Renewable Heat and Heat from Combined Heat and Power Plants - Study and Analysis

Report

FUTURE
ENERGY
SOLUTIONS

From AEA Technology

Title	Renewable Heat and Heat from Combined Heat and Power Plants - Study and Analysis
Customer	DTI & Defra
Customer reference	
Confidentiality, copyright and reproduction	Copyright AEA Technology plc This document has been prepared by AEA Technology plc in connection with a contract to supply goods and/or services and is submitted only on the basis of strict confidentiality. The contents must not be disclosed to third parties other than in accordance with the terms of the contract.
File reference	M:\Projects\DTI\Renewable Heat and CHP\Report\Published version 1
Reference number	ED02137 Published version 1

Future Energy Solutions
AEA Technology
The Gemini Building
Fermi Avenue
Harwell International Business Centre
Didcot
OX11 0QR
Telephone 0870 190 6240
Facsimile 0870 190 6336

Future Energy Solutions is a business division of AEA Technology plc

Future Energy Solutions Quality Management Systems are certified to ISO9001 and ISO14001

Authors	Name	Adam Brown Paul Maryan Howard Rudd
Approved by	Name	Cathy Durston
	Signature	
	Date	

Executive Summary

BACKGROUND

Around 30% of total energy (excluding transport) consumed in the UK is in the form of heat for space and process heating. Around 1% of this heat is currently generated from renewable sources and 8% is met from combined heat and power (CHP) systems fuelled by fossil fuels or renewable sources. There are significant opportunities to reduce the UK's carbon emissions by increasing the contribution from renewable energy and CHP to this market.

Despite the market potential, the amount of renewable energy supplied as heat has declined in recent years both as a proportion of the whole and in absolute terms.

There has also been little growth in CHP, although the Government has in place a number of existing support mechanisms for CHP. These include Climate Change Levy exemption for good quality CHP, Enhanced Capital Allowances for CHP equipment, business rates exemption, the Community Energy programme and a 15% target for CHP electricity in Government Departments.

In contrast, the output from electricity-producing renewables is growing rapidly in response to the Renewables Obligation and other market creation measures.

The purpose of this study, carried out for the DTI and Defra, is to quantify the potential for expanding the contribution to the heat market from renewable energy and the heat from CHP, and the associated costs. To achieve this we have assessed the economic performance and the technical and non-technical barriers to adoption of candidate renewable technologies and CHP. Given the nature and complexity of the heat market, we then considered the potential performance of each of the chosen technologies in three different market sectors. This allowed us to identify where there is a good fit between technology and market.

By considering each technology in the context of the markets that they might serve, we have been able to provide answers to the following questions for each technology:

- What is the size of the resource and what level of market penetration might be achieved in 2010, 2015 and 2020?
- What are the potential carbon/CO_2 savings that would result?
- What would be the cost per tonne of the carbon saved?
- At present, how far from economic and commercial viability is renewable heat and heat from CHP produced from each resource and conversion technology?
- What is the likely effect of achieving technological progress and economies of scale through market development and what difference might these developments make to the costs and competitive viability of heat delivery projects?
- What are the barriers preventing the development of the market?

Having answered these questions we have then considered the following issues:

- Is financial support required to make renewable heat and heat from CHP commercially viable, and, if so, how much?
- How might the market contribution and carbon savings rise with increasing levels of support and what might the costs and benefits in terms of carbon savings be?

RENEWABLE HEAT TECHNOLOGIES

Potential

We have assessed the potential contribution that renewable energy technologies could make to UK heat demand, and calculated a "projected contribution" which allows for the technical, market and commercial constraints. Our analysis indicates that renewables could contribute an additional 6.0 TWh/y to the heat market in 2010, rising to 34.9 TWh/y in 2020 (equal to 0.8% and 4.7% of total UK heat demand). If all this potential were taken up by 2020 this would lead to carbon savings of 2.0 MteC/y (around 1.2% of current total UK carbon emissions (152 MteC/y)).

Costs of Heat Supply

Having defined this potential contribution, we have looked at the cost of supplying heat from appropriate renewable technologies into appropriate market sectors, comparing these costs with those of heat from fossil fuels. We have examined cases where gas is available, and also considered off grid opportunities where the competing fossil fuel option is oil. In calculating the delivered cost of heat we have applied a 15% discount rate to the capital and operating costs. For the renewable technologies we have also considered the potential for cost reduction in the future, as the technologies and delivery infrastructure mature and higher volume, more competitive markets develop.

The cost of supplying heat to the residential sector from renewable energy is high compared with the costs of heat from conventional sources even when projected technology cost reductions to 2020 are included. For the commercial and industrial sectors heat from biomass, energy from waste (EfW) and anaerobic digestion (AD) are more competitive.

Cost of Carbon Savings

We have also estimated the cost of carbon savings from each of the options. We have done this by calculating the difference in carbon emissions, and the difference in the cost of delivered heat from the renewable source and from the fossil fuel equivalent. For example, in the residential sector analysis indicates that in 2010 these costs range from £1085 to £4,200/teC. By contrast, in the industrial and commercial sectors the analysis shows that costs of carbon savings associated with biomass, energy from waste and anaerobic digestion are lower (£364-35).

Barriers and Need for Support

There are a number of factors that may constrain the rate of take-up of the renewable technologies we have studied, even where the investment case appears attractive. In the commercial and industrial sectors there are barriers that will hold back development of those resources even where the costs are favourable (for example heat from biomass, EfW and AD). These barriers include:

- poor current technology take-up in the UK leading to a lack of awareness of the opportunity and confidence in the technology and commercial infrastructure;
- in the biomass area there is no well established supply chain that can assure access to sufficient fuel, within a reasonable transport distance, that has been processed economically to the right specification for the boiler application concerned;
- lack of available capital within the user organisations who will prefer to use their capital for mainstream production investment and therefore require a very short payback period on investments of this type (typically 2 – 3 years);

- sensitivity of return on investment to fossil fuel prices – while prices currently make these projects attractive the volatility in energy prices makes future savings uncertain;
- competition for resource with non-energy uses and also with electricity only applications, including biomass fuel being used for co-firing, which benefits from support under the Renewables Obligation.

Some of these barriers are being addressed by existing Government initiatives. However, in order to stimulate the market for heat from renewable energy additional financial support may be required to help offset the perceived risks, including fuel price volatility, and create a level playing field for heat with electricity producing projects.

As well as financial support, these technologies could also be helped by non-financial measures such as changes to the building regulations, standards on the government estate and local authorities and changes to the planning system.

Impact of Support

We have modelled the effect of additional financial support for renewable heat on supply and demand in the market. From this we have identified the fraction of the potential that would be taken up at a particular level of support.

The Renewables Obligation (RO), which currently costs consumers approximately £470 million per year, rising to £1,000 million per year by 2010, can be used as a benchmark against which we can compare the effect of potential support. The level of annual carbon savings expected to arise from the Renewables Obligation is between 5.5 and 7.4 Mte of carbon per year, costing approximately £153 per year for each tonne of carbon saved.

Our analysis of the residential sector indicates that financial support for renewable heat and heat from renewable heat would have to be very large before significant carbon savings were stimulated and that the relative cost to Government would be high.

- Support of £50/MWh might stimulate 50% of the potential savings, around 400,000 teC by 2020, but at a cost of £775/teC.
- At a support level of £10/MWh (equivalent to £150/teC, a similar level as the Renewables Obligation), very little contribution would be stimulated, even by 2020.

Support at these levels in the residential sector may not be cost-effective in comparison with other carbon savings options in this sector. The development of renewables in this sector may be better stimulated by technology-neutral measures, which support carbon emission reduction measures in buildings more generally. This would allow consumers, if they choose, to opt for renewables within a range of other carbon saving options. Similarly, non-financial measures such as modifications to the building regulations may have an impact in the residential sector, although this would principally be limited to new build and major refurbishments.

In contrast, the analysis indicates that in the commercial and industrial sectors most of the potential from biomass, anaerobic digestion (AD) and energy from waste (EfW) could be catalysed by a lower level of support than would be needed in the residential sector. Support of £15-20/MWh should stimulate most of the potential savings at a cost of £250-330/teC.

The analysis suggests that it would be worthwhile introducing a support scheme for renewable heat and heat from renewable and fossil fuel fired CHP in the industrial and commercial sectors. A level of support of around £10/MWh would:

- stimulate annual savings of around 0.13 MteC by 2010 and of 0.81 MteC by 2020 (providing savings equivalent to around 0.7% of current carbon emissions), at a cost of around £170/teC;
- cost around £23 million by 2010, rising to £132 million by 2020.

This level of support would also be broadly equivalent to that available to electricity producing renewables.

The impact of non-financial measures, such as changing building regulations, could also be beneficial in the commercial and industrial sectors but, as in the residential sector, would be limited to new build and major refurbishment.

CHP

In addition to renewables, this report also considers the potential contribution of fossil fuel CHP systems to the heat market. As CHP involves the generation of thermal and electrical energy in a single process, CHP installations can convert up to 90% of the energy in the fuel into electrical power and useful heat, resulting in savings in carbon emissions compared with separate generation of heat and electricity. CHP is normally natural gas-fired, though the full range of fossil fuels can be used. The technology for delivering CHP is well developed and understood, with the principal current obstacle to implementation being poor cost-effectiveness.

We have based our work on three key studies by BRE, Cambridge Econometrics and FES for DTI. These have analysed the sensitivity of the CHP market to the value of the heat produced in the community heating, commercial and industrial sectors. We have used these studies to analyse the contribution and carbon savings from fossil fuel CHP increase with increasing levels of support. We have used this information to assess the costs of the carbon saved.

Our analysis indicates that a large contribution to carbon savings can be gained, particularly from fossil fuel CHP in the industrial sector, with additional contributions from the commercial and community heating sectors. Most of this potential could be brought forward at a level of financial support between £10 and £20/MWh, and at a level of £10/MWh savings of 2.7 MteC/y could be stimulated by 2020 (2% of current carbon emissions) at a cost of around £210/teC.

RECOMMENDATIONS

Given the potential for saving carbon by stimulating the market for heat in the industrial and commercial sectors from renewable energy and from CHP, we recommend that DTI and Defra should consider mechanisms for delivering that support. Further analysis is needed to build on this study and assess the most appropriate form of financial and non-financial support. Options for financial support could include mechanisms similar to the Renewables Obligation, and capital grants, amongst other measures.

We do not recommend broadening the scope of such a scheme to include renewable energy in the residential sector, as the costs of carbon saved are too high. Instead it would be better to include renewable energy in this sector within schemes aiming to support low carbon measures in the residential and small scale commercial sectors on a technology neutral basis so that consumers could opt, if they choose to, to install renewable technologies as one of a range of options.

In addition to measures aimed directly at providing the right financial environment that will allow projects to proceed, there should be continued support for measures that address some of the other barriers to developing these projects, including the lack of awareness of and confidence in the technologies, the lack of commercial and physical infrastructure to develop and support projects (particularly in the biomass supply sector) and, in some sectors, skills shortages that could be addressed by training.

Contents

Annexes – Supporting technical Information and Methodology

1 INTRODUCTION

1.1 BACKGROUND TO THIS STUDY

In recent years Government measures to stimulate renewable energy and CHP have focused mainly on electricity. For example, the main renewable energy policy tool, the Renewables Obligation (RO), is designed to stimulate electricity production.

A number of other Government initiatives do provide support for renewable and CHP heat. For example, there is no Climate Change Levy (CCL) on renewable fuels such as biomass, natural gas used by good quality CHP is exempt from CCL, a range of renewable-heat and CHP equipment qualifies for Enhanced Capital Allowances. Also, biomass heat-only boilers are eligible for the bio-energy capital grants scheme and the community energy scheme supports district heating projects that could be fuelled by renewables.

Around 30% of the 1,186 TWh/y of total non-transport energy services consumed in the UK is in the form of heat for space and process heating. This represents a considerable opportunity for the deployment of renewable energy and additional CHP.

Some of the heat demand is already supplied from renewable energy sources or as heat from CHP. Around 1% of heat (7.7 TWh_{th}/y) is currently generated from renewables. Additional carbon savings could be achieved if this were increased. However, despite this potential, the amount of renewable energy supplied as heat has declined in recent years both as a proportion of the whole and also in absolute terms, as some industrial wood fired systems have been decommissioned because of tightened emission regulations.

This trend is shown in Figure 1, where a slight downward trend can be seen in amount of heat from renewables. This is in contrast to the electricity producing renewables, which are growing rapidly in response to the Renewables Obligation and other market creation measures.

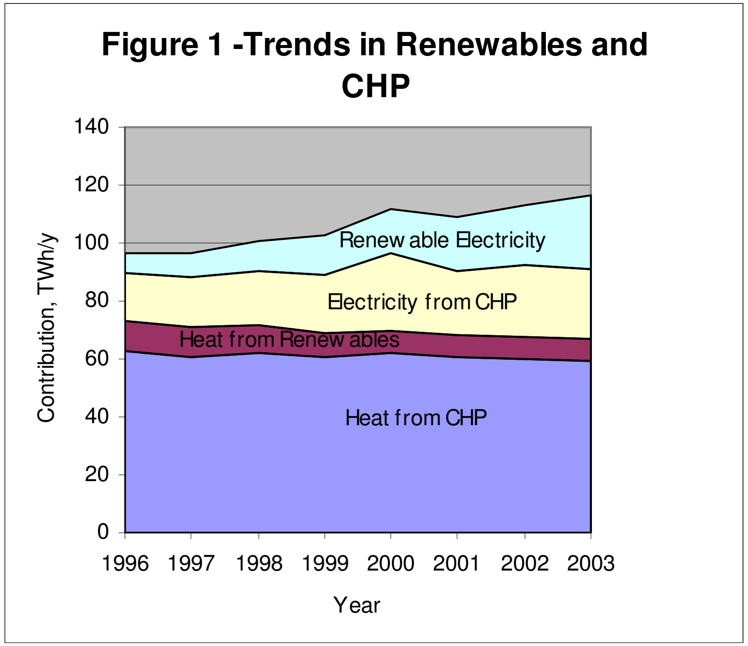


Figure 1 -Trends in Renewables and CHP

A similar situation exists for CHP. 8% (59 TWh_{th}/y) of UK heat demand is met from CHP systems fuelled by fossil fuels though the rate of new installations has slowed in recent years.

Increased deployment of CHP and renewable energy sources for heat production would deliver significant reductions in emissions of carbon adding to the savings already being made from electricity producing technologies. This would assist the UK in meeting its targets under the EU Renewables Directive.

During the passage of the Energy Act, Stephen Timms, the then Minister responsible for Energy, gave a commitment to undertake an investigation to answer a number of questions about promoting heat from renewable sources. Additional support for the development of a heat market has come from the Biomass sector. In its 2004 report The Royal Commission on Environmental Pollution stated "There is a significant gap in government energy policy regarding heat production. Using heat instead of, or as well as, electrical energy could increase conversion efficiencies substantially - from typically 30% to around 80%. Biomass can be a reliable, controllable source of both heat and power and the use of this additional benefit should therefore be central to biomass exploitation".

There has also been a Private Member's Renewable Heat Bill introduced that, whilst it did not complete its passage through the Commons, highlighted the widening interest in opening up the market for heat from renewable sources.

In keeping with this rising interest the purpose of this study, commissioned by DTI and Defra, is to quantify both the potential contribution to UK carbon reduction targets, the likely cost and the extent to which support may be required to make renewable heat and heat from CHP plants economically and commercially viable between 2005 and 2020. This will enable the policy options for stimulating carbon savings via increased use of renewable and CHP heat to be considered.

1.2 SCOPE AND PURPOSE

The technologies that we consider in this report are:

- Biomass, including biomass CHP;
- ground source heat pumps;
- solar water heating;
- geothermal aquifers;
- energy from waste;
- anaerobic digestion;
- landfill gas;
- fossil-fuel fired CHP.

There are a number of distinct market sectors for heat, each with its own characteristics. In order to properly understand the economic performance, potential for carbon savings and the technical and non-technical barriers to adoption of each technology listed above, we have considered the opportunities for each in a number of market sectors. These are:

- residential dwellings;
- commercial & public office, warehouse and factory buildings;
- industrial process heating.

We have also looked at the role of district heating, which is a delivery mechanism that can potentially link renewable energy technologies, or the heat from CHP, to markets where individual installation in each building is not possible.

By considering each technology in this range of markets we have then been able to provide answers to the following questions for each technology:

- What is the size of the resource and what level of market penetration might be achieved in 2010, 2015 and 2020?
- What are the potential carbon/CO_2 savings that would result?
- What would be the cost per tonne of the carbon saved?
- At present, how far from economic and commercial viability is renewable heat and heat from CHP produced from each resource and conversion technology?

- What is the likely effect of achieving technological progress and economies of scale through market development and what difference might these developments make to the costs and competitive viability of heat delivery projects?
- What are the barriers preventing the development of the market?

From these answers we have determined:

- Whether additional support is required to make renewable heat and heat from CHP commercially viable and if so how much.
- How the contribution and carbon savings may rise with increasing levels of support and what the costs and benefits in terms of carbon savings may be.

1.3 REPORT STRUCTURE AND THE METHODOLOGY

The structure and methodology are as detailed below. More detail on the methodology is provided in each of the relevant Sections of the report and in the Annex.

1.3.1 Market analysis

The starting point for our analysis has been the “heat market”. In **Section 2** of the report we consider each market sector listed above in terms of:

- market size and trends;
- conventional fuel use;
- heat demand patterns;
- costs of heat production from conventional sources;
- factors affecting investment decisions.

1.3.2 Technology analysis

In **Section 3** we review the renewable energy technologies with significant heat generating potential. For each of the technologies we have:

- assessed the status of the technology and its current contribution to UK heat supply;
- considered the fit between the technologies and markets sectors to identify the most promising combinations;
- estimated the projected contribution of the most promising technologies taking into account constraints to the rate of market development;
- used the analysis to project potential market size for 2010, 2015 and 2020;
- assessed the costs associated with delivering the heat from each potential source and compared these costs to those of fossil fuel equivalents;
- estimated the potential for cost reductions in future years e.g. decreasing manufacturing costs in response to increasing market size and through the so-called “learning effect”, where the efficiency increases and costs decrease as industry becomes familiar with the technology;
- estimated the carbon savings that may be provided by the deployment of each technology together with the costs of achieving those savings;
- identified the main barriers to deployment and indicated what may be done to overcome these barriers. This includes a view on the need for additional financial support.

In **Section 4** we have carried out a similar analysis for fossil fuel, which has been based on a number of definitive studies recently completed for DTI and Defra.

1.3.3 Impact of financial support

Section 5 shows the impact of additional financial support for renewable or CHP heat and estimates the impact of support in bringing forward additional contributions to heat supplies. We have also calculated the associated carbon savings and the cost of providing such support.

To do this we have:

- constructed demand curves for each technology and sector. We have done this by estimating the costs of heat supplied from conventional sources (usually gas or oil) and looking at the investment criteria applied in each sector.
- constructed supply curves based on the information in Sections 3 and 4;
- identified the impact of government support in bringing forward the use of renewable or CHP heat;
- estimated the benefits in terms of carbon savings and compared these with the costs of the support.

1.3.4 Conclusions and recommendations

The conclusions are presented in **Section 6** of this report, and some recommendations in **Section 7**.

2 MARKETS FOR HEAT

2.1 HEAT VS ELECTRICITY GENERATION – WHAT ARE THE ISSUES?

Before we consider the heat market, it is important to understand clearly how this market differs from the electricity market. There are some significant differences that must be taken into account when considering the prospects for heat producing technologies.

The main issues are summarised in Table 1.

2.2 DESCRIPTION AND CHARACTERISATION OF HEAT MARKETS

Unlike electricity generation, the nature of the heat market is intrinsically linked with the physical nature of the buildings, processes and locations being supplied with heat. This makes the heat market diverse and in order to properly assess the issues associated with the whole of the heat market we have divided it into the following three sectors:

- Residential dwellings.
- Commercial & public buildings, offices, warehouses and factory buildings including both those with intermittent demand, and those with continuous heating demand such as hospitals, universities, leisure centres etc.
- Industrial process heating.

2.2.1 Fuel prices

In considering these markets we need to be aware of the current cost of fuel used in each for heating and how these might change in the future.

During the course of the study, fuel prices have been changing significantly, with oil prices now close to $60 a barrel, significantly above all reputable projections made last year, and making future prices difficult to project. These increases in fuel prices make the investment case for renewable heat projects better, but price volatility and uncertainty makes investment planning difficult. CHP prospects are less sensitive to absolute fuel prices but very sensitive to the relative prices of gas and electricity. In both cases it is the perception of future price trends that affects significant investment decisions rather than prices at any particular time. There now seems to be a growing expectation that fuel prices are unlikely to fall back to earlier levels, and if this trend is confirmed this should improve the prospects for investment in these technologies.

We have based our base case analysis on DTI's fuel price projections that are being used in the Climate Change Programme Review, and these are given in Table 2 – these show fuel prices declining in future years. We have also tested the conclusions of the report against a scenario in which fuel prices remain at the 2005 levels in the Table.

Table 1 – Differences between heat supply and electricity generation.

Issue	Heat	Electricity
Plant location	**Must be at the point of heat use**	**Does not need to be close to point of use and can therefore be close to the fuel source.**
Cost of fuel conversion	**Low (direct heating of hot air or water)**	**High (must be converted to steam or gas before electricity generation can begin).**
Fuel conversion efficiency	**High - almost all energy available as heat**	**Low - even with advanced combustion technology, fundamental thermodynamics limits the conversion efficiency for non-CHP mode.**
Market for the product	**Relatively low value space or process heating.**	**Relatively high value and so not generally used for heating.**

The energy prices used are shown in Table 2.

Table 2 - Energy price assumptions in p/kWh excluding VAT and CCL

		2005	2010	2015	2020
Residential	Gas	2.34	1.91	1.97	2.04
	Oil	2.09	1.49	1.58	1.66
	Electricity	6.00	6.00	6.00	6.00
Intermittent	Gas	1.50	1.03	1.08	1.14
Commercial	Oil	1.76	1.26	1.33	1.40
	Electricity	4.20	4.20	4.20	4.20
Continuous	Gas	1.50	1.03	1.08	1.14
Commercial	Oil	1.76	1.26	1.33	1.40
	Electricity	3.34	3.34	3.34	3.34
Industry	Gas	1.52	0.92	0.98	1.05
	Oil	2.04	1.43	1.51	1.60
	Electricity	4.203	4.203	4.203	4.203

Source: DTI July 2005.

Different levels of taxation apply to different market sectors, with VAT (at 5%) applied only to domestic fuels and Climate Change Levy (CCL) applied only to commercial and industrial customers. For this reason, the figures in Table 2 exclude VAT and CCL, to allow a direct comparison of fuel prices across the market sectors. However, in our analyses we have applied VAT to domestic fuel at 5% and CCL at the full rate in the commercial and industrial sectors, irrespective of whether they are in Climate Change Agreements except for CHP where we have assumed that no CCL is payable in line with the exemption for good quality CHP. The cost of energy efficiency improvements needed to maintain a Climate Change Agreement is assumed to be approximately equivalent in cost to the CCL discount.

In addition to differing fuel costs, each of the sectors considered exhibits a range of characteristics including:

- the current size of the market sector;
- heat demand patterns;
- current fuel use;
- factors affecting investment decisions;
- costs of heat from conventional sources taking account of fuel, capital and operating costs as appropriate;
- other (often non-technical) issues which influence the sector.

In the sections below, we look at each of these issues for the residential, commercial and industrial markets.

2.2.2 The role of district heating

District or community heating is not in itself a market or a heat generation technology, but is a method of delivering heat from fossil sources, including CHP, or renewable energy to the markets described above.

The benefits of supplying heat to a district-heating scheme are as follows.

- The load on a district heating system, which can be made up of a mixture of residential, commercial and industrial users, may be steadier than the heat demand of individual users. This is a particular advantage where a capital-intensive systems such as a biomass combustion system is concerned, and for CHP where heat production is usually led by the opportunity to produce heat.

- The load being served is bigger than for individual premises, so allowing economies of scale in the heat-producing technology and, in the case of biomass, in the fuel supply chain. These larger scale operations can also often operate more fuel efficiently.

- It may be easier to provide heat from renewable systems that require space (such as biomass and ground source heat pumps) to residential and other properties where space is at a premium.

- As well as having a more stable instantaneous load profile, a district-heating scheme is less vulnerable to longer-term changes in consumer behaviour and preferences. This is because there are several different categories of consumer connected to the system and changes in their respective behaviours can to some extent cancel out.

The disadvantages are:

- the cost of installing a district heating system infrastructure is high, particularly in a retrofit situation;

- the commercial arrangements for supplying heat to a multiplicity of customers are inevitably more complex;

- the price of the heat supplied to the consumer must be competitive with heat derived from fossil fuel even though district heating must take into account the cost of the distribution system in addition to that of the heat generation technology. The heat generation technology must therefore be substantially cheaper than the conventional alternative in order to ensure that the combined cost of heat generation and distribution system is competitive.

In terms of scale, load factor and conventional fuel prices, the characteristics of the installations supplying this market are very similar to the industrial sector with a lower utilisation rate (typically 50%).

In practice these factors mean that district heating can provide a useful market opportunity, particularly where heat can be produced at a very low marginal cost – for example from energy from waste plants or from CHP operations. The opportunities are also more attractive where new developments are considered, and the infrastructure costs can be reduced. It also means that residential and smaller commercial systems can be accessed through larger scale heat producing systems so benefiting from economies of scale.

2.3 RESIDENTIAL DWELLINGS

2.3.1 Current market size

There are approximately 25 million residential dwellings in the UK with a wide variety of ages and types. Using data from BRE's Domestic Energy Fact File we have derived the estimates for space heating and hot water demand for the year 2001 shown in Table 3:

Table 3 Space and water heating demand in the residential sector for 2001.

Type of dwelling	Space heating & hot water (TWh/y)
Semi-detached	**134**
Terraced	**119**
Flat	**62**
Detached	**100**
Bungalow	**36**
Other	**1.3**
Total	**452**

Source: Derived by FES from data contained in BRE Domestic energy fact file 2003[1] and Northern Ireland housing statistics[2].

With a total energy demand of 452 TWh/y, the residential heat market is significant, accounting for around a quarter of the UK's total energy consumption (based on the DTI's UK Energy Brief of July 2004).

In this report we also consider the projections for new house-building and the effect this will have on the heat market. To do this we have used the projections published in the Barker Review[3] of Housing Supply. This envisages around an extra million houses in the UK by 2020. The need for an increased rate of new house building presents an opportunity for the Government to influence energy performance through setting building regulations for these new build developments.

2.3.2 Heat demand patterns

Residential heat demand is almost all for space heating and for domestic hot water, making the market highly intermittent and seasonal in nature. This gives low utilisation factors for residential heating systems.

In our analysis we have taken the average household heat demand at 18,000 kWh/y and assumed that a boiler rated at 15 kW_{th} supplies this heat, operating with a utilisation factor of 13.7%. We have assumed that new fossil fuelled boilers are of the condensing type with efficiencies of 90%.

In this sector there are competing pressures on energy demand. Increasing efficiency of heating appliances and improvements in insulation are leading to reduced residential energy demand. This is offset by an increase in householders' comfort standards leading to increasing residential energy demand. Together, these two effects have led to reduced energy demand by the sector as a whole, but at a slower rate than would have been predicted by the energy efficiency improvements alone.

---

[1] L D Shorrock and J I Utley, "Domestic energy fact file 2003", BRE Report BR 457, ISBN 1 86081 623 1.

[2] Table 1.6 page 20 of Northern Ireland Housing Statistics 2003-04.

[3] www.hm-treasury.gov.uk/media/0F2/D4/barker_review_report_494.pdf

Overlaid on this is the effect of the projected new house building. To understand the effect of this we projected two different future energy demand scenarios in the residential sector. The first assumes business as usual (BAU) where current house building rates continue to 2020. The other was a “high build rate” scenario (HBR) referring to build rates as recommended in the Barker Review. The results of our projections are that energy demand falls by around 10% under BAU or remains more or less constant under HBR. Therefore, as the UK is almost certain to require the additional housing projected by Barker, we have assumed that the real total energy demand by the residential sector as a whole will remain largely constant during the period to 2020.

2.3.3 Current fuel use

Gas is the fuel of choice in the residential sector but approximately 4.42 M houses are currently not connected to the mains gas supply. These properties tend to be rural in nature and depend on oil for heating. Both the restriction of fuel availability and the likelihood that these properties will have more space associated with them make them prime candidates for installation of renewable systems.

2.3.4 Factors affecting investment decisions

We have assumed that, given a choice, domestic consumers prefer to invest their money in home improvements other than boiler replacement.

Therefore, consumers who need to replace their heating system at the end of its lifetime make up the principal market for renewable heat. Boiler replacement usually happens around once in 20 years, giving an annual market of around 5% of the total. Voluntary investment outside this timescale is unlikely except in the case of a small number of wealthy, environmentally conscious consumers who invest earlier in low emission systems.

Selecting an appropriate discount rate for this sector is problematic as it is likely that boilers will be replaced when they fail rather than against the outcome of a detailed investment appraisal. There is also a range of ways in which the domestic customer might raise the money for such a purchase. At one end, this might come from savings, in which case an interest of around 4-5% might be foregone. At the high cost end, consumers may purchase on credit card where interest rates significantly above 20% are possible. Given this range, we have assumed that it is appropriate to annualise the capital costs of the system over the 20-year boiler life using a discount rate of 15%.

2.3.5 Cost of heat from fossil sources

Using these assumptions and the data from Table 2 we have calculated the delivered cost of heat from gas and oil fired systems and how these costs will change between 2005 and 2020. Over this period, heat supplied by gas is estimated to cost around £41/MWh in 2005, reducing to £36 by 2010, and increasing to £38 by 2020. Heat from oil is estimated to cost £51/MWh in 2005, reducing to £46 by 2020.

2.3.6 Other issues influencing this sector

The residential sector is expanding due to new development and the existing housing stock is being constantly upgraded, with many houses undergoing extension or refurbishment. This makes the sector amenable to influence by the Building Regulations, which can provide stimulation for many low carbon technologies.

The VAT position in this sector is complex. Some “energy efficient” technologies, including solar heating, are rated at 5%, so long as the purchase involves both the supply of the system and its professional installation. Other energy efficient technologies, such as biomass boilers, ground source heat pumps and domestic scale CHP units qualify for this lower rate of VAT only if the equipment is provided as part of a grant package which "has an objective of funding the installation of energy efficiency measures in the homes of the less-well-off people". (HMRC Reference: Notice 708/6 (June 2002)). In our estimates of costs throughout this report we have assumed that VAT is applicable at 5% for solar heating systems, but at the full rate 17.5% on all other systems used in the domestic sector. Reducing the VAT level to 5% for all domestic applications would reduce the cost to the residential consumer and both improve the rate of return on the investment and reduce the capital required and so improve the likelihood of these technologies being taken up. However this change on its own would be unlikely to open up the residential markets for these technologies, given the relatively high price of heat produced and the other barriers to adoption.

2.4 COMMERCIAL & PUBLIC OFFICE, WAREHOUSE AND FACTORY BUILDINGS

2.4.1 Current market size

Figures for energy use in this sector have been derived from the BRE non-residential energy fact file (2001). These are shown in Table 4.

2.4.2 Heat demand patterns

In this market we allowed for two separate sub-sectors. The first is where heat is used for space and water heating and where the demand is similarly seasonal to that in the residential sector. The other has a continuous demand for heat, giving a higher boiler utilisation rate.

Table 4 – Energy demand in the commercial sector

Sector	TWh/y
Commercial Offices	**23.8**
Communication and Transport	**4.1**
Education	**23.8**
Government	**16.0**
Health	**13.7**
Hotel and Catering	**29.2**
Retail	**15.4**
Sport and Leisure	**36.8**
Warehouses	**12.1**
Other	**30.2**
Total	**205.1**

Source: Derived by FES from data contained in BRE Domestic energy fact file 2003[4] and Northern Ireland housing statistics[5].

We have analysed the energy use in the sector as a whole and estimate that, of the total market demand of 205 TWh/y, 125 TWh/y is taken up by the "intermittent" sub sector and the balance of 80 TWh/y used by sites with continuous demand.

It is assumed that heat is currently supplied in this sector by a suitably sized packaged gas boiler operating at a utilisation rate of 23% in the 'intermittent' sub- sector and 60% in the 'continuous' sub-sector.

2.4.3 Current fuel use

As in the domestic sector, gas is the fuel of choice when available. For premises that are off the gas grid oil will be used. Again, we have assumed no significant LPG use.

---

[4] L D Shorrock and J I Utley, " Domestic energy fact file 2003", BRE Report BR 457, ISBN 1 86081 623 1.

[5] Table 1.6 page 20 of Northern Ireland Housing Statistics 2003-04.

2.4.4 Factors affecting investment decisions

In this sector we have assumed that consumers will largely invest in new boiler systems when their current equipment is in need of replacement i.e. around once in 20 years, giving an annual market of around 5%. We have assumed that it is appropriate to annualise the capital costs of the system over the 20-year boiler life, using a discount rate of 15%. Where more capital-intensive solutions are considered we have assumed that a payback period of between 1 and 3 years is required on the marginal capital involved.

2.4.5 Cost of heat from fossil sources

Based on the fuel price assumptions in Table 2, we have calculated that gas derived heat for the ‘intermittent’ sub-sector costs around £21.54/MWh for gas and £23.07/MWh for oil. In the ‘continuous’ sub-sector the cost of heat from gas is £18.43/MWh and £21.60/MWh from oil.

For most commercial gas users the Climate Change Levy of £1.50/MWh for gas applies. This adds around £1.80/MWh to the cost of heat produced. Climate Change Levy is not applied to oil.

2.4.6 Other issues influencing this sector

Given the relatively modest energy consumption by most of the organisations comprising this sector, it is unlikely that energy issues figure highly in managers’ priorities. Therefore, this sector is likely to be relatively uninformed about energy issues and is likely to see risk in technologies that are not in wide-scale use in the UK.

2.5 INDUSTRIAL PROCESS HEATING

2.5.1 Current market size

Energy use data for this sector are taken from the DTI publication “Energy consumption in the UK” (as updated in 2004). These are shown in Table 5.

Table 5 – Annual energy demand in the industrial sector

Sector	TWh
Chemicals	**32.08**
Food & drink	**32.61**
Textiles	**3.52**
Paper & board	**12.50**
Total	**80.71**

Source: DTI - "Energy Consumption in the UK"[6]

2.5.2 Heat demand patterns

In this sector process heat is used as well as space heating and hot water production so the utilisation factor is high. System sizes vary widely between 50 kW and 3 MW or greater.

Again we have assumed that suitably sized packaged boilers operating at a utilisation rate of 65% supply heat.

2.5.3 Current fuel use

This sector tends to use more than one fuel source for reasons of security of supply. This is certainly the case where process-critical heating

---

[6] DTI/Pub URN 02/1049, 2002

applications are present. While gas is used when present, gas is often supplied on an interruptible basis, with heavy fuel oil as a back up.

2.5.4 Factors affecting investment decisions

We have assumed in this sector that consumers will primarily be interested in investing in new boiler systems when the current equipment is in need of renewal i.e. around once in 20 years, giving an annual market of around 5%. We have further assumed that it is appropriate to annualise the capital costs of the system over the 20-year boiler life using a discount rate of 15%. Where more capital intensive solutions are being considered we have assumed that a payback period of between 1 and 3 years is required on the marginal capital involved i.e. no investment will happen if the payback is greater than 3 years and all investors will make the additional investment if a payback of 1 year or less is achieved.

2.5.5 Cost of heat from fossil sources

Based on the assumptions in Table 2, the delivered cost of heat from gas in 2005 is estimated at around £20.42/MWh and £27.38/MWh for oil.

We have allowed for gas users in this sector paying Climate Change Levy of £1.50/MWh which adds around £1.80/MWh to the cost of heat produced from gas. Many users in this sector will be included within Climate Change Agreements which will earn a rebate on CCL, but we have assumed that the move to renewable fuels would have a value equivalent to a full reduction in CCL. Climate Change Levy is not applied to oil.

2.5.6 Other issues influencing this sector

In this sector there is usually stiff competition for capital within the individual companies. Investment leading to greater productivity is therefore likely to be favoured over more discretionary projects. This presents a major barrier to investment in new heat generating systems beyond the normal cycle of boiler replacement.

As this sector will comprise larger energy users, it is normal for energy managers to be appointed, making this sector potentially the best informed about energy issues. However, this means that the business risks associated with moving to new technologies will also be closely reviewed and many organisations may choose to wait until technologies become more ‘main-stream’ before investing in them.

3 RENEWABLE ENERGY TECHNOLOGIES

3.1 METHODOLOGY

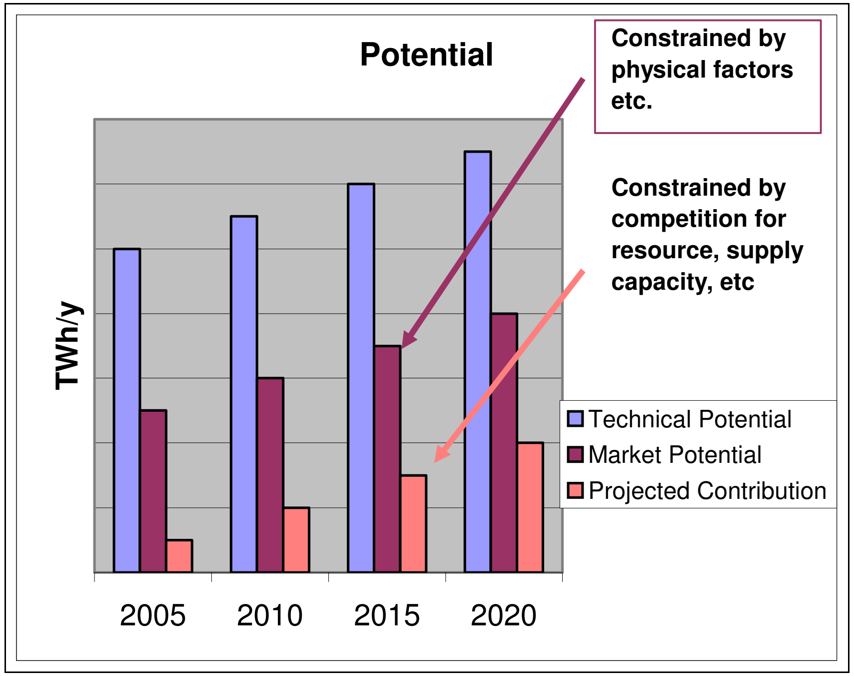
In this section we have assessed the potential for heat supply and carbon savings from the renewable energy technologies under consideration.

For each of these technologies we have:

- Assessed the status of the technology and the current contribution to UK heat supply based on the figures available via the Digest of UK energy statistics and collected via RESTATS;
- Considered the fit between the technologies and markets sectors;
- Focused attention on the most promising combinations and estimated their potential contribution to heat supply in three stages, defined as:
    - Technical Potential - taking into account constraints on resource availability and overall market size.
    - Market Potential – taking into account physical and other constraints e.g. delivery and storage of fuel that may limit maximum market penetration.
    - Projected Contribution – taking account of constraints to the rate of market development including, for example, supply side capability, competition for fuel with electricity production, etc. to provide an estimate of the likely contribution to heat supplies in 2010, 2015 and 2020.

    - These potentials are illustrated in Figure 2

Figure 2 Representation of the differences between technical potential, market potential and projected contributions.



- Assessed the costs associated with delivering the heat from each potentially significant source. We have taken into account fuel and operating costs as well as the capital costs of the system involved. We have included a capital element associated with each kWh produced by calculating an annual capital charge based on a 15% discount rate over the lifetime of the project. These costs have been compared with those of the fossil fuel equivalents. We have estimated the potential for cost reductions in future years arising as a result of the increased market size, through the "learning effect" that leads to increased manufacturing and installation and efficiency;
- Identified the main barriers to deployment and indicated how these might be overcome including the need for additional financial support;
- Estimated the carbon savings that could be provided by the deployment of each technology and estimated the costs of achieving these savings.

3.2 BIOMASS

3.2.1 Background

Biomass is used to describe combustible material of biological origin that can be burned to generate heat or electricity. It includes plant material grown as crops or produced as co-products from other harvesting activities, for example residues from tree harvesting and straw from cereal production. It is also possible to expand the biomass resource by establishing more crops with fuel as the target market. These crops can be based on fast growing tree species such as willow grown on a coppice system that allows harvest every two to three years, or energy-grasses such as miscanthus (on an annual cycle).

Biomass can provide 'base load' energy production because the combustion plants can be operated to match demand.

There are a number of issues affecting the production of heat from biomass. These relate to raw material supply, fuel preparation, fuel transport and storage, fuel combustion and heat supply. The complex range of issues associated with biomass for energy are being considered by a Task Force, led by Sir Ben Gill, and due to report in the Autumn of 2005.

DEFRA commissioned a study into possible support mechanisms for biomass generated heat. The study, completed by Ilex in 2003 described a number of potential support mechanisms including a "Heat Obligation" similar to that used to stimulate electricity from renewable energy. (Possible Support Mechanisms for Biomass Generated Heat, Ilex Energy Consulting Ltd, December 2003, accessible via DEFRA website).

3.2.2 Description

Biomass fuels are solid and relatively dry. They are thus ideally suited to fuelling combustion processes. The energy density of these fuels is in the range 15 to 20 GJ/oven dry tonne (odt), around two thirds that of coal. This means that more fuel is needed to produce the same amount of heat compared with fossil fuels, and means that handling systems have to be larger and more expensive than for equivalent fossil fuelled systems. The higher moisture content and composition of the biomass fuels impact on the design of the combustion system, which must be physically larger than for fossil fuels for a given heat output, which also leads to higher costs.

Wood fuel combustion systems can come in a range of sizes from room sized wood burning stoves hand fed by logs, to multi-megawatt, fully automatic systems burning chipped wood fuel fed by an auger or other automated system. Recently, residential scale automatic wood pellet fired boilers have become popular in mainland Europe and North America.

While straw fuel is usually drier than wood, these fuels have a low ash melting temperature. This means that the ash can become 'sticky' and adhere to heat exchange surfaces, reducing their efficiency, or solidify into a glass-like deposit in cooler areas of the boiler. To overcome these problems, straw combustion systems must be carefully designed. These low temperature ash-melting characteristics make straw unsuited to the production of high temperature process steam heat.

Straw fired systems come in a range of sizes. The smallest tend to be batch fed systems, where whole bales are manually fed into the combustor, and the heat produced stored in an accumulator, which is a reservoir of hot water from which the heating system is fed via a heat exchanger. As with wood, multi-megawatt fully automatic systems are also available. Here the bales are fed onto a conveyor and the straw either automatically sliced off the bale or augured into the combustion chamber, or the bale is fed directly into the combustor such that the front face burns away (a so-called cigar burner system).

One of the major issues with biomass energy schemes is the supply of fuel. This has two elements, sourcing the raw material and processing it into a fuel with the right properties for the application in mind.

Wood fuel can be sourced from existing forestry operations. The branches and treetops left after stem wood harvesting are the usual source of chipped or processed fuel and small diameter stem material from thinning operations usually provides fuel logs. Both require the raw material to be processed to make it into the correct physical form to be used by the combustion system owned by the customer. In order to compete with fossil fuels, this must be part of a wider infrastructure that can guarantee delivery of quality fuels to customers as required.

Another source of wood fuel is from the energy crop short rotation coppice (SRC). This makes use of the capacity of deciduous trees to coppice (re-sprout) when the stem is cut to the ground. By applying this technique to fast growing trees like willow that establish well from cuttings, wood for energy can be grown such that it is harvested every 2 to 3 years. This makes SRC an ideal farm crop, but one that has required bespoke machinery to aid production. Farm crop production potential is intimately linked to land availability, which in turn relates to the relative economics of SRC versus food crops and EU farming policy.

Wood fuel from any source (including SRC) can be harvested virtually year-round, reducing the need for storage other than to achieve a degree of natural air-drying.

Straw is a co-product of cereal production. It is either routinely harvested and baled to service markets such as animal bedding, or ploughed back into the soil to displace some of the fertiliser requirement of the next crop.

Straw is harvested seasonally so requires potentially long-term storage if it is to be used as a fuel. This adds to the cost and logistical problems.

Energy crops such as miscanthus and grasses with high yields such as switch grass are well placed to augment the straw resource as they can be harvested and baled much like straw. Miscanthus has the added advantage of a woody stem and so can also be chipped for use in wood heating systems. Miscanthus is established from rhizome cuttings and many grass crops are seed-sown. Unlike SRC, these energy crops do have harvesting seasons, which will again introduce the need for storage.

Biomass fuel pellets can be produced from all of the biomass sources discussed here but wood is the usual feedstock, especially where an existing source of sawdust is available. The pelletisation process requires very dry, finely divided feedstock, which is then compressed in a die and heated to make the lignin sticky to ‘glue’ the pellet together. This makes pelletisation an energy expensive process and one that requires major capital investment in plant. However, the product is a relatively energy dense, low dust product for use in a residential (or larger) scale automatic heating boiler.

3.2.3 Status

Biomass is used for both heat and power generation in the UK at present. For example six biomass combustion electricity generation schemes were stimulated by NFFO, the SRO. One of these is a 31 MW_e straw fired plant. The others mainly use chicken litter, augmented with some wood chip. The first power generation plant funded under the Bioenergy Capital Grant Scheme has also recently commenced operation. This is a wood-waste burning CHP plant at Balcas timber processing facility near Enniskillen, Northern Ireland. The facility also manufactures wood pellet fuel for sale to domestic and other consumers. Some 7 other power generation plants are in the development and planning stages. In addition, by the end on March 2005, 64 heating installations with a combined capacity of 7.3MWth have been stimulated by the Scheme.

A number of large coal fired power stations are co-firing biomass fuels such as imported food processing residues and local wood processing residues.

Where wood fuel is being used in the UK, it currently comes mainly from forestry sources. Areas of SRC were planted for the ARBRE project, but with only limited markets available for SRC until now, investments in crop mechanisation have been limited and this had resulted in slow progress with the reduction of production costs. The same is true of other potential energy crops.

The largest energy market for biomass remains the residential consumption of logs for space heating, along with those industries producing surplus clean wood from their processes which also have a long tradition of using it for space and process heat generation. However, recent tightening of environmental legislation has closed many of these installations as it has been cheaper to switch to fossil fuel than replace or upgrade the wood heat combustion system to meet the legislation.

3.2.4 Current contribution

The current contribution to heat from these sources in the UK is 6.3 TWh/y, made up as shown in Table 6.

Table 6 - The current contribution of biomass to the UK heat market

Source	Contribution TWh/y
Wood combustion - residential	**2.38**
Wood combustion - industrial	**3.09**
Straw	**0.84**
Total	**6.31**

Source: DUKES

3.2.5 Resource availability

The potential contribution of biomass to the UK heat market is dictated by the availability of fuel. This fuel is either from existing resources such as forestry and from straw produced from the annual harvest of cereals. This resource could be extended by growing energy crops in the UK. The potential energy crop supply is in turn linked to land availability on which the crops can be grown. This would displace other cropping or land use activities. There is also potential to import biomass materials to supplement indigenous supplies.

A number of co-products from timber production and processing are technically available as fuels for heat production. Each of these products has a range of other potential market outlets, making estimation of the fuel wood availability problematic.

The Forestry Commission has published a view of the biomass fuel currently potentially available for fuel use in the UK, together with an estimate of the quantities of energy crop that could be produced if a secure market was available. To this we have added information from the agriculture industry on the amount of surplus straw that is potentially available for energy use. This is shown in Table 7.

Table 7 – Biomass fuel supply technical potential

	Modt/y	**Average Energy Content (MWh/odt)**	**Resource** TWh/y
Forest and wood industry residues	**1.31**	**4.7**	**6.16**
Straw	**4.0**	**4.2**	**16.80**
Energy Crops	**4.1**	**4.7**	**19.27**
Total	**9.41**		**42.23**

Source: DTI, Report, Woodfuel Resource in Britain available via www.woodfuelresource.org.uk

Many wood co-products, such as chip and sawdust, are traded internationally as are wood pellets. If a strong market for biomass developed then fuels could be imported from low cost sources such as Russia and the Baltic States, North and South America. Currently such materials are being imported for co-firing with coal in power stations at costs similar to those applying to indigenous UK materials. Extensive long distance transport of fuel would, of course, add CO_2 emissions to the fuel cycle thereby reducing the carbon savings achieved and would also contribute to other environmental burdens such as congestion and reduced air quality. Wood products have a relatively low energy-density compared with fossil fuels so transport-related CO_2 emissions per MWh delivered would be greater. Further work would be needed to quantify the effect of international trade on sustainability for these fuels.

The largest operating cost for a biomass heat system is for fuel supply. The cost of biomass fuel depends on the cost of processing the raw material into the physical form that suits the boiler. Depending on the form of fuel being produced, the capital cost of the fuel-processing equipment can be high, potentially requiring a chipper or hammer mill, a screen to remove out-of-specification size particles and a drier. Pellets are the most costly biomass fuel to produce as the wood must be dried, milled to a small size and then pelletised in a specialist machine.

As biomass fuels have a relatively low energy density compared with fossil fuels, transport costs are another critical component of the delivered price of the fuel. Table 8 shows the range of indicative delivered fuel costs.

Table 8 – Indicative biomass fuel costs

Fuel	Indicative Cost £/MWh
Wood chip	**5.30 –8.50**
Wood pellets (residential supply)	**15-30**
Straw	**7.50 – 12.50**
Energy crops (as chip)	**6.80 –12.70**

Source: Data collected from various sources by FES as part of this project.

3.2.6 Biomass for heat, electricity and CHP, and District Heating

As well as producing heat from biomass, it is also possible to use biomass to produce electricity or to operate in CHP mode, producing electricity and heat. Biomass power generation technology is almost exclusively steam turbine based, with steam being generated in a biomass-fired boiler. At scales of operation which are practical with biomass, steam turbine power generation has a lower electrical efficiency and, in CHP mode, a higher heat to power ratio than the technologies considered for gas fired CHP, with performance depending on scale of operation.

Several novel gasification technologies are under development, which may yield a higher electrical efficiency. For the purposes of this study these are considered to be emerging technologies that are not yet ready for a commercial application, although they may be able to play a role over the period covered by this study (i.e. by 2020).

The capital costs per unit of heat supplied by CHP systems are significantly higher than those of heat only systems. CHP is a more attractive option where scale is high and particularly where there is a steady heat load. The carbon savings associated with each tonne of biomass or MWh of heat produced are higher in CHP mode than when heat or power are produced alone.

The Annex contains a comparison of the costs and efficiency for biomass operation in heat, CHP and power generation modes. Table 9 summarises the financial and operating characteristics for a system generating 10MW of heat only and a CHP system supplying a similar heat load, and operated in "heat led" mode (i.e. used only when there is a use for the heat produced).

In the absence of any incentives for producing renewable electricity, the analysis indicates that producing heat from biomass is significantly more attractive financially than operating biomass-fuelled CHP. The heat only system gives an internal rate of return (IRR) of over 21% under the assumptions chosen and with no support for the heat produced, compared with 5.4% for CHP.

Table 9 – Comparison of Heat Only and CHP Systems

	Heat Only	**CHP**
Heat capacity, MW	10	10
Power capacity (MW(e))		2.52
Capital Cost, £M	2.0	6.0
Operating hours/y	6570	6570
Heat produced, MWh/y	65700	65700
Electricity Produced, MWh/y		18774
Annual fuel costs, £k	649	1,009
Carbon savings, kgC/MWh heat	55	91.6

However the electricity produced would be eligible for Renewable Obligation Certificates (ROC), and these improve the rate of return – at a ROC value of £30/Mwh the IRR improves to 15.5%, and a ROC value of £45/MWh the rate of return is equivalent to that for the heat only scheme.

Both producing heat and CHP at this scale are more financially attractive than producing power only – the IRR for power generation is negative with no ROC, and increases to only 12% at a ROC value of £45/MWh. Power only projects are more attractive at a larger scale.

The financial return of the CHP option is sensitive to the operating regime. Operating in "power led" mode (and dumping some excess heat produced) is less attractive both in financial terms and in terms of the overall efficiency.

The financial return for the CHP option is particularly sensitive to the number of operating hours, given the high capital cost involved. CHP operation at lower utilisation rates (such as might be appropriate for supplying heat loads for the commercial or residential sectors) is much less attractive than producing heat alone. The unit capital cost CHP systems increases more rapidly then that of heat only systems as the scale of operation goes down, and the electrical efficiency declines. For these reasons biomass CHP is best suited to larger scale applications in the industrial sectors where more constant heat loads are available. We have therefore only included CHP as an option in considering biomass in the industrial sector in the analysis below.

One potential market opportunity for biomass is providing heat to district or community heating systems. There is potential to use biomass as a fuel for existing systems, replacing the fuel used in the central boiler house. There is also the potential to use biomass where new housing developments are being constructed with community heating as part of the original design.

In practice the heat would be provided by systems similar to those proposed for industrial and commercial heating loads, with similar capital and fuel costs. The Annex provides an analysis of the relative costs and carbon savings associated with using biomass in this way. Where the infrastructure is in place, community heating provides a more cost effective way of using biomass for residential heating than using individual biomass fired boilers at the residential scale, and potentially opens up opportunities in urban situations where using individual boilers would not be practicable. We have therefore included an analysis of the potential and costs of using biomass in these systems below.

3.2.7 Market opportunities

We have considered four market opportunities for using biomass;

- Use in the residential sector, where we have assumed that pellets are used in automatically fed boiler systems.
- Use in commercial and institutional markets using wood chip as a fuel in a boiler.
- Use of wood chip at a larger scale in industrial situations and to feed heat to district heating plants.
- Use of wood chip for CHP in industrial and other larger scale markets.
- The potential role of biomass as a fuel for district heating, particularly for new residential developments.

3.2.8 Residential market

Pelletised fuels are ideal to drive expansion of the residential market as this fuel overcomes many of the problems associated with the residential use of logs or chips. We consider that the principal market for residential scale biomass heating will be in more rural locations not served by the gas grid - 4.42 M premises. New premises will add a further 160,000 to this total by 2020. If each of these has a heat demand of 18,000 kWh/y, this gives a giving a technical potential of 75.6 TWh/y, rising to 78.5 TWh/y by 2020. This is the maximum technical potential of the residential market. We have estimated the market potential by assuming that around 25% of these premises could or would use biomass pellets if other factors were favourable. This gives a potential market size of 1.1 million houses, and energy potential of 18.9 TWh/y, rising to 19.6 TWh/y by 2020.

In the residential sector the market potential is unlikely to be achieved rapidly. The rate of installation will be constrained by the availability of fuel and by the ability of the combustion equipment supply industry to meet the demand. The wood pellet market has been developing rapidly in some European countries, particularly in Denmark, Austria and Germany, in response to incentives. Installation rates are currently reaching around 5,000 units/year, and expected to rise to around 10,000 units per year. We have therefore assumed that in the UK under favourable market conditions, the rate of installation might rise to 5,000 units per year between 2005 and 2010, to 10,000 units by 2015, and 20,000 units by 2020. Taking these constraints into account gives a projected contribution for heat supply in the residential sector rising to 2.4 TWh/y by 2020, potentially saving 0.15MTeC/y by then.

Table 10 summarises the results for biomass heat in the residential market, and indicates that carbon savings associated with each of the estimated potential figures.

Table 10 - The residential market for biomass heat

Year	2010 (TWh/y) (MTC/y)	2015 (TWh/y) (MTC/y)	2020 (TWh/y) (MTC/y)
Technical Potential	**76.4** 4.6	**77.5** 4.6	**78.5** 4.7
Market Potential	**19.1** 1.1	**19.4** 1.2	**19.6** 1.2
Contribution Projection	**0.3** 0.02	**1.0** 0.06	**2.4** 0.15

3.2.9 Commercial market

In the commercial or industrial markets the increased cost of pelletised fuels will be unacceptable, and the large size and weight of straw bales makes them unattractive except in niche applications such as on farms themselves. This leaves wood chip the most suitable fuel for the commercial and industrial sectors.

Like the residential sector, the commercial sector is also constrained by physical space for boiler installations and by cost-effective access to biomass fuels. This again will favour rural locations. We have taken the off gas grid market in this sector as the technical potential, estimated at 24.9 TWh/y (9% of the market sector total). This is the technical potential of the commercial/industrial market.

Our experience is that only a fraction of sites will have the space and access required to accommodate the larger size boiler and associated handling equipment needed for biomass. We have therefore assumed that the potential is around 10% of premises in the lower ‘intermittent’ utilisation sector and 15% of the more energy intensive ‘continuous’ sector. This implies a market potential of 3.0 TWh/y.

In the commercial sector we have assumed a penetration rate for this market of 5% per year. As a result, the projected contribution for 2020 amounts to 2.2 TWh/y, which would lead to C savings of 0.13 MTC/y.

Table 11 summarises the results for biomass heat in the commercial market, and indicates that carbon savings associated with each of the estimated potential figures.

Table 11 - The commercial market for biomass heat

Year	2010 (TWh/y) (MTC/y)	2015 (TWh/y) (MTC/y)	2020 (TWh/y) (MTC/y)
Technical Potential	**24.9** 1.5	**24.9** 1.5	**24.9** 1.5
Market Potential	**3.0** 0.18	**3.0** 0.18	**3.0** 0.18
Contribution Projection	**0.7** 0.04	**1.5** 0.09	**2.2** 0.13

3.2.10 Industrial

While the industrial sector may be less constricted for space and other reasons than the commercial sector, we have still taken the non-gas market as the primary market opportunity for biomass in this sector. Based on Energy Paper 68[7] we estimate the technical potential in this sector at 75.5 TWh/y.

Even in this sector, space, access to reliable fuel supply and other factors will play a part. For this reason we have assumed that 15% of the potential could be accommodated, giving a market potential of 11.33 TWh/y.

In order to calculate the contribution projection we have assumed a 5% annual market penetration. This gives a projected contribution rising to 8.5 TWh/y by 2020, with associated carbon savings of 0.51 MTC/y.

The industrial market for biomass heat is shown in Table 12.

Table 12 - The industrial market for biomass

Year	2010 (TWh/y) (MTC/y)	2015 (TWh/y) (MTC/y)	2020 (TWh/y) (MTC/y)
Technical Potential	**75.5** 4.5	**75.5** 4.5	**75.5** 4.5
Market Potential	**11.33** 0.68	**11.33** 0.68	**11.33** 0.68
Contribution Projection	**2.83** 0.19	**5.67** 0.40	**8.50** 0.59

As discussed above, some of this potential could be supplied by heat only systems and some by CHP operations. In calculating the associated carbon savings we have assumed that heat only systems supply 67% of the market potential, and CHP the remainder.

3.2.11 Community and district heating

Currently around 1% of UK housing demand is supplied through community or district heating systems, providing some 4TWh/y of heat.

The projection for new housing construction in the UK that we have used , based on the Barker report (See Section 2.3) is that around 1M additional houses will be built by 2020, with a total heat demand for space and water heating of around 16TWh/y. If 10% of these new developments included community heating schemes, then this would provide a market opportunity of 1.6TWh/y, and the potential market would therefore rise to 5.6TWh/y by then.

While there is no definitive assessment of the ability to convert these systems to biomass fuelling, many of the existing facilities will be in urban areas where space is limited and the opportunity to retrofit biomass

---

[7] ·DTI: "Energy Paper 68: Energy projections for the UK", December 2000, ISBN 0115154965, downloadable from www.dti.gov.uk/energy/inform/energy_projections/index.shtml

heating is limited – we have assumed that 5% of the existing market could be converted to biomass heating, with a higher potential for new build schemes (10%). This gives a potential of 0.2TWh/y rising to 0.36TWh/y by 2020.

3.2.12 Capital and operating costs

The capital cost of a biomass system is significantly higher than for an equivalent gas or oil-fired system. This is due to the need for solid fuel storage and handling systems and the physically larger combustion units and gas cleaning systems necessary for burning these fuels.

Because the system is more capital intensive than the equivalent fossil fuel conversion systems, the costs of delivered heat are particularly sensitive to the extent to which the systems are used. This utilisation rate or load factor means that the economics will favour situations where there is a regular demand for the heat produced.

We now consider boiler capital costs by sector.

Residential

In this sector we have modelled the costs for a wood pellet fired system used for supplying all heating and hot water needs and rated at 8.8 kW. The capital cost of such a unit to the householder is £3,600. These prices exclude the cost of heat delivery, which is usually through a wet radiator or under-floor heating system. Costs are not expected to be significantly different between new build and retro fit applications.

Commercial/institutional

In this sector we have looked at two cases. For the sub-sector where utilisation is likely to be low (space heating of offices and other premises) we have considered a boiler unit with a capacity of 120 kW, fuelled with wood chip and operating at an average load factor of 23% across the year. The capital cost of such a unit is estimated at £36,000.

We have also considered a larger 1 MW unit, which might be appropriate where a more continuous pattern of use is possible. The capital cost of such a unit would be £250,000.

Industrial

Here we have considered a 10 MW unit operating to supply heat for process use at a high utilisation rate. The capital cost of such a unit would be £2.0 million. A CHP system delivering 10MW of heat (along with 2.52MW of electricity) is estimated to cost £6.09M.

Table 13 summarises these capital costs.

Table 13 - Biomass capital costs by sector

	Residential	Commercial Intermittent	Commercial Continuous	Industrial Heat	Industrial CHP
Rated Thermal Capacity	8.8 kW	120 kW	1 MW	10 MW	10 MW
Capital Cost £	3,600	36,000	250,000	2,000,000	6,090,000

The largest operating cost for a biomass heat system is for fuel supply. The cost of biomass fuel depends on the cost of processing the raw material into the physical form that suits the boiler chosen. Depending on the form of fuel being produced, the capital cost of the fuel processing equipment can be high, potentially requiring a chipper or hammer mill, a screen to remove out-of-specification size particles and potentially a drier. Pellets are more costly to produce as the wood must be dried, milled to a small size and then pelletised. As biomass fuels have a relatively low energy density compared with fossil fuels, transport costs are another critical component of the delivered price of the fuel. We will now consider typical costs for biomass supply for each market sector.

Residential

The most significant operating cost is that of the fuel. Pellets are a high quality fuel, which could be supplied to this market at around £25.40/MWh (£112/odt).

Commercial and institutional

For the low-utilisation sub-sector of this group we have assumed wood supplied from local sources at £13.30/MWh (£59/odt). For the larger fuel supply demanded by the continuous operation sub-sector, we have assumed a lower price of £10.60/MWh (£47/odt).

Industrial

Larger industrial boilers create the potential for local investment in bespoke wood fuel harvesting systems. We have assumed that this, plus economies of scale will reduce the delivered cost of fuel to £8.00/MWh (£35.50/odt).

3.2.13 Heat costs

Using the capital cost and fuel costs specified above we have calculated the costs of heat from biomass in each of these sectors using a 15% discount rate and making provision for operating and maintenance costs. The results are summarised in Table 14.

In the CHP case the cost of the heat produced is affected if it is assumed that the electricity qualifies for payments for ROC production. The Table calculates the heat cost assuming that ROC's are valued at £30/MWh. (See the Annex for the detailed heat cost calculations and a discussion of the impact of ROC values.).

For the community heating market we have assumed that heat is provided by a biomass heating boiler with similar capital and operating costs to those associated with an industrial scale 10MW unit (although in practice the scale of operation would in most cases be lower), but with a lower utilisation factor of 50%.

Table 14 – The cost of heat from biomass

Heat cost @15% discount rate, £/MWh	Residential	Commercial		Industrial		District Heating
		Intermittent	Continuous	Heat	CHP	
Year \ Capacity, kW	8.8	120	1,000	10,000		
2005	**105.10**	**46.90**	**21.32**	**16.63**	**17.91**	**19.90**
2010	**95.50**	**43.70**	**19.88**	**15.50**	**16.70**	**18.56**
2015	**85.90**	**40.55**	**18.44**	**14.38**	**15.49**	**17.21**
2020	**76.40**	**37.38**	**17.00**	**13.26**	**14.28**	**15.87**

3.2.14 Scope for cost reduction

The technology for biomass combustion across a range of scales of operation is well developed internationally. Similarly the equipment for processing and handling the fuels are well developed and available commercially. There is an established industrial capacity which can deliver boilers at the larger scale of operation associated with the commercial and industrial sectors, although the supply chain for smaller scale boilers for the residential market is still relatively small despite the impact of current initiatives such as Clear Skies and the Biomass capital grants scheme. However the infrastructure for supplying, processing and delivering biomass fuels is not well established in the UK and there is considerable scope to develop a more effective and competitive fuel supply. This provides scope for reducing costs through efficiency and competition as the market increases.

Using the methodology described in the Annex, we have estimated that the cost of heat from this source could reduce by 1.8% per year between 2005 and 2020 in the residential sector, and by 1.3% per year in the other sectors. Table 14 shows how costs of delivered heat reduce by 2010, 2015 and 2020.

3.2.15 Carbon savings

Biomass fuels are widely regarded as being carbon neutral, i.e. there is no net emission of CO_2, but this is not strictly true as fossil energy is used in the production (energy crops, not residues), processing, storage, transportation and use of the fuel. Energy crops represent the worst case as far as carbon balance is concerned, as all of the fossil energy used in their production and use is allocated to the fuel.

A number of studies have been undertaken over the last 20 years investigating the carbon cost of biomass fuels. A review of the carbon balance associated with energy crops, which reviewed all earlier studies estimated that the use of biomass fuels will almost always save at least 95% of the carbon from the fossil fuel, and this is the factor we have used in our calculations.

The net saving of carbon amounts to 73 kg C/MWh compared to using oil to produce heat and 55 kg C/MWh compared to gas. In the case of CHP operation, higher carbon savings can be achieved. If the system is operated in “heat-led” mode (i.e. only when all the heat produced can be used) the carbon savings associated with each MWh of heat rise to 91.5kg/MWh. In calculating the carbon savings associated with biomass use in the industrial sector we have assumed that 33% of the available potential for heat supply is provided by CHP systems and the remainder by systems supplying only heat.

3.2.16 The cost of carbon savings

Table 15 shows the cost of the carbon saved, calculated by dividing the difference in cost per kWh between heat supplied from biomass and by oil or gas by the amount of carbon saved. (Note that negative numbers imply that substitution by biomass is already cost effective under the assumptions used here.) The Table also shows how these costs will change in time as the cost reductions discussed earlier occur and fuel prices vary.

Table 15 – The cost of carbon savings from biomass

	£/Te C							
	2005		2010		2015		2020	
	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil
Residential	1170	717	1085	683	897	543	707	403
Commercial - Intermittent	464	315	505	351	436	298	367	245
Commercial - Continuous	390	-4	364	55	337	25	311	-5
Industrial - heat	-69	-110	37	-29	4	-57	-30	-85
Industrial - CHP	-27	-65	35	-17	15	-35	-7	-175
Community Heating	-9	-67	93	11	56	-20	18	-51

3.2.17 Barriers to uptake

Factors that may discourage or constrain the rate of uptake of biomass for heating purposes include;

- lack of space to house the physically larger systems and allow for fuel delivery and storage,
- biomass conversion systems are more capital intensive than equivalently rated fossil fuel systems, and enterprises may be reluctant to use scarce capital on service supply.

We have taken account of these constraints in considering what constitutes a realistic estimate of the projected contribution for each sector. However there are some other barriers that will inhibit the take up of biomass as a fuel for heating.

- In the commercial and industrial sectors biomass heating appears financially competitive when heat costs are calculated using 15% as the base case discount rate. However the payback periods offered on the investment 4-6 years) are unlikely to be attractive to many industrial and commercial investors who would typically want a payback of 2-3 years before investing, particularly since the return is sensitive to volatility in fossil fuel prices which are uncertain.

Even if the rate of return were judged to be adequate, there are a number of risks and barriers that in some cases would hold back development of these resources. These include;

- absence of a well established supply chain that can assure access to sufficient fuel that is 1) within a reasonable transport distance and 2) processed economically to the right specification for the boiler application concerned,

- lack of awareness of the opportunity and confidence in the technology and commercial infrastructure, given the small number of successful examples in the UK,
- potential competition for resource with non-energy uses, and also with fuel being used for co-firing and electricity-only applications which benefit from support under the Renewables Obligation.

Some of these barriers are being addressed by existing initiatives – for example Defra's Energy Crops Scheme (ECS) is bringing forward planting of energy crops which could augment the supply and the Producer Group scheme[8] and the Bioenergy Infrastructure Scheme[9] are stimulating investment in fuel processing and delivery infrastructure.

The DTI Bioenergy Capital Grant Scheme is bringing forward a number of exemplar projects both at large scale and in the commercial and institutional sector. Biomass boilers up to 15MW already qualify for Enhanced Capital Allowances, and exemption from Climate Change Levy improves the economic case for biomass compared with fossil fired alternatives.

However, this is still seen as a risky investment by industry and dealing with these non-financial barriers would not on their own be sufficient to stimulate widespread adoption of these technologies. In order to stimulate the significant and low cost carbon saving opportunities some additional financial incentive, which insulated projects to some extent from the fuel price volatility and created a level playing field for heat as opposed to electricity producing projects, would be an effective way of stimulating the market. In order to create confidence in a longer term market, which would encourage the development of the supply side industry needed to bring costs down, some ongoing support for the generation of renewable and CHP heat may be worthwhile.

Biomass fired CHP systems already benefit from support for the power they produce via the Renewable Obligation. The economic analysis indicates that producing heat is more cost effective than installing biomass CHP, but that the inclusion of the ROC value makes the rate of return broadly similar. Biomass CHP leads to greater carbon savings than heat only operation, and is therefore to be encouraged. We therefore suggest that if some support for biomass heat is developed, this should apply equally to heat from biomass CHP, so levelling the playing field and making the support for heat, electricity and CHP broadly equivalent on a carbon saving basis.

In the residential sector, the gap between the cost of heat from biomass and from fossil fuels is wider and similar infrastructural barriers apply. Some incentives are provided into this sector via, for example, the Clear Skies Programme but in order to stimulate this market sector some additional incentive is required. Other measures could be introduced which would improve the economic case for investment in these systems – for example by reducing the level of VAT on such systems. Another option would be to use the Building Regulations to achieve carbon savings without explicit government subsidy. This has not been assessed in detail in this report, and there are many different ways in which such regulations could be formulated that could have different impacts on carbon emissions. This approach could potentially cover all new-build houses, not just those in off-gas grid locations.

Providing the support needed to stimulate the biomass heating market would provide carbon savings and also contribute to other Government objectives by providing an economic stimulus to the rural sector, catalysing jobs in the fuel supply industry for example.

---

[8] http://www.defra.gov.uk/erdp/schemes/energy/producer.htm
[9] http://www.defra.gov.uk/farm/acu/energy/infrastructure.htm

3.2.18 Case study

Type of Project: Community Heating
Location: Llanwddyn

Summary: Llanwddyn is a small community in the remote forested Vyrnwy valley in Montgomeryshire comprising a number of 1950s houses together with a school and community centre. There is no mains gas in the area. An Energy Services Company (ESCO) was set up under a design and build contract to construct a dedicated boiler house and associated heat distribution system. Local availability of wood meant that wood-chip was the best fuel for the application. A 600 kW wood-chip boiler has been installed and now supplies heat to the community.

Technical data: A 600 kW wood-chip boiler linked to a smaller backup oil-fired boiler rated at 315 kW

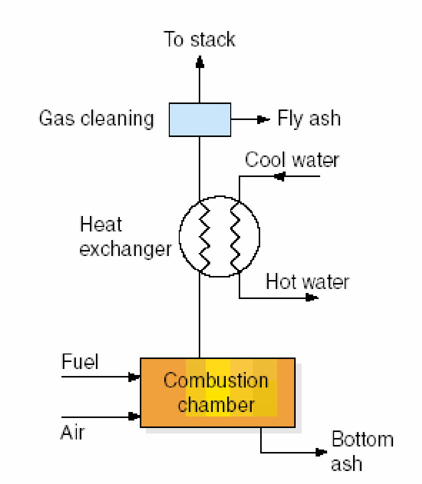
Energy data: It is estimated that the school and community centre will save £750 per year compared to previous consumption patterns. The present residential average heating cost is around £450 per year. Annual savings for residential consumers are predicted to range from £20 for oil fired heating, to £210 for off-peak electricity.

Environmental data: Predicted to save 1,805 tonnes of CO_2 over the next 5 years.

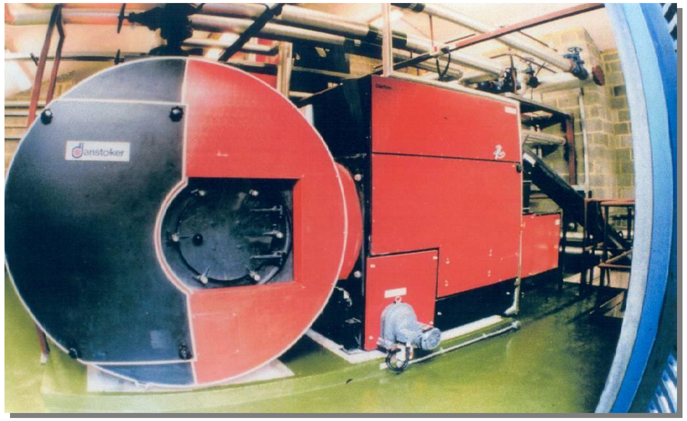
Economic data: The sources of funding were the European Regional Development Fund and the Local Regeneration Fund, and the Welsh Development Agency. Powys County Council also applied successfully to the Government's £50 million Community Energy programme for grant funding. The total project cost was £375,000.

Source: Energy Saving Trust

Figure 3 – The basic operation of a biomass boiler



A 350 kW wood fired heating boiler



3.3 GROUND SOURCE HEAT PUMPS

3.3.1 Description

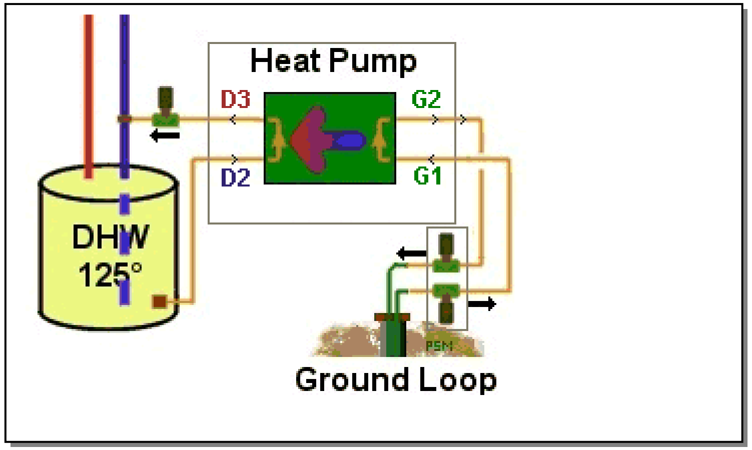
Heat pumps transfer heat from colder to hotter bodies by performing mechanical work on a fluid (on the same principles as a refrigerator). The work required to transfer the heat can, if the conditions are suitable, be much less than the heat transferred, effectively converting a small amount of electricity into a large amount of heat.

Ground Source Heat Pumps (GSHP) use the fact that the earth has a constant temperature of 12°C below approximately 1.5 metres from the surface. By running pipework containing a heat transfer fluid either horizontally in trenches or vertically down into a borehole, the ground can be used as a heat reservoir, with heat pumped for use in heating applications (see figure 4).

The maximum temperature that GSHPs can efficiently achieve is approximately 50°C, which is ideally suited to systems such as underfloor heating. GSHPs can also be used on a radiator system although the temperature is at the lower limit of suitability for this application. Systems can be installed with capacities from 3.5 kW (suitable for housing applications) up to 400 kW (suitable for commercial applications).

GSHPs are well suited to production of low-grade heat for space and water heating applications where a steady heat load exists enabling high levels of plant utilisation. They are therefore appropriate in residential and commercial and institutional heating applications. However, access to suitable land in which a borehole or trench can be dug close to the heat load is a prerequisite for this technology. The need for this potentially disruptive groundwork is a barrier to retrofit installation, making it more likely that GSHPs will be installed in new build situations.

Figure 4 - Schematic representation of a ground source heat pump.



3.3.2 Status

The technology is well developed and understood and there is a significant market in mainland Europe, particularly in the Netherlands, and USA. Despite support from the Clear Skies Programme, the installer industry in the UK is small given the low level of current demand due to the current high cost of the technology and other barriers to deployment

3.3.3 Current contribution

A recent survey[10] has indicated that there is about 5 MW_{th} of installed GSHP in the UK, made up of around or about 600 to 700 units. Between them they provide around 30 GWh_{th} of "carbon free" heat.

3.3.4 Technical potential

Residential sector

One identified potential market for GSHP is the residential sector where the off gas grid sector may be particularly suited, since alternative fuel costs are higher and there is likely to be more space for installation of the heat pump. There are estimated to be 4.42 million houses in this sector, each with an average heat demand of 18 MWh/y. The technical potential in this sector is therefore around 76.4 TWh/y, which if realised would lead to carbon savings of 3.8 MTC/y, after allowing for the electricity required for operation.

The Barker Review projected that there might be as many as 1 million extra dwellings in the UK by 2020. If a similar proportion of these premises were off the gas grid as at present and had appropriate access to suitable land, which is likely due to the use of green field sites for many housing schemes, this new housing could add a further 160,000 opportunities to the GSHP market, adding a further 2.9 TWh/y to the technical potential, increasing the total carbon saving potential to 3.9MTC/y.

Commercial and industrial sectors

In addition to the constraints that apply in the residential sector, the commercial and industrial sectors face additional problems. These are associated with land availability and tenure, as most commercial premises are leasehold. Given the value of commercial/industrial land it is rare for large areas of land to be available immediately outside the building structure. This means that most installations will have to be borehole systems, which in turn require more specialist contractors compared with trenches. Other issues are those of boring close to building foundations and services. This is compounded by the larger physical collection systems that will be required by the commercial/industrial sector. The combined effect of these factors is such that GSHP installations are more likely to be installed in new build rather than retrofit situations. Another non-technical issue is one of tenure. Most commercial/industrial premises are leased and it is unclear how willing landlords might be to allow borehole installation close to their buildings. Again, this will be less of an issue for new-build where the GSHP is planned into the building design. Also, in many instances, depending on the nature and costs of the available alternative heating options, a GSHP system may not give a finite payback period, despite the fact that its overall energy cost is less than some other options. This is because GSHPs have an ongoing electricity consumption that can cost slightly more than the gas for a gas-fired alternative. This fact could have a major impact where payback is used as an investment criterion.

For these reasons we have assumed that only 25% of the 1.35 million commercial and industrial buildings (from the 2004 Commercial and Industrial Floor space statistics published by ODPM), are suitable for GSHP and can contribute to the technical potential. Furthermore, we have

---

[10] Private communication from National Energy Foundation - survey not yet published at time of writing.

assumed that the size of each commercial/industrial unit is 400 kW, which is at the top end of the current size range of installations. To this we have added the same average rate of new build as has been seen in recent years, giving 144,000 new premises by 2020. For new build we have assumed that 75% of commercial/industrial properties will be geologically suitable for GSHP, again with 400 kW units installed at each location. This makes the Technical Potential in this sector 1.4 TWh/y in 2010, rising to 0.3 TWh/y by 2020, an associate carbon saving potential rising from 0.08 to 0.09 MTC/y during this period.

3.3.5 Market potential

Residential sector

The potential for GSHP will be limited by space to install the heat collectors and the heat pump. While there are no firm data on the proportion of houses with enough space and suitable geology to install these systems, we have assumed that this might be possible in 25% of cases. This gives a market potential of 18.9 TWh/y, rising to 19.6 TWh/y by 2020.

Commercial and industrial sectors

For reasons described above, we consider that installations will be constrained by the capacity to install retrofit systems. Unlike the residential sector, we consider that most commercial/industrial installations will be based on boreholes and that these services will be provided by a different set of contractors/installers than in the residential sector where trench systems will predominate. We have assumed the same rate of growth of capability in this sector as in the residential one, hence the capability to supply grows rapidly from a low base to 10,000 units per year by 2010, 35,000 by 2015, and 55,000 by 2020. We have assumed no such constraints in the new build sector, as the required ground-works can be easily included in the construction process and undertaken as a normal part of building construction.

3.3.6 Projected contribution

Residential Sector

Achieving the market potential in the residential sector by 2020 would require 70,000 systems to be installed each year between 2005 and 2020. In the early years, the capability of the supply industry to meet this need is likely to be restricted. This is the major constraint to the rate at which a contribution from this source could be established, as it would require a considerable investment by the industry to expand its capacity compared with the current low level of installation. We have assumed that the capability to supply grows rapidly from a low base to 10,000 units per year by 2010, 35,000 by 2015, and 55,000 by 2020. This would lead to the contributions shown in Table 16.

Commercial and Industrial Sector

We have further scaled down the market potential, taking account of the issues associated with land tenure and geophysical problems potentially associated with collector installation. For these reasons we project that only half of the market potential can be reached by 2020, not least because we predict difficulties overcoming problems of tenure preventing installation on many sites.

Table 17 summarises these estimates of potential.

Table 16 - Potential for GSHP in the residential sector

	2010 (TWh/y) (MTC/y)	2015 (TWh/y) (MTC/y)	2020 (TWh/y) (MTC/y)
Technical Potential	76.4	77.5	78.5
	3.82	3.87	3.92
Market potential	19.1	19.4	19.6
	0.96	0.97	0.98
Contribution projection	0.5	2.8	7.3
	0.03	0.14	0.36

Table 17 - Potential for GSHP in the commercial/industrial sector

	2010 (TWh/y) (MTC/y)	2015 (TWh/y) (MTC/y)	2020 (TWh/y) (MTC/y)
Technical Potential	1.5	1.7	1.9
	0.077	0.084	0.093
Market potential	0.3	0.4	0.5
	0.015	0.019	0.023
Contribution projection	0.1	0.2	0.3
	0.004	0.009	0.017

3.3.7 Capital and operating costs

The cost of GSHP systems for residential applications can range from £800 to £1,300 per kW depending on geology and ease of access to the ground, with £1,000 per kW being typical. Lower costs are possible in new build situations (£800/kW), and for larger scale commercial applications (£800 – 600/kW).

Using the capital costs specified above we have calculated the current costs of heat from GSHP, using a 15% discount rate for the residential and commercial sectors respectively and for new build and retrofit applications. This analysis is summarised in Table 18 which shows that GSHP is currently significantly more expensive than heat from oil or gas.

Table 18 – The cost of heat from GSHPs

		Residential		Commercial / Industrial	
		Retrofit	New Build	Retrofit	New Build
Unit Capital Cost	£/kW	1000	800	800	600
Heat cost @15% discount rate	£/MWh	100	76	70	34

3.3.8 Scope for cost reduction

The technology for GSHP is well developed internationally. A recently published paper gave the following breakdown of the international market.

Country	MW_{th}	GWh/yr	Number Installed
Austria	**275**	**370**	**23,000**
Canada	**435**	**600**	**36,000**
Germany	**640**	**930**	**46,400**
Sweden	**2,300**	**9,200**	**230,000**
Switzerland	**525**	**780**	**30,000**
USA	**6,300**	**6,300**	**600,000**

Source: Lund *et al* 2004[11]

Although there is so far only a small market in the UK, there is considerable scope to develop a more competitive network of developers and installers. There is scope for reducing costs through efficiency and competition as the market increases. Using the methodology described in the Annex, we have estimated that the cost of heat from this source could reduce by 1.8% per year between 2005 and 2020, reducing from £100 to £80/MWh for the residential sector by 2020 and from £70 to £56/MWh for commercial sector applications.

3.3.9 Carbon savings

The electricity used to drive a GSHP system means that there are some carbon emissions associated with its use. Allowing for these emissions the net saving of carbon amounts to 61 kgC/MWh compared to using oil to produce heat and 43 kgC/MWh compared to gas.

Table 18 shows the cost of the carbon saved, by dividing the savings by the difference in cost between heat supplied by GSHP and by oil or gas.

These costs will reduce as the difference between the cost of heat from GSHP and conventional heating decreases, and the Table also shows how the cost of carbon will reduce as the cost reductions discussed earlier occur. For example the cost of carbon saved in the residential sector when oil is being replaced reduces from £811 to £516/t C.

Table 19 – Cost of carbon saving from GSHP

	£/T C							
	2005		2010		2015		2020	
	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil
Residential	1382	1295	1340	818	1165	690	989	563
Commercial	1668	822	1555	839	1443	746	1330	653

3.3.10 Barriers to uptake

Although there are a growing number of installations, the high installation costs and poor payback period associated with GSHP installation is at present a major barrier to the widespread adoption of this technology. In addition, heat pumps are not well known or understood, and there is a lack of understanding and confidence around their use amongst both potential users and investors. Not surprisingly, given the current low level of demand, the current marketing and installer network lacks strength.

Existing initiatives in the UK are leading to some examples of GSHP installation, stimulated via Clear Skies and the Energy Efficiency Commitment Scheme. Even with these measures financial support to improve the economics it also likely to be required.

---

[11] J Lund, B Sanner, L Rybach, R Curtis & G Helstrøm; "Geothermal (Ground-Source) Heat Pumps, A World Overview, GHC Bulletin, September 2004.

These stimuli would need to backed up by;

- demonstration and promotional effort to increase awareness and confidence in the technology;
- support and training to help grow the network of installers required.

3.3.11 Case study

Type of Project: Ground source heat pumps in residential dwellings

Location: Marazion, Cornwall

Summary: Penwith Housing Association took the opportunity to install ground source heat pumps to a development of four new, conventionally constructed semi detached bungalows. The bungalows were each fitted with a horizontal closed-loop, ground coupled, water-to-water heat pump, rated at 4kW. These pumps take low temperature heat from the ground using a heat exchanger (or collector coil) and convert it to heat energy, which is distributed to every room by radiator. In order to maximize efficiency the heat pump was sized so as not to meet occasional peak winter heat demands, which will be dealt with by an auxiliary electric flow boiler.

Technical data: Horizontal closed-loop, ground coupled, water-to-water heat pump, which is rated at 4 kW.

Installer: GeoScience Limited
Energy data: Total heating and hot water costs for each bungalow are predicted to be in the region of £100 per year, the majority of which is the cost of electricity to run the heat pump system.

Economic data: The supply and installation of each system cost approximately £4,450. Each system was partially subsidised by an EST grant arranged by SWEB covering the additional cost over and above a conventional oil-fired central heating boiler (£1,125 per system), representing approximately 25% of the capital cost.

Source: Renewable Energy in Housing case study

3.4 SOLAR WATER HEATING

3.4.1 Background

Solar water heating is an established and globally applied technology, especially in areas with high average annual solar. Uptake in the UK is low, mainly because of less favourable climatic conditions than in more southerly countries leading to lower heat yield per unit area of solar collector and relatively low price of conventional energy. This results in long payback times even in the most favourable UK conditions.

As a result, a substantial proportion of solar panels manufactured in the UK are exported to meet the overseas market demand.

3.4.2 Description

Solar water heating, sometimes also called active solar heating (ASH), involves the collection of solar heat-radiation by water flowing through collector panels that are usually mounted on the roof of a building. The heat can be used for a number of applications such as space heating, hot water supply or to preheat water going into boilers. Figure 5 shows a schematic of a solar water heating system.

The majority of installations consist of panels fixed onto an approximately south facing roof. In some systems, water is circulated within a closed system with the heat collected by the panel being transferred via a heat exchanger to the existing hot water supply. In other systems water is heated directly by the panel. It is normal to retain conventional heating as well as the solar heating to ensure that hot water demand can be met during periods of low solar radiation, or when hot water demand is high.

Solar water heating is technically not well suited to producing high temperature heat and so is not likely to contribute to industrial heat requirements except by providing small volumes of localised hot water for hand washing or similar, or to pre-heat water going into other heat generating processes such as boilers.

There are also niche applications for solar water heating such as to heat swimming pools, supplement conventional heating in district heating systems and for use in agricultural applications. These markets are relatively small and accurate data to support projections of technology uptake are poor. For these reasons we have excluded them from our calculations.

3.4.3 Status

Solar technologies that provide heat and hot water for residential, commercial and industrial use have a long history of commercial application. Several million solar hot water systems have been installed worldwide. Historically, the United States, Japan, Israel and Australia have had the largest share of the solar thermal market. More recently, there has been significant growth in Europe and Asia.

Figure 5 – Schematic of a solar water heating system

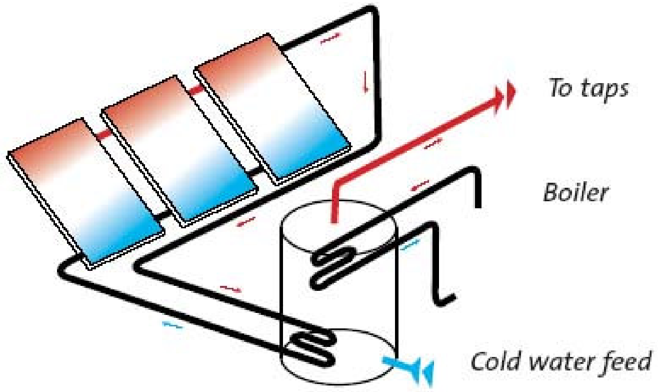


Photo of a domestic scale solar water heater panel

The technology continues to develop, increasing efficiency and reducing cost. In particular the use of:

- new materials with better properties and/or lower cost;
- ‘drain back' systems that keep the collector empty of water when out of use overcoming potential problems with freezing;
- direct heat transfer systems, where hot water from the collector actually mixes with the water in the hot water tank instead of merely transferring heat via a coil heat exchanger.

These improvements should lead to better performance and reduced cost, although no hard evidence has yet been published to confirm this.

3.4.4 Current contribution

It is estimated that there are over 60,000 ASH systems operating in the UK. These are primarily for residential hot water applications and are generally found in environmentally conscious households.

The current estimate of heat supplied by solar water heating is 0.23 TWh/y (UK Digest of Energy Statistics).

3.4.5 Residential sector

To date, the dominant sector has been the residential market. The technical potential in the residential sector is equal to the number of residential dwellings that can accept a solar water heating system, multiplied by the typical average output of each residential sized system.

The number of dwellings (all tenures) in the UK in 2003 was 25.6 million. Based on figures quoted by the industry, the average size of existing installations supplies 1,250 kWh/y. Therefore, the technical potential is 32 TWh/y, which if realised would lead to carbon savings of nearly 2 MTC/y.

It is now widely accepted that the number of houses in the UK needs to increase. The Barker Review of housing concludes that 70,000 private homes per year must be constructed to match demand and keep levels of price inflation low. If this rate is achieved from 2006 onwards then there will be an additional 980,000 homes by 2020. Using the same model that we have applied to the current housing stock, these new houses will add 1.2 TWh/y to the technical potential by 2020 if the average size of installation remains at the 1,250 kWh/y size. As these new build installations are at lower cost, we have undertaken separate calculations of payback and therefore uptake in our cost models. The technical potential will therefore rise from 32.4 to 33.2 TWh/y between 2010 and 2020.

The number of residential buildings physically capable of accepting a solar water heating system is widely accepted as being 50% of the UK housing stock, giving a market potential of 16 TWh/y, which will increase to 16.6 TWh/y by 2020 as new housing is built.

Achieving the market potential in the residential sector by 2020 would require 850,000 systems to be installed each year between 2005 and 2020. In the early years of their period, the capability of the supply industry to meet this need is likely to be restricted, and this would be the major constraint to the rate at which a contribution from this source could be established, as it would require a considerable investment by the industry to expand its capacity compared with the current low level of installation. We have assumed that with favourable market conditions the capability to supply the demand to retrofit systems could grow rapidly from a low base to 50,000 units per year by 2010, 300,000 by 2015, and 800,000 by 2020.

In the new build market we do not consider that there will be the same constraints on the availability of installers. This is because the installation will be undertaken during construction by the same tradesmen that fit the plumbing and electrical systems and install the roofing. We have assumed that these effects combined gives the new-build practical potential shown below. Here we have assumed that only 25% of the theoretical potential is adopted in 2010, rising to 50% in 2015 and 75% in 2020 as house builders acquire the required installation skills and house designs evolve to better accommodate solar heating systems.

These assumptions on build rates lead to the contribution projections and carbon savings given in Table 20.

Table 20 - Potential for solar in the residential sector

	2010 (TWh/y) (MTC/y)	2015 (TWh/y) (MTC/y)	2020 (TWh/y) (MTC/y)
Technical Potential	32.4	32.8	33.2
	1.94	1.97	1.99
Market potential	16.2	16.4	16.6
	0.97	0.98	1.00
Contribution projection	0.2	1.6	5.5
	0.01	0.10	0.33

3.4.6 Commercial and industrial sectors

In the commercial and industrial sectors, a study for DTI indicated that allowing for the technical suitability of the existing building stock, the technical potential for solar water heating was 1.4 TWh/y. There will be additional potential associated with new build or major refurbishment applications. Statistics from the ODPM show that in 2004 there were 1,354,890 industrial and commercial buildings in England and Wales. The same source shows an average increase of 9,000 properties per year in this sector, which would lead to 144,000 new premises by 2020. We can find no estimates of the average size of the systems that might be installed in these market sectors, but based on the relative roof areas of commercial and residential buildings we consider that an estimate of average output at 3,125 kWh/y is reasonable. This would lead to an increase of 0.45 TWh/y in the technical potential by 2020, so potential carbon savings would rise to around 0.11 MTC by 2020.

In the commercial/industrial sector the potential will be constrained by a number of factors and the report referred to above concluded that in practice the level of market penetration in the existing building stock would be limited to around 16% of the technical potential, or 0.23 TWh/y. In the new build sector we have assumed that a higher proportion of buildings could be made suitable for solar heating, and that 50% of the new buildings could use solar water heating.

In this sector the capacity of installers is less likely to be an issue, given the smaller numbers of installations involved. We have assumed that 25% of the market potential is achieved by 2010, 50% by 2015 and 75% by 2020.

Table 21 summarise the potential and associated carbon savings for the residential and commercial sectors respectively.

Table 21 - Potential for solar in the commercial and industrial sectors

	2010 (TWh/y) (MTC/y)	2015 (TWh/y) (MTC/y)	2020 (TWh/y) (MTC/y)
Technical Potential	1.54	1.68	1.85
	0.09	0.10	0.11
Market potential	0.30	0.37	0.46
	0.02	0.02	0.03
Contribution projection	0.08	0.19	0.34
	0.00	0.01	0.02

3.4.7 Capital and operating costs

Solar heating systems typically convert up to 40% of the solar energy falling on the solar collectors into useful heated water. The amount of heat provided depends on the surface area fitted, but a typical system would have an area of around 3 m^2 and deliver approximately 1,250 kWh of heat to the household per year.

Data from the solar water heating industry show that typical solar water heating systems installed into existing households are priced in the range of £2,000 to £2,500 (depending on the size of house, type of collector, etc.) and that for new build applications this costs falls to between £1,300 and £1,500.

3.4.8 Heat costs

Using the capital costs specified above we have calculated the costs of heat from solar, using a 15% discount rate for the residential and commercial sectors and for new build and retrofit applications. This is shown in Table 22, which illustrates the fact that solar heat is currently much more expensive than heat from fossil sources, and this is one of the major barriers to widespread deployment.

Table 22 – The cost of heat from active solar sources

		Residential		Commercial / Industrial	
		Retrofit	New Build	Retrofit	New Build
Annual output	**kWh**	**1,250**		**3,250**	
Capital Cost	**£**	**2,000**	**1,400**	**4,200**	**2,900**
Heat cost @15% discount rate	**£/MWh**	**300**	**179**	**206**	**206**

3.4.9 Scope for cost reduction

There is a mature market for solar water heating systems, which are internationally traded. The UK installation and commercial networks are less strong, but would develop significantly if the market developed in line with the estimates of potential above. Using the methodology outlined in the Annex we have estimated how the cost of heat from solar will reduce by 2020. This is shown in Table 23.

Table 23 - The impact of cost reduction by 2010, 2015 and 2020.

Impact of Cost Reduction
Heat Cost £/MWh @15% Discount Rate

Sector	2005	2010	2015	2020
Residential - retro	300	280	260	239
Residential - new	179	167	155	143
Commercial - new	206	193	179	165
Commercial - retro	206	193	179	165

3.4.10 Carbon savings

Solar water heating saves all the carbon used to produce the heat from gas, oil or electricity.

Table 24 shows the cost of the carbon saved, by dividing the savings by the difference in cost between heat supplied by solar and by oil or gas.

These costs will reduce as the differential between cost of solar and conventional alternatives decreases.

Table 24 – Cost of carbon saved from solar

	£/T C							
	2005		2010		2015		2020	
	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil
Residential	4468	3281	4204	3107	3842	2827	3479	2547
Commercial	3560	2432	3319	2326	3079	2132	2838	1938

3.4.11 Barriers to uptake

The current costs of the technology are significantly higher than those of heat from oil or gas, and this is a major impediment to the growth of a mass market for solar water heating in both the residential and commercial sectors.

The well-established UK trade representative body, the Solar Trade Association, has published an analysis of the UK solar market that identifies the following barriers to growth:

- shortage of skilled solar installers;
- complaints about hard selling techniques by sales people visiting homes, leading to the perception that there are “cowboys” in the industry;
- insufficient labelling and side-by-side testing of components makes informed choices by installers difficult and manufacturers rely on sales gimmicks instead of verified data.

In addition, there have been some instances of planning permission failing to be granted for retrofit applications, though these may be fewer in the future because of the recent updates on planning guidance for renewable energy technologies.

Existing initiatives are leading to some examples of solar heating installation, stimulated for example via Clear Skies, and the Energy Efficiency Commitment Scheme. However, in order to get a significant contribution from solar to UK heat supplies some significant additional stimulus is required. This could be through financial support to improve the economics, or regulatory pressure via Building Regulations. This would create the opportunity for:

- support and training to help the network of installers required;

- promotional effort that aimed to increase awareness and confidence in the technology.

3.4.12 Case study

Type of Project: Residential solar water heating

Location: Blairgowrie, Scotland

Summary: A solar water heating system was installed in a three-bedroom bungalow in Blairgowrie, Perthshire. It was installed with the aid of a grant from the Scottish Community and Householder Renewables Initiative.

Technical data: A 4m^2 solar water collector was used to provide residential hot water.

Energy data: The solar power replaces liquid petroleum gas fuel and offers an estimated annual fuel saving of £120, on an estimated annual hot water output of 2,500–3,000 kilowatt hours.

Environmental data: Predicted to produce an annual carbon saving of 380 kilograms.

Economic data: The total cost of this scheme to the householder was £2,625, with 30% of this coming from the Scottish Community and Householder Renewables Initiative.

Source: DTI

3.5 GEOTHERMAL

3.5.1 Background

The temperature of the earth increases with depth below the surface and this geothermal temperature gradient causes a continuing outward heat flow from the very hot inner regions of the Earth deep below the crust. This effect is seen most markedly at faults in the surface. Because the UK is far from the active tectonic and volcanic areas of the Earth, heat flows in this country are generally low. The geothermal gradient is a maximum of 30°C/km in the UK.

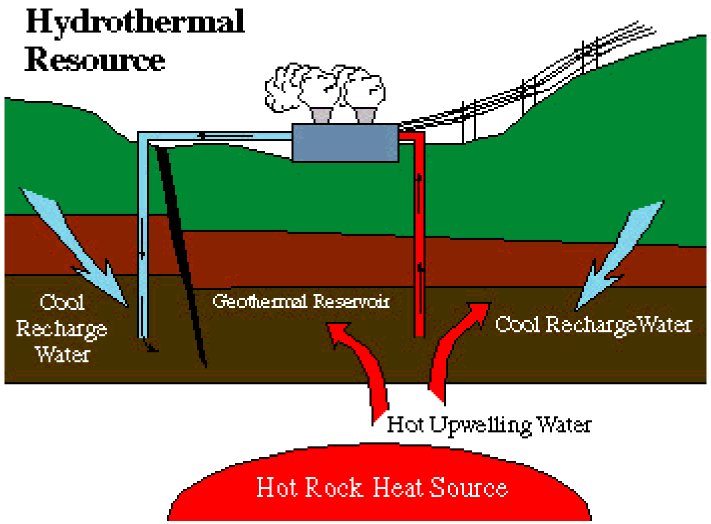
Geothermal aquifers are naturally occurring geological formations containing water that has become heated by the movement of heat away from the Earth's core. This hot water can be made to flow to the surface through a borehole and can be used as a source of heat. While geothermal heat is an alternative source of energy it is not truly renewable as the source of the heat is not being replaced.

Geothermal aquifers should not be confused with Hot Dry Rock (HDR) 'reservoirs' or with ground source heat pumps.

3.5.2 Description

At its simplest, a geothermal aquifer may be visualised as a uniform permeable layer of rock of infinite extent bounded above and below by impermeable rocks. When a borehole is drilled into the aquifer, the fluid rises to a level determined by the hydraulic pressure in the aquifer, though often a pump is needed to bring the water to the surface. In practice, variations in aquifer thickness and permeability and the existence of discrete faults are likely to restrict the volume that can be accessed by a geothermal system.

Figure 6 – Schematic of a geothermal heating system



3.5.3 Status

Aquifer schemes can be designed using one or two boreholes. In a single borehole system, the sub-surface water is removed and not replaced. In a double scheme two boreholes are drilled; hot water is extracted from one and cooled water returned to the other. To avoid the returning water cooling the aquifer, a separation distance between the boreholes of about 1 km is necessary so that when it reaches the extraction well again it has been heated by passing through the rock. A system life of 20-30 years is typical before the aquifer cools to uneconomic levels.

At the wellhead of a producing geothermal aquifer, a large titanium plate heat exchanger is used to transfer the aquifer's heat to the fluid that circulates through the heating load. This often supplies a district-heating scheme. Where aquifer temperatures are low, heat pumps may be used to raise the flow temperature to the level necessary for space heating. As the cost of the heat distribution pipe network is significant, the heat load needs to be close to the wellhead to minimise heat losses.

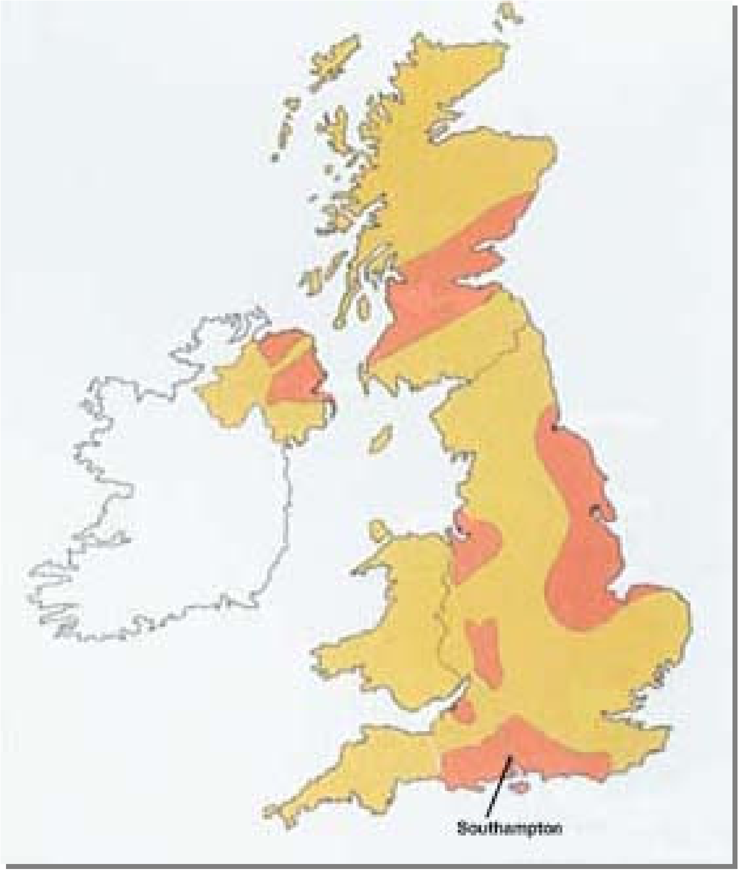
3.5.4 Current contribution

The Southampton Geothermal Heating Scheme is the only example in the UK of the use of geothermal heat. Here, the Civic Centre, the Institute of Higher Education, other council offices and an extensive range of private sector buildings are linked by a 2 km hot water main. This runs to and from a 'heat station' located close to the wellhead of the Southampton borehole. 2 MW of usable heat is recovered and fed into the scheme.

3.5.5 Technical potential

The UK has only limited geothermal potential, as shown in Figure 7.

Figure 7 - Principle areas of potential geothermal aquifers in the UK



Estimates from the British Geological Survey put the available resource (defined as availability of 40°C or greater) at 55 GJ, which if it were exploited over the 20-year life of a normal extraction project, puts the maximum resource at 2.75 GJ/y, which is equivalent to less than 0.0002% of annual natural gas consumption in the UK.

Practical potential

Practical exploitation of geothermal aquifers depends on making a significant investment of the cost of drilling boreholes in advance of any income from heat sales. The final heat yield and this income potential can also only be accurately measured once the boreholes are sunk. How these projects are funded and who bears the risk is a major barrier to market penetration. The Southampton scheme went ahead only because the Government ‘donated’ the borehole created through its earlier geothermal research programme to the city.

For these reasons, we consider that the practical potential of this technology is effectively zero. We have therefore undertaken no further analysis of this technology option.

3.6 ENERGY FROM WASTE

3.6.1 Background

This section focuses on Energy from Waste (EfW) where energy is generated from Municipal Solid Waste (MSW) during the disposal process. While technologies for recovering energy from these wastes have been available for over 100 years, the UK has much less experience of EfW than many other European countries. This is because of the UK's historic reliance on landfill as the principal waste disposal route for MSW. In particular the Nordic countries, the Netherlands and Switzerland operate a number of EfW plant to feed heat into large district heating schemes. This makes EfW a common and accepted technology in these countries.

The primary function of any waste disposal plant is safe and cost-effective disposal of waste. Waste related issues rather than energy considerations primarily drive decisions on disposal methods. The principal factors concern compliance with legislation associated with recycling and environmental performance and the overall cost of disposal, although the income from energy recovery, where this is part of the preferred solution, does influence the economics.

The overall mix of waste disposal options for the UK is driven by the Government's Waste Strategy[12]. This sets out a number of scenarios for the evolution of the waste management mix over coming decades. These scenarios allow for the construction for between zero and 166 new EfW plant.

Where energy recovery is part of the overall package of waste disposal options chosen, the combustion plant must comply with stringent regulatory requirements concerning pollutant emissions to atmosphere, land and water. To meet these requirements, costly abatement plant and accurate control of combustion conditions are needed. Both combustion and abatement plant are subject to economies of scale, so that larger plants tend to be more cost effective. 100,000 te(MSW)/y seems to be the lower economic size limit under current market conditions.

The requirement for large plant size, together with the fact that waste incinerators are extremely unpopular with the public, means that to get through the planning process new EfW plants tends to be located far from centres of population and therefore far from potential heat consumers. Consequently opportunities for using heat from such plant are rare and are most likely to be industrial facilities. EfW plant therefore predominantly tend to generate electricity only.

In the UK, EfW has received much bad publicity linked to isolated issues with the operation of some plants. This has caused some environmental groups to oppose the construction of new plant and have effectively mobilised public support against EfW.

3.6.2 Description

EfW is a collection of technologies for thermally treating MSW. The primary functions are to reduce the volume of the waste, render it inert and recover energy from its combustible content. The main technologies used in EfW facilities are:

- mass-burn - a large-scale combustion process in which all of the MSW is burnt *ed en masse,* based on conventional grate combustion technology;

- fluidised bed combustion - smaller scale combustion process where the MSW is burned in a bed of sand made fluid by the combustion gases, this ensures more complete ‘burn-out’ of the fuel and can be operated at smaller scale than mass-burn systems;

---

[12] Waste Strategy 2000, The stationery Office May 2000, ISBN 0 10 146932 2, which is currently undergoing a review by Defra.

- pyrolysis-gasification - advanced thermal processes where the fuel is burnt with limited oxygen to produce a gas or liquid fuel for use in engines or turbines. These processes offer cleaner fuel use but are not yet fully developed commercially.

In addition, refuse derived fuel (RDF) can be prepared from MSW in a process that separates the combustible fraction and processes it into a physical form that can be burnt on conventional grate type combustion systems or could in principle be co-fired in large scale coal fired boilers, although the emission control regime associated with the Waste Incineration directive is likely to be a major discouraging factor.

3.6.3 Status

There are currently 15 EfW facilities in the UK, most of which are mass-burn incinerators with steam turbine generator sets. Together they generate 210 MW electricity from 300 Mt/y waste. Three of these are CHP facilities feeding district-heating schemes.

Additionally, four facilities are under construction, of which two will be connected to CHP schemes. Two schemes, Kirklees and Neath, Swansea, will supply heat to district heating in the future.

3.6.4 Current contribution

Currently 391 GWh/y of heat is supplied by MSW combustion (UK Digest).

3.6.5 Technical potential

The Government's Waste Strategy published in 2000, which is currently subject to a review being carried out by Defra, examined five alternative scenarios for the waste management mix. These scenarios contained different numbers of EfW plant ranging from zero to 166. If all 166 incinerators were built and their average capacity were 100,000 te(MSW)/y, then this would amount to 16.6 Mte of municipal solid waste (MSW) incinerated each year. The net calorific value of MSW is typically 8.5 MJ/t or 2.5 MWh/t. Modern EfW plants typically have an overall thermal efficiency of 75% and electrical generation efficiency of 20%. Consequently, the maximum heat resource available would be 22.8 TWh/y, which we have assumed to be the maximum technical potential for EfW. If, as is likely, the number of EfW built were less than this or the technology mix differed, the available heat resource would be correspondingly less. Similarly, an increase in the biological treatment of the organic fraction of MSW, would reduce the potential for waste combustion, though in this case more energy might be produced from anaerobic digestion. Our estimate of technical potential is therefore particularly uncertain.

3.6.6 Market potential

There are many factors associated with waste disposal policy and practice and with local planning issues that will affect where and when future EfW plants are built. Increasing costs of compliance with waste combustion legislation is making smaller plant less financially attractive than larger ones. These larger plants have more lorry movements associated with them, favouring location away from residential or commercial districts and thus away from major heat loads.

Where appropriate waste combustion plants are built, energy recovery will be included for electricity generation as the power market is readily available and stable. Heat will be produced and sold where a local market exists and provides sufficient guaranteed income to justify the costs of installing the heat distribution systems. These costs can be marginal for industrial heat loads co-located with the EfW plant or significant if an extensive district-heating scheme is installed to serve a large number of residential heat customers.

The principal barrier to using the heat from MSW is associated with the availability of appropriate heat loads close to the plant, similar challenges to those facing any other CHP or district heating application. We have assumed that up to 25% of the potential heat supply might be in locations where such a market exists, giving a market potential of 5.7 TW/y.

3.6.7 Projected contribution

Given the lead-time for constructing such plant, it is unlikely that plant not yet permitted will be in operation before 2010. If the additional plant came on stream between 2010 and 2020, then the contribution would rise to 2.9 TWh/y by 2015, and 5.7 TWh/y by 2020.

The estimates of contribution and associated potential carbon savings are summarised in Table 25.

Table 25 - Contribution and associated potential carbon savings from EfW

	2010 (TWh/y) (MTC/y)	2015 (TWh/y) (MTC/y)	2020 (TWh/y) (MTC/y)
Technical Potential	22.8	22.8	22.8
	1.14	**1.14**	**1.14**
Market potential	5.7	5.7	5.7
	0.285	**0.285**	**0.285**
Contribution projection	0	2.9	5.7
	0	**0.145**	**0.285**

3.6.8 Capital and operating costs

The capital cost of an EfW plant is very much greater than that of a conventional electricity generating station of the same capacity. This is due to two main factors;

- the low energy density of MSW compared with other renewable fuels (and even more so compared with conventional fossil hydrocarbon fuels) necessitating physically much larger plant,
- the need for advanced pollution control equipment fitted to the plant and the costs of safe disposal of ash and other residues.

A 100,000 t/y EfW plant would cost approx £50 - 60 million although capital costs can vary by 2-5% depending on the location, ground conditions etc. The additional cost associated with incorporating heat supply at the design stage is relatively small, being in the order of £100k.

Operating costs are also high, but these are offset by the gate fees that the plant operator can charge for taking the waste. The gate fees are the largest source of income to an EfW plant. They are set in relation to the costs of alternative disposal routes, and in order for the plant operator to get an economic return on the investment in the plant. Gate fees are currently typically £35 to £55/t, but as the volume of waste going to landfill is constrained by the Landfill Directive and other measures then these fees will rise substantially, potentially to £65/t or more.

3.6.9 Heat costs

The value of energy produced by a plant supplements the income from waste disposal. This either increases the revenue to the plant operator, improving the return on investment in the plant, or offsets some of the cost that must be passed on to the waste disposal authority. In electricity producing mode, around 450 kWh of electricity are produced from each tonne of waste, which has a value of £11.25 at £25/MWh. In heat producing mode, if heat is produced at 75% efficiency, and 60% of the heat can be sold, then the income is again equivalent to £11.25/tonne of waste at a heat value of £10/MWh. Some additional infrastructure would be needed to make the heat available to a nearby distribution system, and this might add £10–20/MWh to the cost of the heat produced, giving a total cost of £20–30/MWh.

3.6.10 Scope for cost reduction

The technology associated with the marginal costs of using heat from EfW – heat distribution and metering systems – is mature and there is restricted scope for cost reduction.

3.6.11 Carbon savings

The composition of MSW varies with the time of year and the locality in which it is produced. Although a number of waste analysis studies have been performed in recent years, a global estimate is subject to considerable uncertainty. We have assumed that around 70% of MSW is of organic origin after the removal of non-combustible recyclables such as glass and metal and can therefore be counted as a biomass resource and therefore carbon-neutral. The net saving of carbon amounts to 61kgC/MWh compared to using oil to produce heat and 46 kgC/MWh compared to gas.

3.6.12 Cost of carbon saved

The cost per tonne of carbon saved is £13 where gas is being replaced, and around zero where oil is being substituted.

3.6.13 Barriers to uptake

As explained above the choice of waste disposal route in a particular location will be influenced by many factors, and the availability of a heat market and income will not be a major driver. However, the availability of a stable and economically viable heat market could encourage the uptake of waste recovery schemes including an energy recovery element, and provide some local benefits which would offset the disruption associated with installation of such a facility.

The main barriers to the use of heat from EfW are similar to those affecting other technologies such as district heating and CHP. These are associated with the availability of stable markets for heat that will support the necessary investment in infrastructure. There are also commercial risks associated in the heat market as, unlike electricity generation, factors affecting the heat customer can lead to changes in demand pattern and the value that can be obtained for the heat. The returns from heat sales look marginal at present, even at current high fuel price levels, making these risks potentially unacceptable. Returns on investment will also be very sensitive to fuel price volatility.

If financial support were available for heat from EfW, then this would underpin the energy price and reduce the risk of investing in systems for heat collection and recovery. This could lead to significant and low cost carbon reductions. Capturing these benefits locally could also encourage local waste disposal, supporting Defra’s waste strategy.

3.7 ANAEROBIC DIGESTION

3.7.1 Background

Anaerobic digestion (AD) involves the conversion of organic matter to energy by microbiological organisms in the absence of oxygen. The methane created can be used as a fuel source for heating or electricity production.

AD tends to occur naturally wherever high concentrations of wet organic matter accumulate in the absence of dissolved oxygen – for example in the bottom sediments of lakes and ponds, in swamps, peat bogs, intestines of animals and in the anaerobic interiors of landfill sites. The process can also be managed to produce gas from suitable substrates by creating appropriate conditions in sealed, airless containers. The raw material is introduced to the digestion tank, warmed and mixed thoroughly to create the ideal conditions for biogas conversion. The process generates three main products;

- biogas - a mixture of methane (CH_4), carbon dioxide (CO_2) and other trace gases (the methane can be used to generate heat and/or electricity);
- fibre (only if originally present in the feedstock), which can be used as a nutrient-rich soil conditioner;
- liquor, which can be used as liquid fertiliser or disposed of via conventional means.

3.7.2 Status and current contribution

The AD process has been used to treat high strength organic wastes such as sewage since the late 19th century. Today it is most commonly used to treat municipal sewage. The process can also be used to treat animal wastes, the organic fraction from MSW, food processing and other industrial organic waste streams. So far in the UK the food processing sector has been slow to adopt AD but it is becoming more common where large volumes of food waste are produced. Pressure on alternative solid and liquid waste disposal routes is increasing waste removal costs, which explains the increasing interest in AD in the food-processing sector. The other sector where AD is being actively developed is to treat the organic fraction of MSW.

Traditionally most interest in AD has been as a route to treat animal wastes, yet the economic performance of this sector is poor as there are no gate fees or other major disposal costs associated with animal slurry disposal.

In all cases the economic drivers for AD installation are avoided or reduced waste disposal cost coupled with the value of renewable electricity generation under the Renewables Obligation. This means that heat is a by-product, making the issue of heat use from AD one of the relative economics of collecting and distributing the heat for use in space heating, or potentially bearing additional cost to upgrade the heat using fossil fuel to make it suitable for process use.

According to RESTATS digestion currently supplies 0.61 TWh/y of heat, almost all from sewage sludge digestion.

3.7.3 Technical potential

We have considered all of the feedstocks potentially available for AD being:

- Sewage;
- MSW;
- farm wastes;
- food processing waste.

Estimating the technical potential in some of these areas is complicated for different reasons. In the case of animal manures, animals are housed for less than half the year. For the rest of the year the manure is dropped on the field and is unavailable for energy production. In the case of food processing waste there have, as yet, been no data generated on liquid waste arisings. These data are hard to obtain as many producers aerobically treat their own waste prior to discharge and the waste disposal contracts between producers and water companies are commercially sensitive. In the case of solid food waste the information tends to be included in the overall commercial waste figures.

However, as an estimate, we have assumed the total amounts arising as shown in Table 26. In calculating gas yields we have assumed that all of this material is available at an average of 40% dry solids (ds) and that an 85% conversion of the organic fraction of the waste can be achieved with a gas production rate of 3.8 MWh/t. This means that each tonne of waste would produce around 1.3 MWh of gas. When used in CHP mode each tonne of waste will therefore yield 0.39 MWh of electricity and 0.78 MWh of heat. This may overestimate the heat availability as in some cases heat is used to warm the digester to achieve better digestion rates.

3.7.4 Market potential

In this sector a number of constraints combine to severely limit the market for heat from AD. We have considered these by feedstock.

Sewage

The issues with sewage digestion are part of a bigger set of issues relating to the ultimate use of the solid material left after digestion (the digestate) and the public acceptance of disposal to farmland, the alternative use of sewage as a feedstock for a combustion process to displace fossil fuels (for example in cement manufacture) and the wider environmental constraints on the water industry. In addition, the water industry is heavily regulated to control capital expenditure. This means that even if an emerging market for renewable heat makes it attractive to install more sewage gas plants it is highly probable that these constraints will make it almost impossible for sewage gas to service these markets. We consider that this will severely limit the capacity to use the technical potential of this resource.

Table 26 – Technical potential of the feedstocks available for AD

Waste	Arisings M tonnes/y	Gas potential TWh/y	Heat Potential (CHP Mode) TWh/y
Sewage	**1 (ds)**	**3.25**	**2**
MSW	**18***	**23.4**	**14**
Housed livestock	**87**	**112**	**68**
Organic food waste arisings	**9****	**12**	**7**
Total (at 40% ds)	116.5	151	91

*** Waste Strategy 2000, The stationery Office May 2000, ISBN 0 10 146932 2, which is currently undergoing a review by Defra.**
****http://www.ace.mmu.ac.uk/Resources/Fact_Sheets/Key_Stage_4/Waste/02.php**

Another constraint is siting of sewage AD systems. They must be where the sewage is available, that being the current network of sewage treatment plants. These all tend to be away from housing and commercial buildings. As a result, there is no ready residential or commercial market for any heat produced. The only potential heat market that we can envisage is one where a factory is located within economic heat transport distance from the sewage works or where new build creates this situation. However, given the severe constraints on using the resource as described above, together with these physical locational issues we consider that the main market for sewage gas is electricity and that the effective heat market is almost certainly zero.

Of course, opportunistic exploitation of heat from sewage gas will still occur where markets and sewage gas plants are co-located.

MSW

This feedstock already has a mature infrastructure for collection and processing. It is unlikely that the availability of markets for heat will significantly alter decisions over plant location etc as these will continue to be dominated by planning and transport considerations.

Legislative drivers to divert biodegradable waste away from landfill are in place, supported by the landfill tax scheme. These drivers have led to investment in facilities to compost this waste. This is good and bad news for MSW AD. On one hand investments have been made to develop a compost market for treated MSW, which effectively competes with AD. On the other hand, should MSW AD prove to be attractive, the infrastructure to supply relatively ‘clean’ green waste is in place. Recent moves towards building mechanical and biological treatment (MBT) plant may support MSW AD. This is because these plants combine increasingly rigorous waste separation and sorting techniques with mechanical treatment and then biological treatment of the separated organic fraction. This biological treatment can be composting, AD or the preparation of a refuse derived combustion fuel.

Despite this, MSW suffers from the same problems as sewage in that it is collected and treated at sites deliberately remote from residential and commercial buildings. The same issues apply in as much that heat can only be economically transported over short distances. Again, this effectively makes the size of the heat market from MSW AD zero, though there will always be instances where opportunistic cost-effective local heat use will occur. However, MBT plant producing refuse-derived fuel (RDF) may be able to contribute more effectively by providing RDF as solid heating fuel. This is discussed more fully in the MSW section of this report.

Animal manures

In practice only a very small proportion of the potentially available agricultural waste is likely to be used for digestion. This is because investment decisions are driven by agricultural and other issues rather than by the energy economics, making other disposal options fit better with current farming practices. Another issue is the lack of significant waste disposal costs in this sector - the size of the ‘gate fee’ is a strong driver in other waste disposal investment decisions. This is confirmed by the fact that the significant stimulus to investment provided by NFFO and the RO has not stimulated any marked increase in digester construction.

There are two models for farm waste AD. One is for the waste of a number of farms to be taken to a large, centralised facility such as that developed at Holsworthy in Devon. Issues affecting plants like these are almost identical to that discussed for sewage gas. This effectively means that there is no potential market for the heat produced by these plants. The other model is for small on-farm AD units. Here, the Renewables Obligation favours electricity generation over straight heat production, despite the latter offering lower cost plant that most farmers will be capable of operating themselves. In both cases we consider that no external heat sales will be possible, making the market one of displacement in the farmsteads with the same market characteristics as the intermittent commercial sector.

Despite this, farms with livestock have slurry storage/handling equipment. We consider these to be involved with dairy, beef and pig production, a total of 98,500 units. Slurry handling systems either comprise of older style lagoons or more modern slurry tanks. We have assumed that both have a life of around 15 years giving an annual replacement rate of just under 7% or 6,566 units/y. We have also assumed that AD will only be installed at the time when the current slurry handling equipment is replaced and that only 50% of farms will be suitable for an AD system. Based on the average heat consumption per farmstead of 36,000 kWh/y (twice normal residential levels in order to service increased space heating and hot water demands) and assuming that AD installation starts in 2006 gives a market potential in the farmstead sector of 0.45 TWh/y in 2010, rising to 1.65 TWh/y in 2020.

Given the potential of this area, RESTATS is currently undertaking a review of the farmyard manure sector and this information will improve our assumptions. This work will be completed in mid 2005.

Table 27 - AD market potential

Feedstock	2010	2015	2020
Farm manures (TWh/y)	**0.45**	**1.06**	**1.65**
Food processing waste (TWh/y)	**1.75**	**1.75**	**1.75**
Total (TWh/y)	2.2	2.81	3.4

Table 28 - AD projected contribution

Feedstock	2010	2015	2020
Farm manures (TWh/y)	**0.03**	**0.18**	**0.48**
Food processing waste (TWh/y)	**0.88**	**1.31**	**1.75**
Total (TWh/y)	0.91	1.49	2.23

Food processing waste

As with the other feedstocks considered in this section of the report, use of food processing wasted by AD will be limited to the industrial sector.

Similar issues apply to the use of digestion to dispose of industrial organic residues such as organic food wastes and decisions on disposal routes will be dominated by waste related factors. However in this case there is more likely to be a suitable heat load available close to the digestion plant once it is installed. In practice we estimate that physical and infrastructural considerations such as limitations on space will limit the market potential of this sector to a maximum 25% of the technical potential of 7 TWh/y.

Based on the analyses described above, we consider the market potential for the AD sector to be as shown in Table 27.

3.7.5 Projected contribution

In the on-farm AD sector, the current rate of UK installations is almost zero. Even in countries like Germany, where uptake has been more vigorous, less than 1,000 units have been installed. For this reason, we consider that significant investment must be made by technology suppliers to produce suitable AD plant for on-farm use. Given the low starting point, we consider that, if the industry were to start the required investment in 2006 the installation of only 250 units/y would be possible by 2010, 1000 units /year by 2015 and 2000 units/y by 2020. This will significantly reduce the projected contribution from this sector as shown in Table 28.

The situation in the food processing sector is different because each plant is potentially larger meaning fewer installations. The industry producing these plants is also physically larger, being typically involved in other large scale technology supply to the world's water industry. For these reasons we consider that there will only be limited constraints in the early years of installation such that 50% of the market potential can be met in 2010, 75% in 2015 and 100% in 2020.

Table 29 summarises the estimates of potential contribution and associated carbon savings from AD.

Table 29 - Potential contribution and associated carbon savings from AD.

	2010 (TWh/y) (MTC/y)	2015 (TWh/y) (MTC/y)	2020 (TWh/y) (MTC/y)
Technical Potential	**91**	**91**	**91**
	5.46	**5.46**	**5.46**
Market potential	**2.2**	**2.8**	**3.4**
	0.13	**0.17**	**0.20**
Contribution projection	**0.91**	**1.49**	**2.23**
	0.05	**0.09**	**0.13**

3.7.6 Capital and operating costs

Costs of exploitation

Decisions on installing an AD plant will be dominated by waste disposal issues and by the value to be gained from the renewable electricity generated. The marginal cost of heat produced will be effectively zero where a heat use is available nearby with the only cost being for distribution pipework.

3.7.7 Scope for cost reduction

The cost of AD plant will fall with volume, making an AD plant more attractive. For the reasons described above, this will have no effect on the price of heat.

3.7.8 Barriers to uptake

AD is a relatively unknown technology. This gives potential customers concerns about risk, which requires the economics to be very attractive to balance the perception of risk. Once the technology is established the perception of risk will progressively reduce.

In the on-farm sector the higher cost of AD compared with traditional waste management options presents a large barrier to farmers.

The lack of technology suppliers and associated field support is a major barrier in the on-farm sector.

3.8 LANDFILL GAS

3.8.1 Background and description

Landfill gas (LFG) is generated on landfill sites from the natural decomposition of organic matter in the waste under anaerobic conditions. The compaction of the waste and the sheer quantity of organic matter drives oxygen out of the atmosphere within the site, enabling degradation to proceed in the absence of oxygen. Under these circumstances a biogas is formed that comprises predominantly of methane and carbon dioxide. The quantity of landfill gas generated, the period of sustained generation and the gas quality depends on the nature of the landfilled waste and conditions within the landfill site. In general the gas is found to be 40-60% methane (by volume), with a calorific value approximately half that of natural gas (18-22 MJ/m^3). Optimal landfill gas generation occurs within the first 10-15 years after filling, with 1 tonne of typical waste yielding around 200 m^3 of gas. If uncontrolled, landfill gas represents an environmental hazard and is a very potent greenhouse gas in its own right.

Piping and using landfill gas as a fuel in boilers or furnaces is relatively straightforward technically, since conventional equipment can be used with minimal modifications. Boilers are generally less sensitive to LFG trace constituents than engines or turbines and therefore require less gas cleanup than other alternatives. However since landfill gas does contain some sulphur containing compounds and other pollutants it needs to be used under carefully controlled conditions and is for example unsuitable for use in individual residential heating or boilers. It could provide a useful fuel for larger scale commercial and industrial enterprises, or for district heating schemes.

In the early days of landfill gas use in the UK (1980s and early 1990s), the most common option for landfill gas heat was direct use, such as process heat and boiler fuel. Examples included the use of landfill gas to generate heat in kilns, to fire boilers (mainly dual fuel boilers), to heat greenhouses or to heat water. In these schemes the most important consideration was the proximity of the user to the landfill site. Most direct heat schemes are within 2 km of the landfill site. For direct use schemes, users need to have a gas demand that closely matches the production from the landfill site.

Since these early days there has been a trend away from direct supply for a number of reasons given below.

- Since the launch of the NFFO and latterly the Renewables Obligation it has become easier and more economic to generate electricity with greater assurance that the price available will be maintained.
- The price of fossil alternative (gas, coal, diesel) dropped appreciably, and has been volatile since. As most direct use schemes were linked to the price of the fossil fuel they replaced this had an immediate effect on returns from the landfill gas schemes. In many cases the original schemes were unable to survive these price drops, and it is difficult to justify expenditure on gas distribution schemes given the price uncertainty.
- Industry restructuring meant that a number of heat loads sited close to landfill sites disappeared or were significantly reduced, undermining confidence. Finding alternative users for gas supplied by a pipeline once installed is difficult, whereas power generation systems are relatively mobile and can be re-sited in response to variations in gas production or energy demand.
- Recent changes in environmental legislation mean that direct firing applications are now subject to environmental emission controls, which can add between £10,000 and £40,000/y to costs.

The use of gas to produce electricity under NFFO or under the Renewables Obligation is a more profitable exercise than selling the gas to users. This preference for power generation is reflected by the current status.

Current legislation is also achieving a diversion of organic material away from landfill, driven by landfill tax legislation. This is having the effect of reducing the future production of landfill gas. This trend will continue such that in 20 years time no commercial volumes of landfill gas will be produced in the UK.

3.8.2 Status and current contribution

The technology for landfill gas abstraction is well developed. There are currently 282 LFG power stations in the UK, with a generating capacity of 631.7 MW, which between them use 12.5 TWh/y of gas, with only 0.16 TWh/y being used directly. Despite this, there is almost no commercial use of the heat generated from landfill gas, let alone any direct use of the gas for heating purposes.

3.8.3 Technical potential

The total recoverable UK landfill gas resource, taking account of site size and suitability is estimated at around 24 TWh/y, of which 12.6 TWh/y are already being used, leaving an unexploited resource of 11.4 TWh/y. This will decline to close to zero over the next twenty years.

3.8.4 Market potential

In order to be marketable, the gas must be produced close to a suitable constant and stable heat load that must be no more than 2 to 3 kilometres distant with the facility to pipe the gas directly to the user. This usually means the negotiation of way-leaves over green fields and not laying pipes through residential areas. The option of using the heat from CHP to feed a district-heating scheme imposes even more constraints on the distance over which the heat can be transported. This severely limits the capacity to use landfill gas as a source of heat.

There is no good information available on the matching of landfill sites with heat loads, although larger landfill sites, suitable for gas collection, are almost always located away from populated areas. We have therefore assumed that only around 5% of the potential is located sufficiently close to suitable heat loads to constitute a market, giving a market potential of around 0.57 TWh/y.

3.8.5 Projected contribution

If landfill gas is being collected for energy use, then the disadvantages and risks associated with heat supply rather than for electricity generation have been discussed earlier. In particular;

- electricity production allows access to a large and stable market, not dependent on individual site energy demands so reducing the risk of stranded assets if business restructuring occurs;
- power generation systems are more mobile. This is important as gas yields continue to fall, as the systems can be relocated to sites with higher gas production.

For these reasons landfill gas generators will prefer to opt for power generation wherever possible, even if support for heat were available which balanced the current incentives for power generation available via the Renewables Obligation. We believe that the amount of heat that will be generated from landfill gas will be a very small proportion even of the market potential, and we have taken the effective practical potential as zero. However, where cost-effective opportunistic matches occur between heat production and demand, the market will continue to choose to exploit them.

Table 30 - Potential contribution from LFG

	2010 (TWh/y)	2015 (TWh/y)	2020 (TWh/y)
Technical Potential	**11.4**	**5.7**	**0**
Market potential	**0.57**	**0.29**	**0**
Contribution projection	**0**	**0**	**0**

3.9 RENEWABLE ENERGY TECHNOLOGIES – A SUMMARY

Table 31 summarises the potential heat contribution from the technologies considered in this report in terms of their technical and market potential and projected contribution for 2010, 2015 and 2020. The Table also summarises the estimates of the carbon savings associated with these projected contributions, and the calculated costs of carbon saved for each technology studied.

The analysis indicates that, taking account the energy resources and potential markets available, there is the opportunity for supplying an additional 88.9 TWh/y of heat from renewable energy, rising to 91.9 TWh/y by 2020 (around 12% of UK heat demand). Further constraints on market share and the rates at which markets can be penetrated reduce this so that the projected contribution in 2010 is 6.0 TWh/y, rising to 34.9 TWh/y by 2020 (0.8 – 4.7% of UK demand). If all this potential were taken up by 2020 this would lead to carbon savings of 2.0MteC/y (around 1.2% of current total UK carbon emissions (152 MteC/y)).

As Figure 8 illustrates, the potential is split between the various technologies considered.

Figure 8 - Projected Contribution in 2020

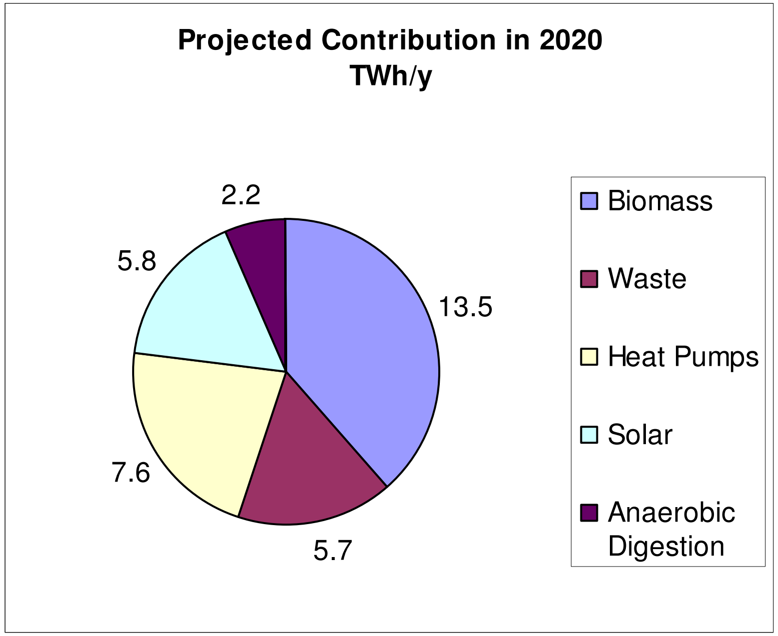


Table 31 - Summary of the potential contribution and Carbon Savings from the Renewable Energy Technologies

	Technical Potential			Market Potential			Projected Contribution						Cost of Carbon Savings					
	TWh/y			TWh/y			TWh/y			MTC/y			Compared with Gas - £/teC			Compared with Oil - £/teC		
	2010	2015	2020	2010	2015	2020	2010	2015	2020	2010	2015	2020	2010	2015	2020	2010	2015	2020
Biomass – Residential	76.4	77.5	78.5	19.1	19.4	19.6	0.3	1.0	2.4	0.02	0.06	0.14	1085	897	707	683	543	403
Biomass – Commercial	24.9	24.9	24.9	3.0	3.0	3.0	0.7	1.5	2.2	0.04	0.09	0.13	364	337	311	55	25	-5
Biomass – Industrial Heat	50.6	50.6	50.6	7.6	7.6	7.6	1.9	3.8	5.7	0.11	0.23	0.34	37	4	-30	-29	-57	-85
Biomass – Industrial CHP	24.9	24.9	24.9	3.7	3.7	3.7	0.9	1.9	2.8	0.08	0.17	0.25	35	15	-7	-17	-35	-175
Biomass – District Heating	4.5	5.0	5.6	0.3	0.3	0.4	0.3	0.3	0.4	0.02	0.02	0.02	93	56	18	11	-20	-51
Total Biomass	**181.3**	**182.9**	**184.5**	**33.7**	**34.0**	**34.3**	**4.1**	**8.5**	**13.5**	**0.27**	**0.57**	**0.89**						
Energy from waste	**22.8**	**22.8**	**22.8**	**5.7**	**5.7**	**5.7**	**0.0**	**2.9**	**5.7**	**0.00**	**0.15**	**0.29**	**101**	**70**	**39**	**17**	**-9**	**-36**
Solar – Residential	32.4	32.8	33.2	16.2	16.4	16.6	0.2	1.6	5.5	0.01	0.10	0.33	4204	3842	3479	3107	2827	2547
Solar – Commercial	1.5	1.7	1.9	0.3	0.4	0.5	0.1	0.2	0.3	0.00	0.01	0.02	3319	3079	2838	2326	2132	1938
Total solar	**33.9**	**34.5**	**35.1**	**16.5**	**16.8**	**17.1**	**0.3**	**1.8**	**5.8**	**0.02**	**0.11**	**0.35**						
Heat Pumps – Residential	76.4	77.5	78.5	19.1	19.4	19.6	0.5	2.8	7.3	0.03	0.14	0.36	1340	1165	989	818	690	563
Heat Pumps – Commercial	1.5	1.7	1.9	0.3	0.4	0.5	0.1	0.2	0.3	0.00	0.01	0.02	1555	1443	1330	839	746	653
Total Heat Pumps	**78.0**	**79.1**	**80.3**	**19.4**	**19.7**	**20.1**	**0.6**	**3.0**	**7.6**	**0.03**	**0.15**	**0.38**						
Anaerobic Digestion	**91.0**	**91.0**	**91.0**	**2.2**	**2.8**	**3.4**	**0.9**	**1.5**	**2.2**	**0.05**	**0.09**	**0.13**	101	70	39	17	-9	-36
Landfill Gas	**11.4**	**11.4**	**11.4**	**11.4**	**11.4**	**11.4**	**0.0**	**0.0**	**0.0**	**0.00**	**0.00**	**0.00**						
TOTAL				**88.9**	**90.4**	**91.9**	**6.0**	**17.6**	**34.9**	**0.38**	**1.06**	**2.05**						

- Note: Technical potentials cannot be added as this would lead to some double counting.

3.9.1 Heat costs

Residential sector

Figure 9 shows the cost of supplying heat to the residential sector from renewable energy compared with heat from conventional sources. This analysis takes account of improvements in costs as the technologies and commercial infrastructure mature and evolve. Clearly these renewable sources are significantly more costly and will remain so despite cost improvements over the coming years.

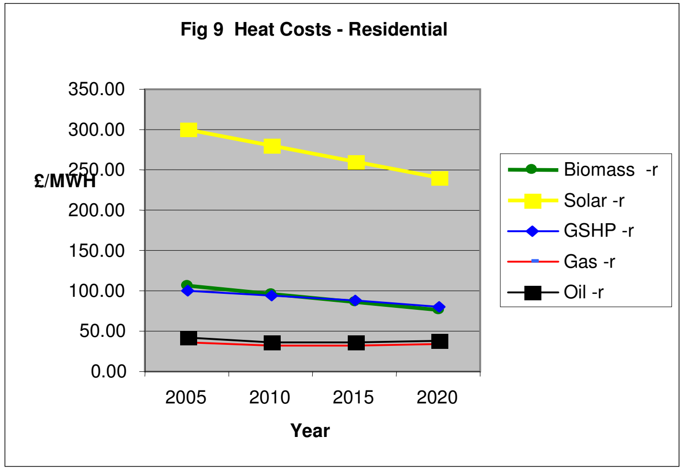
Commercial and industrial sectors.

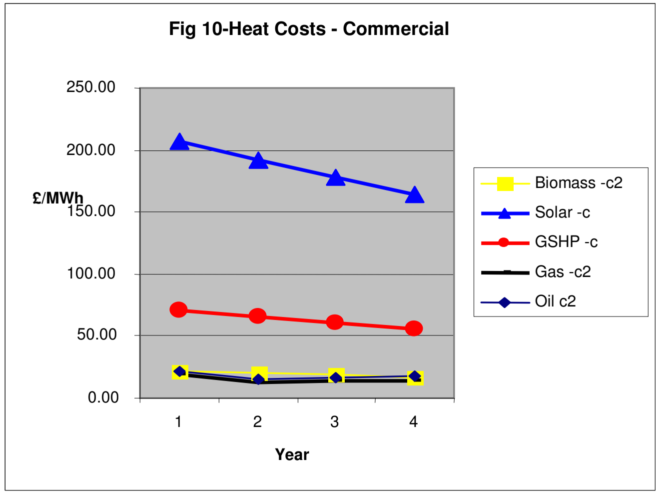
Figures 10 and 11 show the analogous data for the commercial and industrial sectors. In this case, whilst the cost of supplying heat from solar and GSHPs remains above the cost of heat from conventional sources, heat from biomass is competitive in the industrial sector based on the assumptions we have used, and projections of increasing relative competitiveness over the coming years. Biomass CHP also becomes cost effective.

3.9.2 Cost of carbon

Table 31 shows the costs of carbon savings associated with the renewable technologies that we have considered for the residential sector, and how they change in future. These costs are high, ranging from £400 to over £4,000 £/teC.

The Table also shows the same data for the industrial and commercial sectors. Here, the cost of carbon savings associated with solar and GSHP are still high but those associated with biomass, MSW and AD are low and become negative in favourable circumstances in the future. This means that there is already some cost effective potential for cost savings from biomass, EfW and AD compared with gas and oil, but that the uptake is being constrained by other barriers.





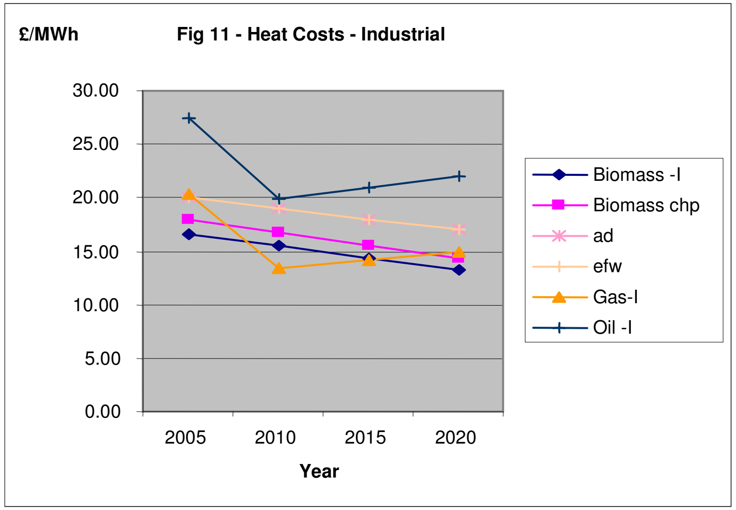


Fig 11 - Heat Costs - Industrial

3.9.3 Sensitivity to Fuel Prices

The fuel prices used in the base case analysis are those being used by DTI and DEFRA for the Climate Change Programme Review, and show some reductions between 2005 and 2020 as shown in Table 2.

Higher fossil energy prices reduce the cost of carbon associated with the renewable technologies. To test the sensitivity of the conclusions reached in the base case, we have also considered a scenario in which fuel prices remain steady at 2005 levels. As Figures 12-14 show, the gap between the cost of heat from fossil fuels and the renewable technologies narrow compared with the base case in future years as technology improvements bring costs down. However qualitatively the conclusions are the same. There remains a large gap between the costs of the technologies available in the residential sector and the fossil fuel options, while in the commercial biomass based technologies become increasing competitive as costs reduce.

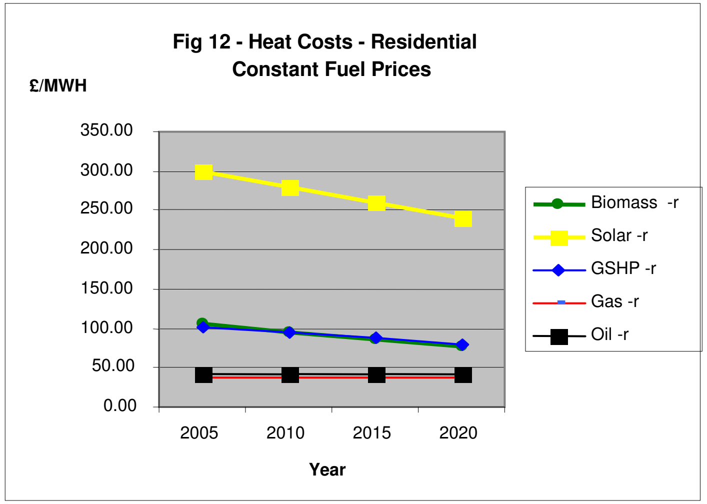


Fig 12 - Heat Costs - Residential
Constant Fuel Prices

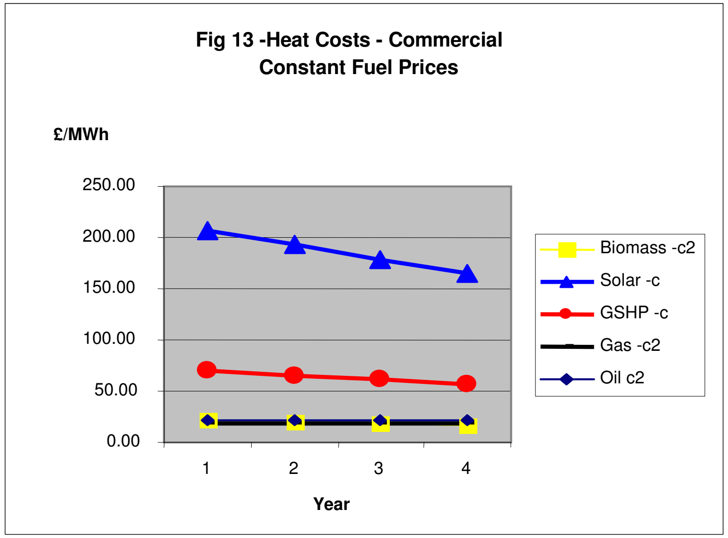
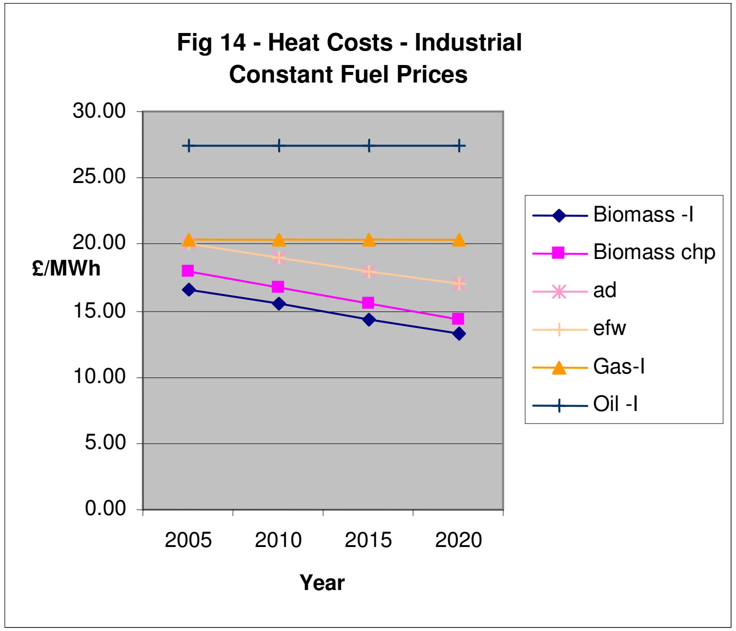


Fig 13 -Heat Costs - Commercial
Constant Fuel Prices



3.9.4 Barriers and support mechanisms

We have identified the factors that may discourage or constrain the rate of uptake of the renewable technologies that we have considered. We have taken account of these constraints in considering what constitutes a realistic estimate of the projected contribution for each sector. These include:

For biomass;

- lack of space to house physically larger biomass heating and fuel storage systems and to allow access for fuel delivery,
- biomass conversion systems are more capital intensive than equivalently rated fossil fuel systems and enterprises may be reluctant to use scarce capital on service supply,
- ability of the biomass supply side industry to scale up rapidly to meet an emerging market need.

For solar and GSHP;

- low current manufacturing volumes potentially restricting technology supply if the market expands rapidly,
- limitations on the number of qualified installers to fit and maintain systems.

For many of the technology options, particularly those relevant to the residential sector, the cost differential between heat from renewable sources and from fossil fuels is very wide and this will be an overriding disincentive in many cases. Without high levels of support to redress this balance these options are unlikely to be taken up.

In the commercial and industrial sectors there are barriers that will hold back development of resources even where the costs are favourable such as with heat from biomass, EfW and AD. These include:

- poor current technology take-up in the UK leading to a lack of awareness of the opportunity and confidence in the technology and commercial infrastructure. In the biomass area in particular there is no well established supply chain that can assure access to sufficient fuel within a reasonable transport distance that has been processed economically to the right specification for the boiler application concerned.
- lack of available capital within the user organisations who will prefer to use their capital for mainstream production investment and a requirement for a very short payback period on investments of this type (typically 2 – 3 years);
- sensitivity of return on investment to fossil fuel prices – while prices currently make these projects attractive the volatility in energy prices makes future savings uncertain;
- competition for resource with non energy uses and also with electricity only applications, including biomass fuel being used for co-firing, which benefits from support under the Renewables Obligation.

Some of these barriers are being addressed by existing initiatives – for example Defra's Energy Crops Scheme (ECS) is bringing forward planting of energy crops which could augment the supply and the Processing and Marketing Grant Scheme[13], the Producer Group Scheme[14] and the Bioenergy Infrastructure Scheme[15] bringing forth investment in fuel processing and delivery infrastructure. The DTI Bioenergy Capital Grant Scheme is bringing forward a number of exemplar projects at varying scales and in the commercial and institutional sectors. Climate Change Levy savings improve the economic viability in some sectors.

However these technologies are still seen as being risky by industry. In order to stimulate the market for heat from renewable energy some additional financial incentive is required to insulate projects, to some extent, from the fuel price volatility and create a level playing field for heat as opposed to electricity producing projects. At the same time this would be an effective way of stimulating significant and low-cost carbon saving opportunities. Allowing these technologies to take full advantage of the Enhanced Capital Allowances by encouraging manufacturers to register them would provide some help. However, in order to create confidence in a longer term market, financial support for the generation of renewable and CHP heat, at a relatively low level (£5 – £20/MWh), would be effective in bringing forward significant carbon savings at a relatively low cost. An added benefit would be the encouragement of investment in the supply side industry, which is needed to bring costs down.

In the residential sector, the gap between the cost of heat from renewables and from fossil fuels is wider. Similar infrastructure barriers apply but these could be overcome if the costs were more attractive, as shown by the rapidly developing markets for such systems, in several other European countries, where incentive packages are in place. Some incentives are provided to this sector via, for example, the Clear Skies Programme. The introduction of higher energy performance standards via the Building Regulations also provides some incentive to include these technologies but this will only affect new build properties which are a small proportion of the overall market. Similarly the development of local planning conditions encouraging the deployment of renewable options could stimulate investment in these systems. For example in the London Borough of Merton new commercial developments above a threshold size are required to include provision of 10% of the energy from renewable systems, and such measures are being considered in other areas, covering both commercial and residential developments. The Energy Efficiency Commitment Scheme is leading to some investment in residential scale applications of solar heating, ground source heat pumps and biomass heating.

---

[13] http://www.defra.gov.uk/erdp/schemes/pmg/default.htm
[14] http://www.defra.gov.uk/erdp/schemes/energy/producer.htm
[15] http://www.defra.gov.uk/farm/acu/energy/infrastructure.htm

Other measures could be introduced which would improve the economic case for investment in these systems – for example by harmonising the level of VAT on such systems at the reduced rate. However this sector is unlikely to make a significant contribution to carbon savings unless the underlying costs of providing heat are reduced through some longer-term support mechanism which can provide very significant levels of support, and the cost of this support in terms of £/TeC would be high.

4 FOSSIL FUELLED CHP

4.1 BACKGROUND

Combined Heat and Power (CHP) involves the generation of thermal and electrical energy in a single process. CHP installations can convert up to 90% of the energy in the fuel into electrical power and useful heat. As a result of the high efficiency of fuel use in CHP plant, savings in carbon emissions are achieved compared with separate generation of the heat and electricity by power only generation. CHP is normally natural gas-fired, though the full range of fossil and non-fossil fuels can be used.

4.1.1 Description

A wide range of different technologies is used to generate combined heat and power. There are four main types of CHP systems:

- steam turbine systems, where steam at high pressure is generated in a boiler and passed through a steam turbine;
- gas turbine systems, often aero-engine derivatives, where fuel (gas or gas-oil) is combusted in the gas turbine and the exhaust gases are normally used in a waste heat boiler to produce usable steam, though the exhaust gases may be used directly in some process applications.
- combined cycle systems, where the plant comprises more than one prime mover. These are usually gas turbines where the exhaust gases are used in a steam generator, the steam from which is passed wholly or in part into one or more steam turbines.
- reciprocating engine systems range from less than 100 kWe up to around 50 MW$_e$, and are found in applications where production of hot water, rather than steam, is the main requirement (e.g. on smaller industrial sites as well as in buildings). They are based on auto engine or marine engine derivatives converted to run on gas.

In addition a range of small-scale options for generating electricity at a domestic scale are under development, relying on micro-turbines or stirling engine technology. While these technologies are at an early stage of commercialisation, it is possible that they will play an important role over the period covered by this study (i.e. by 2020). Given the uncertainties around the rate of technology and market development we have not included this technology in this analysis but acknowledge that the situation might change rapidly necessitating separate analysis of the potential.

The choice of technology depends on the scale of the application and the match with power and heat loads at the specific site. The characteristics of the technologies are summarised in Table 32.

Table 32 – Comparison of CHP technologies (all figures are based on GCV)

Technology	Typical Scale of Operation (MW)	Electrical efficiency %	Typical Capital Cost £k/MW(e)
Steam turbines	**5 - >100**	**10 –28**	
Gas turbines	**0.03 - >100**	**23 –30**	**555-620**
Combined cycle systems	**>70**	**35 – 50**	**555**
Reciprocating engines	**<0.1 - 50**	**28 –38**	**500 -800**

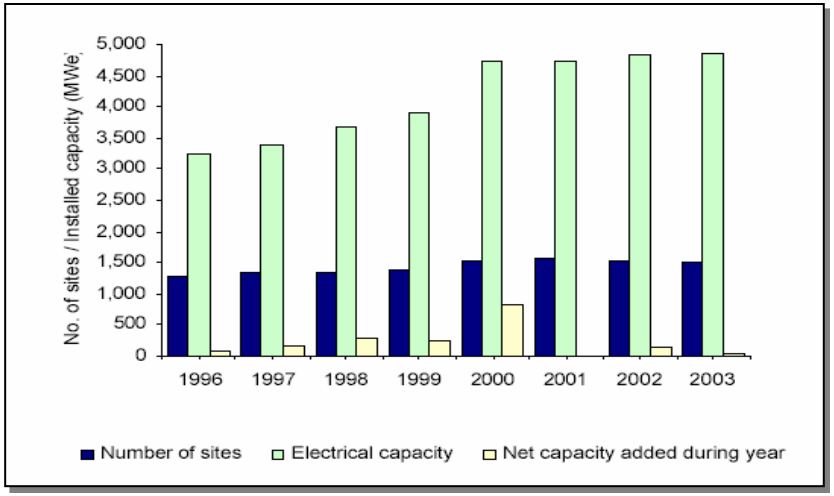


Figure 15 Installed CHP Capacity by Year

CHP is usually sized to supply the base load heat demand, with other plant (e.g. heat-only boilers) supplying the difference. However, a detailed feasibility study is required to optimise the size and configuration of the CHP unit and associated equipment.

4.1.2 Status

Recent trends in CHP development are summarised in Figure 15. During the 1990's advantageous energy prices (low gas and higher electricity prices) assisted growth of CHP from around 2,000 MW_e to just below 5,000 MW_e in 2000. The current target is 10,000 MW_e by 2010. However, since 2000, market conditions have changed dramatically as the result of rapid and significant changes in both electricity and gas prices. As a result, CHP development has largely stagnated.

Most of the heat produced by CHP schemes is used in the industrial processes. CHP schemes in buildings account for less than 10% of the total CHP capacity. However, this represents over 70% of the total number of CHP schemes. At an average size of 300 kWe (heat power ratio of 1.9:1), buildings represent the major application of CHP systems of less than 1 MW_e but the contribution from renewable power CHP is small.

4.1.3 Current contribution

There are currently about 1,500 CHP schemes in the UK, with an aggregate capacity of 4.88 GW_e (based on 2003 data), and a thermal capacity of 11.2 GW_{th}, producing between them some 59.3 TWh/y of heat.

4.2 POTENTIAL

An analysis of the economic potential for CHP, based on a number of recent studies indicates that the technical potential is 32.2 GW_e, and 57.1 GW_{th} including existing schemes. An analysis of the technical potential for CHP indicates that there is an additional 183 TWh/y available. We have assumed this as the technical potential of CHP.

For CHP we have used a market-led approach to defining the potential contribution to the heat market.

Residential Market

In the residential market the main potential for CHP evaluated in this report is associated with the use of heat from CHP via community heating schemes. We have based our analysis on the BRE study, which has looked at the market for Community Heating in buildings. The sensitivity to the level of potential support was based on the average economics of Community Heating CHP schemes as a function of running hours. This gave levels needed to break even for different types of Community Heating schemes.

The base case assumed that up to 100 MW_e would be installed with the continuation of the Community Energy* (CE) Programme. Once the CE programme has finished, development would slow significantly.

We have also constrained the rate of market development to a rate of 80 MW_e per year and given the extensive planning period for planning and financing such projects we have assumed that the first projects stimulated by any support scheme commence operation in 2008.

Table 33 shows the rate at which capacity would grow in response to the impact of the support available. The additional capacity delivered by each potential support level compared to the no-support case is detailed in the lower half of Table 33.

Table 33 – Impact of support on the rate of increase of CHP capacity on the residential market.

	Delivered Heat TWh/y			Electrical Capacity GW_e		
	2010	2015	2020	2010	2015	2020
Total capacity						
No support	**0.6**	**0.6**	**0.6**	**0.10**	**0.10**	**0.10**
£10/MWh	**0.9**	**0.9**	**0.9**	**0.15**	**0.15**	**0.15**
£20/MWh	**1.7**	**7.7**	**7.7**	**0.30**	**1.20**	**1.20**
£40/MWh	**1.7**	**8.3**	**14.1**	**0.30**	**1.30**	**2.20**
Incremental capacity						
£10/MWh	**0.3**	**0.3**	**0.3**	**0.05**	**0.05**	**0.05**
£20/MWh	**1.1**	**7.1**	**7.1**	**0.20**	**1.10**	**1.10**
£40/MWh	**1.1**	**7.7**	**13.5**	**0.20**	**1.20**	**2.10**

Commercial Market

We have based our analysis here on the potential size of the CHP heat market in the commercial sector from a study carried out by Cambridge Econometrics and on the economics of a typical scheme. There may be some overlap with the Community Heating potential discussed in the previous section, as they will often include commercial premises. It is not possible to determine the extent of the overlap. This analysis also assumed that the systems were based on fossil fuels rather than biomass.

We have assumed that the full economic potential identified will be reached in 2020. Given the extensive period for planning and financing such projects, the first projects stimulated by any support scheme are likely to commence operation only in 2008 and we have assumed that for 2 years the growth will be constrained to 20 MW_e per year. After the first two years, development is likely to speed up as projects move from the development stages to implementation and commissioning, and we have assumed that by 2015 sufficient capacity to bridge half the gap between 2010 and 2020 will be built.

Table 34 shows the rate at which capacity would grow in response to the impact of the support available. The additional capacity delivered by each level of potential support compared to the no-support case is detailed in the lower half of the table.

Industrial Market

We have based our analysis here on two sources of information, an analysis of the site heat demands for larger industrial sites[16] and an analysis of the potential for CHP in the UK carried out by Cambridge Econometrics. The analysis is based on the economics of individual CHP schemes under different scenarios of renewable heat support. This is scaled to national economic potential using information on the individual heat demands of the larger sites and estimated heat output from the Cambridge Econometrics modelling for the rest. The base case assumed a continuation of existing policies and current fuel prices.

Table 34 – Impact of support on the rate of increase of CHP capacity on the commercial market.

	Delivered Heat TWh/y			Heat capacity GW			Electrical capacity, GW		
	2010	2015	2020	2010	2015	2020	2010	2015	2020
Total capacity									
No support	0.15	3.03	6.00	0.03	0.53	1.05	0.02	0.41	0.70
£5 /MWh	0.30	3.25	7.50	0.05	0.57	1.32	0.04	0.44	0.88
£10 /MWh	0.30	6.50	15.00	0.05	1.14	2.63	0.04	0.88	1.76
Incremental capacity									
£5 /MWh	0.15	0.22	1.50	0.03	0.04	0.26	0.02	0.03	0.18
£10 /MWh	0.15	3.47	9.00	0.03	0.61	1.58	0.02	0.47	1.05

In determining the capacity at different years, we have made a number of assumptions:

- to 2010
    - in the no-support case, CHP development continues at a rate of 250 MW_e per year from 2005. This is based on anticipated developments in CHP in 2005/6 and is consistent with the Cambridge Econometrics model results (excluding specific policies such as the Quality Improvement Programme);
    - given the long lead time required for CHP planning and development stages, we have assumed that the first projects

---

[16] Study for Defra to prepare heat maps for the UK – to be published

stimulated by any support scheme commence operation in 2008;
  - with support of 0.5 p/kWh, the rate of build can double to 500 MWe per year from 2008;
  - with higher subsidies it reaches the maximum rate achieved previously of 600 MWe per year (which means an extra 350 MWe/year as a result of this support).

- after 2010;
  - development is likely to speed up and we have assumed that by 2015, sufficient capacity to bridge half the gap between 2010 and 2020 will be built.

Table 35 – Impact of support on the rate of increase of CHP capacity on the industrial market.

	Heat output TWh			Heat Capacity GW_{th}			Electrical capacity GW_e		
	2010	2015	2020	2010	2015	2020	2010	2015	2020
Total capacity									
No support (base case)	**10.68**	**25.84**	**41.00**	**1.63**	**3.93**	**6.24**	**1.25**	**3.03**	**4.80**
£1 /MWh	**14.95**	**29.97**	**45.00**	**2.28**	**4.56**	**6.85**	**1.75**	**3.51**	**5.27**
£5 /MWh	**16.65**	**32.83**	**49.00**	**2.54**	**5.00**	**7.46**	**1.95**	**3.84**	**5.74**
£10 /MWh	**16.65**	**56.83**	**97.00**	**2.54**	**8.65**	**14.76**	**1.95**	**6.65**	**11.36**
Incremental capacity									
£1 /MWh	**4.27**	**4.14**	**4.00**	**0.65**	**0.63**	**0.61**	**0.50**	**0.48**	**0.47**
£5 /MWh	**5.98**	**6.99**	**8.00**	**0.91**	**1.06**	**1.22**	**0.70**	**0.82**	**0.94**
£10 /MWh	**5.98**	**30.99**	**56.00**	**0.91**	**4.72**	**8.52**	**0.70**	**3.63**	**6.56**

Table 35 shows the rate at which capacity would be installed in response to the impact of the support available and does not include capacity installed to date (4.9 GW_e in 2003). The additional capacity delivered by each support level compared to the no-support case is detailed in the lower half of the table.

4.2.1 Summary

The analysis shows that there is significant scope to stimulate additional contributions from CHP, particularly in the industrial sector, and that this potential could be stimulated if support were made available at levels below £10/MWh. This raises the issue of additionality. Support would normally be given to all new generation, but if some CHP schemes would go ahead anyway then this money would not deliver additional carbon savings. This issue is addressed in the cost analysis.

The no-support case is based on information that suggests there is still some increase in capacity expected over the next two years and extrapolating this increase to 2010. However, it is clear that in general the CHP market has stagnated, and if these conditions do not improve it may be that even the limited build now will slow, perhaps to nothing.

The conclusion from actual market behaviour is that for significant investment to occur, the return on investment needs to be much better than it is now. Support for renewable and CHP heat would go some way to improve the rate of return from projects and improve investor confidence.

4.2.2 Scope for cost reduction

Most for the CHP technologies under consideration here are mature. Some cost reduction can be anticipated as the market grows and allows a more competitive and efficient industry to develop. More significant cost reduction is likely in the emerging micro CHP and biomass gasification areas.

4.2.3 Capital and operating costs

The capital costs associated with typical CHP systems are shown in Table 32.

4.2.4 Carbon savings

Using the methodology and assumptions outlined in Energy Trends, existing fossil fuel CHP in 2003 saved between 0.65 and 0.89 MteC per 1,000 MW_e compared to equivalent electricity-only and heat-only generation. We have used a figure of 46kgC/MWh heat produced as the savings associated with CHP compared with separate generation of heat and power from gas,

4.2.5 Barriers to uptake

The barriers to CHP deployment are in many ways similar to those for renewable energy. The principal obstacle to CHP development in current conditions is cost-effectiveness, with projected returns on investment below the levels needed to stimulate development. With recent rises in energy prices, prospects have improved for CHP but investors see significant risks arising from the volatility in energy prices and these rises will be discounted.

Many companies that previously developed CHP schemes have closed down or moved into other markets. Even if the issue of cost-effectiveness were addressed, this lack of active market players will slow a revival in CHP development. Additionally, CHP schemes are generally tied to a specific industrial site and there is a reluctance in industry and commerce to commit the significant capital required for non-core activities. For third party developers, this tie-in with industrial sites adds additional risk as the projects rely on a guaranteed market for the heat.

5 POTENTIAL UPTAKE AND CARBON SAVINGS

This section of the report examines the impact of financial support on bringing forward additional contributions to UK heat supplies from renewable energy and CHP. It also estimates how much carbon saving this support might stimulate and the cost to government of introducing such measures.

5.1 RENEWABLE ENERGY

The analysis in **Section 3** has provided information on the projected contribution from renewable sources of heat for each of the technologies in each of the sectors that we have considered. These potentials do not take account of the relative costs of heat from the source being considered and from the fossil fuel equivalent.

We then estimated the relative cost of heat from the RE sources and from fossil fuels to allow us to estimate how much of this potential might be taken up. From this we have constructed supply curves that show how much of the resource might be available as the market value of heat increases.

For the next part of the analysis we constructed demand curves for each technology using the methodology described in the Annex. This methodology considers the range of payback periods likely to be acceptable in the market sector concerned and estimates what fraction of the maximum potential would be taken up. The market potential of the technology is then being determined by the intersection of this demand curve and the supply curve for the technology. The maximum and minimum payback periods for each sector have been chosen according to the investment criteria that apply, as shown in Table 36.

Table 36 - Investment criteria

Sector	Payback - Maximum	Payback - Minimum
Residential	**10**	**1**
Commercial	**3**	**1**
Industrial	**3**	**1**

We have taken into account the impact of additional financial support by shifting the cost resource curve parallel to the price axis and looking how much additional potential is made available.

Using these data and the information on how much carbon is saved for every kWh substituted we have estimated.

- the contribution to heat supplies brought forward by an increasing level of support for renewable and CHP heat;
- the carbon saving associated with that contribution (MteC/y) as the level of support increases;
- the cost to Government of providing that support.

To put this analysis into perspective, the Renewables Obligation is presently costing consumers approximately £470 M per year. This is expected to rise to £1 billion per year by 2010 (National Audit Office), when 10% of UK's electricity will be supplied by renewable energy sources. The level of annual carbon savings that arise as a result of the Renewables Obligation are expected to be between 5.5 and 7.4 million tones per year of carbon. Thus, in terms of carbon saved, the Renewables Obligation is costing approximately £153 per year for each tonne of carbon saved annually. Presently, the ROC value, which is the closest parallel to the financial support we have modelled in this report, is in the region of £45/MWh for electricity with the buy-out figure set at £30/MWh.

Given the relative differences in efficiency for heat and electricity production (85% and 25% respectively for biomass systems for example), the £30/MWh buy out figure for renewable electricity is equivalent to around £8.9/MWh for heat; the £45/MWh traded ROC price is equivalent to £13/MWh for heat production.

In considering the results of the analysis we have used a figure of £10/MWh as a benchmark and considered:

- What level of support is needed to promote the contribution of a significant proportion of the Projected Contribution, what level of carbon savings are involved and at what cost?
- What carbon savings are prompted by support at a level of support equivalent to £10/MWh?
- How much carbon saving is prompted at a carbon cost of £150/teC?

For renewables we have considered the residential and commercial sectors separately, as the cost of carbon differs widely between those sectors.

5.1.1 Residential sector

Table 37 shows the results of the analysis for the residential sector.

As an illustration, Figure 16 shows the impact of increasing the heat support available in the residential sector in 2020. As it is increased above £10/MWh consumers begin to take up biomass as a fuel. At a level of around £15/MWh GSHP begin to be deployed at a low level, but solar heating only starts to appear once the level reaches £90/MWh. Figure 17 indicates the carbon savings stimulated, which reach 540,000teC/year at a support level of £10/MWh.

As expected for this sector, subsidies have to reach high levels before significant carbon savings are stimulated, and the relative cost to Government is high. For example;

- support of £50/MWh is needed to stimulate 50% of the potential savings of around 400,000 teC by 2020, but at a cost of £775/teC,
- at a support level of £10/MWh or equivalent to £150/teC (a similar level as the Renewables Obligation) very little contribution is stimulated even by 2020.

Table 37 - Summary of results from the Residential Sector

Support	Stimulated Contribution TWh/y			Stimulated Carbon Savings Mte(C)/y			Cost to Govt £M/y		
£/MWh	2010	2015	2020	2010	2015	2020	2010	2015	2020
5	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
10	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
15	0.00	0.00	0.08	0.00	0.00	0.00	0	0	1
20	0.00	0.04	1.13	0.00	0.00	0.08	0	1	23
25	0.01	0.07	1.76	0.00	0.00	0.12	0	2	44
30	0.02	0.41	3.26	0.00	0.03	0.22	1	12	98
35	0.09	1.03	4.32	0.01	0.07	0.28	3	36	151
40	0.21	1.46	5.11	0.01	0.10	0.33	8	59	204
45	0.30	1.79	5.71	0.02	0.12	0.37	13	81	257
50	0.36	2.05	6.19	0.02	0.13	0.40	18	102	310
55	0.42	2.25	6.59	0.03	0.15	0.42	23	124	362
60	0.46	2.42	6.91	0.03	0.16	0.44	28	145	415
65	0.50	2.56	7.19	0.03	0.17	0.46	32	167	467
70	0.53	2.68	7.43	0.03	0.17	0.48	37	188	520
75	0.55	2.79	7.67	0.04	0.18	0.49	41	209	575
80	0.58	2.88	7.89	0.04	0.18	0.50	46	230	631
85	0.60	2.97	8.08	0.04	0.19	0.52	51	252	687
90	0.61	3.05	8.25	0.04	0.20	0.53	55	274	742
95	0.63	3.12	8.40	0.04	0.20	0.54	60	296	798
105	0.65	3.18	8.54	0.04	0.20	0.54	65	318	854

Figure 16 - Contribution from Renewables 2020
Residential Sector

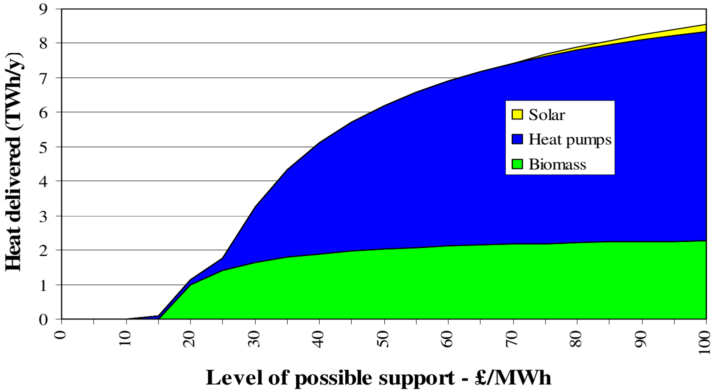
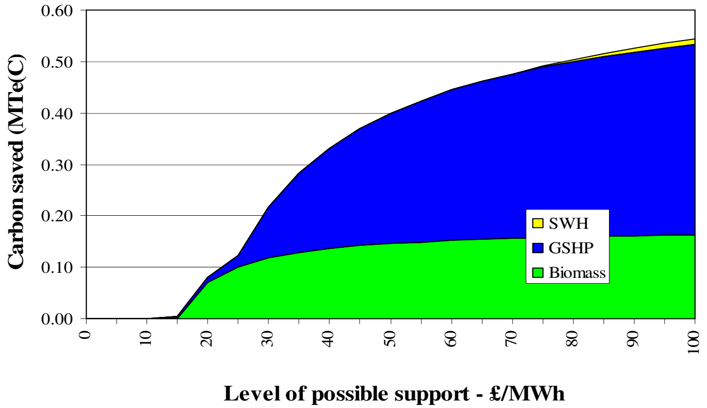


Figure 17 - Renewables Carbon Savings - 2020
Residential Sector



5.1.2 Commercial and industrial sectors

The analogous Table and Figures for the commercial and industrial sectors to those for the residential sector are shown below. In contrast to the residential sector, significant contribution can be stimulated at a low cost:

- The potential from biomass heat and CHP, and from AD and EfW is catalysed by support level of around £15/MWh. At these levels savings could amount to 0.15 MteC/y by 2010, 0.45 MteC/y by 2015 and 0.9 MteC/y by 2020.
- £10/MWh stimulates a contribution equivalent to 2.3 TWh/y by 2010, rising to 13.2 TWh/y by 2020, and stimulating carbon savings of 0.13 Mt/C in 2010, rising to 0.81MteC by 2020 and at an annual cost of £23 million in 2010, rising to £132 million by 2020.

Table 38 Summary of results from the Commercial/industrial Sector

Support £/MWh	Stimulated Contribution TWh/y			Stimulated C Savings Mte(C)/y			Cost to Govt £M/y		
	2010	**2015**	**2020**	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**
5	1.64	6.18	11.47	0.09	0.36	0.67	8	31	57
10	2.28	6.91	13.24	0.13	0.40	0.81	23	69	132
15	2.62	7.46	13.99	0.15	0.45	0.88	39	112	210
20	2.95	8.00	14.35	0.18	0.49	0.91	59	160	287
25	3.17	8.35	14.57	0.20	0.52	0.92	79	209	364
30	3.32	8.57	14.68	0.21	0.54	0.93	100	257	440
35	3.42	8.74	15.08	0.22	0.55	0.95	120	306	528
40	3.50	9.04	15.35	0.22	0.58	0.96	140	362	614
45	3.62	9.39	15.55	0.23	0.60	0.98	163	423	700
50	3.84	9.62	15.72	0.25	0.61	0.99	192	481	786
55	3.97	9.79	15.85	0.26	0.62	0.99	218	538	872
60	4.06	9.93	15.97	0.26	0.63	1.00	244	596	958
65	4.14	10.04	16.06	0.26	0.64	1.01	269	652	1,044

Figure 18 - Renewables Contribution - 2020
Industry and Commercial Sectors

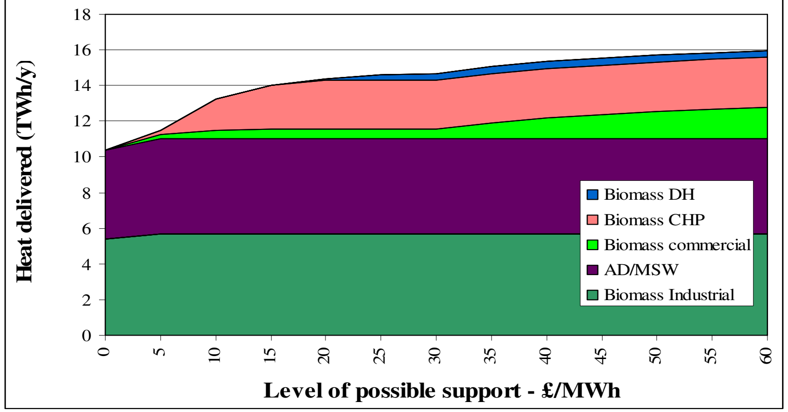
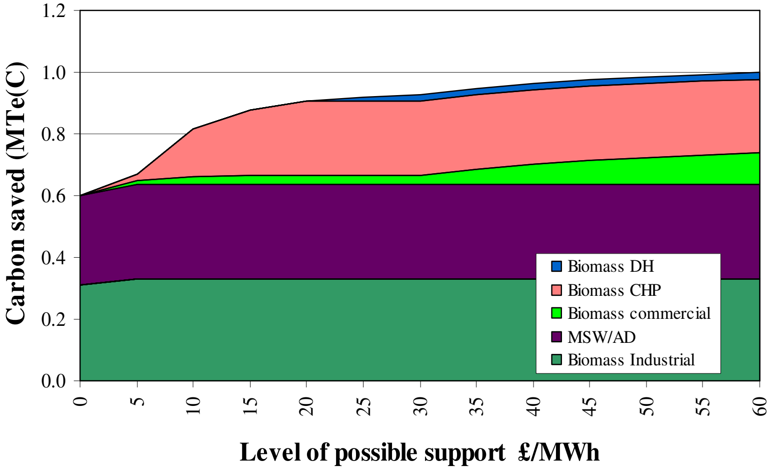


Figure 19 - Renewable Carbon Savings - 2020
Industrial and Commercial sectors



5.1.3 Conclusions for renewables

The analysis suggests that it would be worthwhile introducing a support scheme for renewable energy for heat production in the industrial and commercial sectors. A level of support of around £10/MWh would stimulate savings of around 0.13 MteC by 2010, and of 0.81 MteC by 2020. The cost of introducing such a measure would be around £23 million by 2010, rising to £132 million by 2020. This level of support would also be equivalent to the level of support available to electricity producing renewables, so levelling the playing field and avoiding market distortion.

The contribution stimulated would come principally from biomass heat and CHP, MSW and AD, which also support other Government policies by promoting rural development and other contributions to environmental improvement and sustainable development.

To achieve significant savings in the residential sector requires higher level of support – around £50/MWh. The level of contribution is lower and costs of carbon saved is significantly higher (approaching £800/teC). We conclude that support of this sort is not cost-effective in this sector. Support for development of renewables in this sector may be better provided by technology neutral measures, which support carbon reduction measures more generally. This would allow consumers to opt for renewables within a range of other carbon saving measures.

5.2 CHP

As previously, we have taken a different route to understanding the need for support in order to catalyse the CHP sector. We have based our work on 3 key studies by FES for DTI, BRE and Cambridge Econometrics, which have analysed the sensitivity of the CHP market to the value of the heat produced in the industrial, commercial and community heating sectors. We have used these studies to develop similar curves to those generated in the renewables sector of this report, showing how the contribution and carbon savings from CHP increase with increasing levels of support. We have then used this information to assess the costs of the carbon saved. In doing this we have used the same benchmark, the Renewable Obligation, to assess the relative size and cost of the carbon savings generated.

Table 30 and Figures 20 and 21 summarise the analysis. They indicate that a large contribution can be gained at low or zero cost, particularly from CHP in the industrial sector, with additional contributions from the commercial and district heating sectors.

- most of the potential is brought forward at a low support level of between £10 and £20 /MWh;
- support equivalent to £10/MWh would stimulate carbon savings of around 0.2 MteC /y by 2010, rising to 2.73 MteC/y by 2020 at cost of some £210/teC and with an annual cost of £38 million /year by 2010, rising to £570 million by 2020;
- a carbon cost of £150/teC (equivalent in this sector to support of around £7/MWh) would stimulate savings of around 0.17 Mt/C in 2010, rising to 2.72 MteC/y by 2020, at an annual cost of £38 million in 2010, rising to £570 million by 2020.

The analysis suggests the benefits of introducing a support scheme for heat from CHP would be comparable to those associated with introducing such a scheme for renewable heat in the industrial and commercial markets, if the level of support were around £10/MWh.

Table 39 - Summary of results from the CHP sector

Support	Stimulated Contribution TWh/y			Stimulated C Savings Mte(C)/y			Cost to Govt £m/y		
£/MWh	2010	2015	2020	2010	2015	2020	2010	2015	2020
5	3.30	5.91	8.29	0.15	0.27	0.40	17	30	41
10	3.78	29.28	56.98	0.17	1.38	2.72	38	293	570
15	3.78	29.28	56.98	0.17	1.38	2.72	57	439	855
20	5.04	35.84	63.54	0.23	1.68	3.06	101	717	1,271
25	5.04	35.84	63.54	0.23	1.68	3.06	126	896	1,588
30	5.04	35.84	63.54	0.23	1.68	3.06	151	1,075	1,906

Figure 20 - Fossil Fuel Heat Contribution - 2020

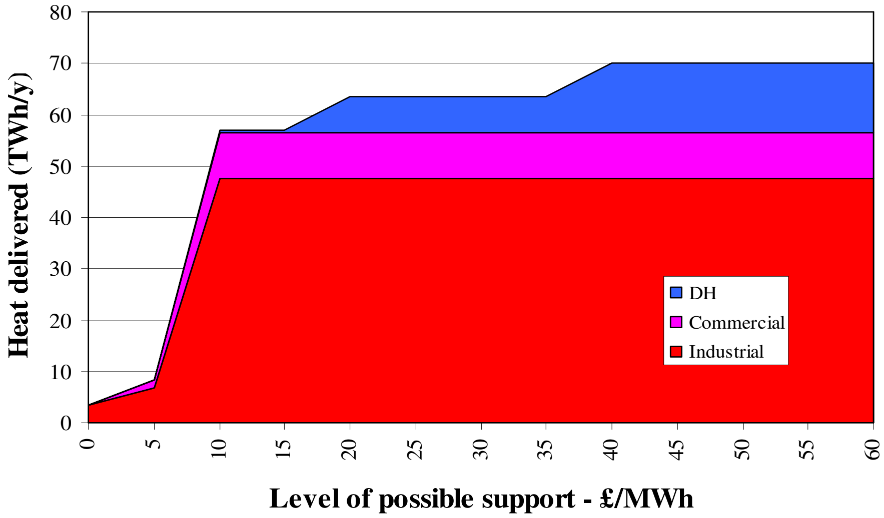
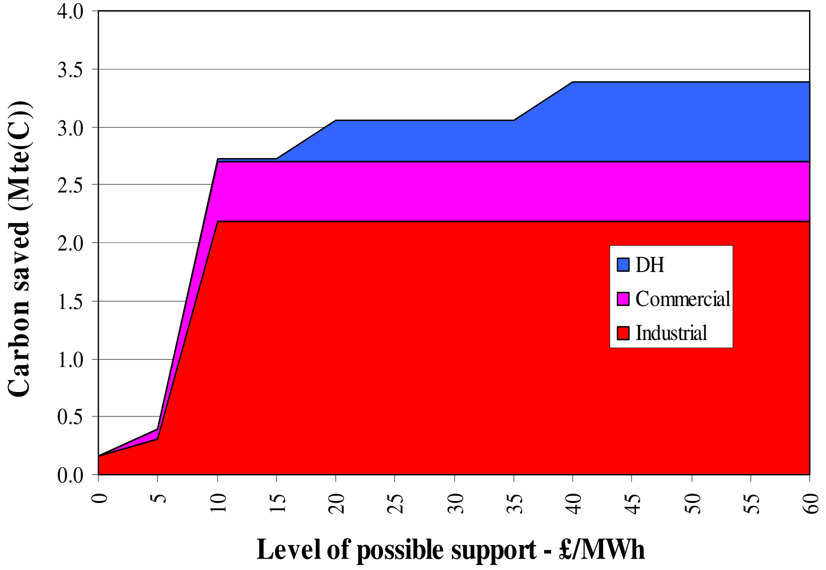


Figure 21 - Carbon savings From Fossil Fuel CHP - 2020



6 CONCLUSIONS

6.1 RENEWABLE ENERGY

The analysis indicates that, taking account the energy resources and potential markets available, there is the opportunity for supplying an additional 88.9 TWh/y of heat from renewable energy, rising to 91.9 TWh/y by 2020 (around 12% of UK heat demand). Further constraints on market share and the rates at which markets can be penetrated reduce this so that the projected contribution in 2010 is 6.0 TWh/y, rising to 34.9 TWh/y by 2020 (0.8 – 4.7% of UK demand). If all this potential were taken up by 2020 this would lead to carbon savings of 2.0 MteC/y (around 1.2% of current total UK carbon emissions (152 MteC/y)).

The cost of supplying heat to the residential sector from renewable energy is high compared with the costs of heat from conventional sources even given the projected technology cost savings for 2020, and the costs of saving carbon by adopting these technologies is correspondingly high. In the industrial and commercial market sectors the cost of heat from biomass, EFW and AD is far more competitive, and the cost of saving carbon is lower.

In the commercial and industrial sectors there are barriers that will hold back development of even those resources where the costs are favourable such as with heat from EfW and AD. In particular.

- there is a lack of confidence in the technology and commercial infrastructure;
- investments are seen as risky because of the sensitivity of return on investment to volatile fossil fuel prices.

Some of these barriers are being addressed by existing initiatives, but we have concluded that to stimulate the market for heat from renewable energy some continued financial incentive is required that to some extent insulates projects from fuel price volatility and creates a level playing field for heat as opposed to electricity producing projects. In order to create confidence in a longer-term market government support for renewable heat at a £5-£20 /MWh would be effective in bringing forward significant carbon savings at a relatively low cost.

In the residential sector, the gap between the cost of heat from renewables and from fossil fuels is wider, and this is the major barrier to deployment of these systems. Similar infrastructure barriers apply in this sector as in the commercial/industrial market. However, in order to really stimulate this market sector some longer term mechanism would be required that provided significant levels of support (of the order of £50/MWh).

We have estimated the effect of providing financial support to renewable heat on the contribution to heat and on the associated carbon savings, and estimated the costs of providing the support, using the Renewables Obligation as a benchmark.

Our analysis of the residential sector indicates that subsidies have to reach high levels before significant carbon savings are stimulated and that the relative cost to Government is high. In contrast the analysis indicates that in the Commercial and Industrial sector significant contribution can be stimulated at a lower cost.

The analysis suggests that it may be worthwhile introducing a support scheme for renewable energy for heat production in the industrial and commercial sectors. A level of support of around £10/MWh would stimulate savings of around 0.13 MteC by 2010 and of 0.81MteC by 2020. The cost of introducing such a measure would be around £23 million by 2010, rising to £132 million by 2020, and this would provide savings equivalent to around 0.7% of current carbon emissions. This level of support would also be equivalent to the level of support available to electricity producing renewables, so avoiding the current market distortion in favour of electricity generation.

The contribution stimulated by this support would come principally from biomass, MSW and AD, all technologies that support other Government policies by promoting rural development and other contributions to environmental improvement and sustainable development.

To achieve significant savings in the residential sector requires higher level of support around £50/MWh. The contribution that this higher level of support will bring about is lower than for the commercial/industrial sector and cost of carbon saved is significantly higher, approaching £800/teC. We conclude that support in the residential sector is not cost-effective. Instead, the development of renewables in this sector may be better promoted by technology neutral measures, which support carbon reduction measures more generally. This would allow consumers to opt for renewables within a range of other carbon saving measures.

6.2 CHP

In addition to renewables, this report also considers the potential contribution of heat from combined heat and power (CHP) systems to the heat market. An analysis of the technical potential for CHP indicates that there is an additional 183 TWh/y available, though much of this is likely to be uneconomic to exploit.

The technology for delivering CHP is well developed and understood but returns on investment are below the levels needed to stimulate market uptake of what is seen as a risky investment. While recent rises in energy prices have improved the prospects for CHP, fuel price volatility is seen as a significant risk by potential investors. In addition, CHP schemes are generally tied to a specific industrial site and there is reluctance in industry and commerce to commit significant capital to non-core activities. The conclusion from actual market behaviour is that for significant investment to occur, the return on investment needs to be more attractive than it is now. Government support for renewable and CHP heat would go some way to improving the rate of return from projects and provide investor confidence.

Our analysis indicates that a contribution to carbon savings can be gained at low cost, particularly from CHP in the industrial sector, with additional contributions from the commercial and community heating sectors. Support equivalent ton £10/MWh would stimulate savings of 0.2 MTC by 2010, rising to 2.73MTC/y by 2020 at an annual cost estimated at 38M in 2010 rising to £570M by 2020.

7 RECOMMENDATIONS

Given the potential for saving carbon at relatively low cost by stimulating the market for heat in the industrial and commercial sectors from renewable energy and from CHP, we recommend that DTI and Defra should consider mechanisms for delivering that support. Further analysis is needed to build on this study and assess the most appropriate form of financial support and non financial measures. Options for financial support would include mechanisms similar to the Renewables Obligation, and capital grants, amongst other measures.

We do not recommend broadening the scope of such a scheme to include renewable energy in the residential sector, as the costs of carbon saved are too high. Instead it would be better to include renewable energy in this sector within schemes aiming to support low carbon measures in the residential and small scale commercial sectors on a technology neutral basis so that consumers could opt to install RE as one of a range of options, if they choose to.

In addition to measures aimed directly at providing the right financial environment that will allow projects to proceed, there should be continued support for measures that address some of the other barriers to developing these projects, including the lack of awareness of and confidence in the technologies, the lack of commercial and physical infrastructure to develop and support projects, particularly in the biomass supply sector, and in some sectors, skills shortages that could be addressed by training.