Results

Table 4.2 shows a breakdown of the UK CH/CHP potential by postcode area for major cities for three different discount rates (note that these postcodes do not necessarily correspond to local government boundaries).

Table 4.2 Breakdown of UK potential between major cities

City/Area	CH/CHP Potential (MWe)		
	3.5%	**6%**	**9%**
London postcodes	2,366	2,026	85
Birmingham postcodes	1,191	948	0
Manchester postcodes	733	644	0
Sheffield postcodes	924	660	0
Southampton postcodes	384	268	0
Leicester postcodes	600	344	0
Liverpool postcodes	804	643	1
Leeds postcodes	546	370	0
Bristol postcodes	559	390	0
Newcastle postcodes	763	609	0
Cardiff postcodes	0	0	0
Other UK in England & Wales	24,362	15,654	5
Sub-total	33,231	22,558	91
Less existing CHP capacity*	44	44	44
Scotland and N.Ireland	3,323	2,256	9
TOTAL	**36,510**	**24,770**	**56**

Domestic buildings are a high proportion of the total heat supplied for all of the discount rates.

The base case results have been analysed for sensitivity to a 20% increase or decrease in gas or electricity prices. The various combinations of these sensitivities for each discount rate are presented in

Table . It can be seen that at 6% the minimum CHP capacity for CH schemes is around 4,200MWe for a low electricity price and high gas price, and the maximum capacity is 30,000MWe for a high electricity price and low gas price.

The economic barrier to the development of CH/CHP could be reduced by measures that result in a lower capital cost, a lower cost of borrowing, lower gas prices or higher electricity prices. The impact of the last two parameters can be judged by reference to the sensitivities on fuel price and the cost of borrowing related to the discount rate variation.

Table 4.3 Sensitivity Analysis on Energy Prices

		Potential (GWe)		
Electricity	**Gas**	**3.50%**	**6%**	**9%**
Straight	High	33.0	9.3	0.0
Straight	Low	33.2	24.6	0.3
High	Straight	46.2	29.3	1.8
Low	Straight	15.9	5.0	0.0
High	High	34.0	27.8	0.6
Low	Low	15.8	5.9	0.0
High	Low	51.2	30.0	4.9
Low	High	15.9	4.2	0.0