
Introducing combined heat and power

A new generation of energy and carbon savings



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20–30%

reduction in energy bills
can be achieved with CHP





Introduction

For many organisations, combined heat and power (CHP) offers the most significant single opportunity to reduce their total fossil fuel consumption from on-site boilers and the power stations they import electricity from.

The average primary energy saving from CHP in the UK in 2007 was around 18%, but savings of around 28% are more typical for small packaged CHP schemes. This, in turn, reduces cost and CO₂ emissions.

Unlike primary energy savings, the average cost savings are more difficult to quantify, because energy prices vary widely from site to site and are constantly fluctuating over time. However, sites typically see annual savings of up to 20%.

A CHP unit only generates economic and environmental savings when it is running, so it will only be viable if you have a high and constant demand for heat – as a rule, at least 4,500 hours per year. However, it could still be suitable on some sites with a lower demand for heat, particularly if there is a high demand for cooling, so it could still be worth exploring.

In this CHP technology guide we introduce the main energy saving opportunities for businesses with appropriate simultaneous heat and power demands, and demonstrate how taking action can save energy, cut costs and increase profit margins. We also explain the different types of CHP system available, outline the financing options and set out the key steps to take if you are thinking about installing CHP.

4,500 hrs
of high and constant heat
demand is needed to make
CHP economical

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Technology overview

Combined heat and power (CHP) is the simultaneous generation of usable heat and power (usually electricity) in a single process. The electricity is generated on or close to your site, allowing you to capture and use the resulting waste heat for site applications.



What is combined heat and power?

CHP, also referred to as ‘cogeneration’ or ‘total energy’, is the simultaneous generation of usable heat and power within a single process. The power generated is usually electricity, but can also be mechanical power for driving equipment such as pumps, compressors and fans.

Definition of CHP

In a heat engine, heat from a hot fluid is used to do mechanical work. Once this work has been carried out, heat remains in the fluid which either dissipates into the surroundings or can be recovered and used. Combined heat and power is defined as the recovery and use of waste heat from power generation. This means there are three stages to CHP which must occur in sequence:

1. Power generation
2. Heat recovery
3. Heat use.

Heat from a CHP plant can also be used to generate cooling by using an absorption chiller unit. CHP that produces heat, electricity and cooling is termed ‘tri-generation’.

A site with a large and continuous cooling demand, and perhaps a declining demand for heat, may consider replacing a conventional electrical cooling system with absorption cooling. Converting an electrical load into a heat load in this way has a number of advantages:

- it reduces the site’s demand for electricity
- it increases the options for heat use
- it ‘irons out’ some of the seasonal peaks and troughs in the requirement for heat.

In some cases, using heat for cooling can turn a marginal CHP case into a viable option.

How CHP works

At the heart of a CHP installation is something called the ‘prime mover’ (heat engine). This is the equipment in a CHP system that provides the motive power to drive the electrical generator and produces the heat. It is generally a gas turbine, steam turbine or internal combustion engine.

The different types of prime mover available mean that CHP can use a variety of fuels and provide for various heat demands – either in the form of hot water or steam. As such, CHP is very flexible and can be tailored to the requirements of each site. It can be used across a wide range of sectors and can provide cost-effective energy solutions for large and small energy users alike.

We explain more about how CHP works, and the different technologies involved, on [pages 16-23](#)



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Where can it be used?

CHP can be considered at any site where there is sufficient heat (or cooling) demand – particularly if that demand is for extended periods. It's particularly suitable for the industrial, public and commercial sectors.

Where is CHP being used?

In the UK, three industrial sectors account for almost 76% of CHP electrical capacity – chemicals (33%), oil refineries (32%), and paper and publishing and printing (10%).

Typical applications of custom-built CHP

- Industrial sectors:
 - chemicals
 - oil-refining
 - paper
 - food and drink
- Large community heating schemes:
 - hospitals
 - universities

CHP applications can be categorised either as 'large-scale', 'small-scale' or 'micro'.

Large-scale CHP refers predominantly to large industrial applications where the plant is custom-built. Small-scale CHP usually applies at small industrial sites, buildings and community heating schemes where CHP is usually supplied as packaged. Micro-CHP is normally used in domestic and small commercial applications, such as care homes. Generally packaged CHP systems are employed for small-scale applications because they are designed in a modular fashion and are manufactured on a large scale – benefiting from economies of scale. Custom-built CHP systems are less common because they have a bespoke design intended for a specific application.

Custom-built CHP has electrical power outputs ranging from the equivalent of one megawatt (MWe) to over 100MWe. These are mainly installed in industrial sectors such as chemicals, oil-refining, paper, food and drink, and in large community heating schemes such as hospitals and universities.

Units used in this guide

A site's heat demand is typically communicated in terms of instantaneous demand, and is usually in terms of:

kWth = kilowatts (thermal)

MWth = megawatts (thermal)

1,000kWth = 1MWth

A site's annual heat consumption is typically communicated in terms of energy and is usually in terms of:

kWhth = kilowatt hours (thermal)

or MWhth = megawatt hours (thermal)

1,000kWhth = 1MWhth

A site's electrical demand is typically communicated in terms of instantaneous demand and is usually in terms of:

kWe = kilowatts (electrical)

or MWe = megawatts (electrical)

1,000kWe = 1MWe

A site's annual heat consumption is typically communicated in terms of energy, and is usually in terms of:

kWh = kilowatt hours (electrical)

or MWh = megawatt hours (electrical)

1,000kWh = 1MWh

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Micro-CHP Accelerator

Our Micro-CHP Accelerator involved a major field trial of 87 units in both domestic and small commercial applications, measured against over 30 condensing boiler installations. The trials showed savings of up to 20% where micro-CHP systems were installed as the main boiler.

Read more about the [Accelerator and its results](#).

Typical applications of packaged CHP

- hotels
- leisure centres
- hospitals
- small community heating schemes

Packaged CHP has electrical power outputs of less than 1MWe and is often supplied as a complete unit ready for installation.

In this guide we have only considered packaged schemes that generate between the equivalent of 25 kilowatts (kWe) and 1MWe of electricity. These are usually referred to as small-scale or 'mini'. Where installed, small-scale CHP has proved to be efficient and reliable. Results have shown that it is cost-effective to install and operate in a wide range of sites and applications.

It is generally used in the public and commerce sector, although smaller industrial sites can also install these units. Typical applications include hotels, leisure centres, hospitals and small community heating schemes.

Packaged schemes with electrical power outputs of less than 50kWe are usually referred to as 'micro-CHP'. These tend to be used in very small businesses and in the domestic sector.

Find out more

Read more about packaged CHP at www.chpfocus.com

You can also download specific guides on CHP usage in hotels, universities, etc. from our website www.carbontrust.co.uk

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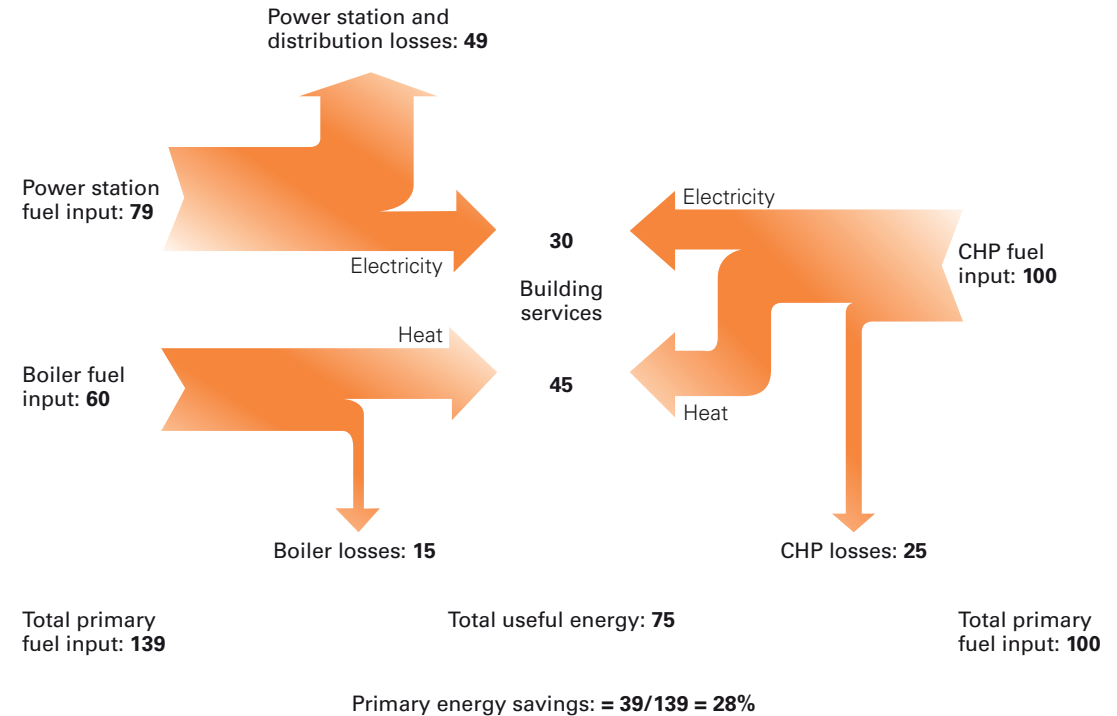
How does it save energy?

CHP makes more efficient use of primary fuel for producing heat and power than separate conventional methods, i.e. on-site boilers and power stations. That means it can deliver significant environmental benefits and cost savings, given the right balance of technical and financial conditions.

This is illustrated in *Figure 1*, which shows that the UK average fossil fuel electricity generator has an efficiency of around 40%. The remaining 60% of the energy is lost, mostly as heat via cooling towers and to a smaller degree in electricity transmission. Packaged CHP that is correctly sized and designed can have an overall conversion efficiency of primary fuel to usable energy (power and heat) of around 75%.

For 100 units of fuel, a packaged CHP would typically produce around 30 units of electricity and 45 units of heat. To produce an equivalent level of heat and electricity, a conventional power station and boiler would need around 139 units of fuel, so CHP yields primary energy savings of around 39/139 or 28%.

Figure 1 Energy savings through typical new small-scale packaged CHP compared to conventional sources of heat and power generation (shown in units of energy)



CHP in operation

There are **1,438** CHP schemes in operation in the UK. Of these, **328** are in the industrial sectors and **1,110** are in commercial, public administration, residential, transport and agriculture sectors.



Benefits of combined heat and power

CHP can cut costs, reduce carbon emissions, ensure a more secure energy supply and improve overall energy efficiency.

CHP requires significant capital investment in plant and resources. However, the high capital outlay is balanced by:

- lower costs
- a better environmental performance
- a more reliable and secure energy supply.

CHPQA Good Quality CHP standards

CHPQA judges the energy efficiency of CHP on its electrical efficiency and on a Quality Index (QI). The QI is a measure of the overall energy efficiency of CHP and the level of primary energy saving that it can deliver compared to the alternative forms of separate heat and power generation.

The QI is calculated by adding the products of electrical efficiency with an X factor and thermal efficiency with a Y factor so

$$QI = X \cdot \eta_{elec} + Y \cdot \eta_{heat}$$

The X and Y factors vary depending on CHP fuel, technology and size. They are designed to ensure a qualifying scheme also meets the European CHP Directive requirements.

The CHP is considered Good Quality if the electrical efficiency is above 20% and the QI exceeds 100. If either is below then there are mechanisms to scale back the fuel and/or electricity that will qualify for fiscal benefits.

You can find more details on the CHPQA programme on the CHPQA website at: www.chpqa.com

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Lower costs

CHP has been shown to reduce energy bills by 20-30%.

As well as reduced energy bills, CHP also offers other financial incentives, which can reduce tax liabilities, if it qualifies as 'Good Quality' under the CHP Quality Assurance Programme (CHPQA).

As well as measuring electricity efficiency, this judges CHP schemes on something called a Quality Index (QI), which measures overall energy efficiency.

If you have Good Quality CHP, registered with the CHPQA, you can benefit from the following where applicable:

- a reduction of exemption from your Climate Change Levy (CCL)
- an Enhanced Capital Allowance (ECA)
- a business rates exemption
- preferential treatment in the Renewables Obligation (RO)
- preferential treatment in the EU Emissions Trading Scheme (EU ETS).

There are also a number of proposed policies that could bring more benefits to those with CHP schemes.

CCL exemption or reduction

If you pay the Climate Change Levy (CCL), you may be eligible for reductions or even a full exemption on your payments by using CHP. You will need to register it with CHPQA, and the size of reduction will depend on how efficient it is.

If you export power from your CHP you may receive a Levy Exemption Certificate (LEC). You can either sell these on, with the exported electricity, or sell them separately to a buyer who can then gain exemption on the corresponding number of units of electricity.

The 2009 budget committed to continuing these benefits for CHP to 2023.

Read HMRC's guidance on the [Climate Change Levy and CHP schemes](#)

There is also more information on the CHPQA website at www.chpqa.com

What is the Climate Change Levy?

The CCL is part of a range of measures designed to help the UK meet its legally binding commitment to reduce greenhouse gas (GHG) emissions. It is chargeable on gas, electricity, coal and LPG (liquid petroleum gas) consumed in business and industry.

All revenue raised through the levy is recycled back to businesses through a 0.3% cut in employers' National Insurance contributions – introduced at the same time as the CCL – and support for energy efficiency and low carbon technologies. The CCL rates are currently 0.47p/kWh for electricity and 0.164p/kWh for natural gas. These are reviewed annually and increased with inflation.

You can find more details in HMRC's [Introduction to the Climate Change Levy](#) and in section 7.37 of 'Budget 2009 Building Britain's Future' at www.hm-treasury.gov.uk

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ECAs

If you pay corporation tax you can claim an Enhanced Capital Allowance (ECA) on any Good Quality CHP plant you purchase for your site.

The ECA scheme offers 100% first-year tax relief on any equipment featured on the Energy Technology List (ETL), which is managed by the Carbon Trust on behalf of Government. This improves cash flow, and means you can write off the whole cost of the equipment against your taxable profits in the year you buy the equipment.

For more information download [Guidance Note 42](#) from the CHPQA website, or visit www.carbontrust.co.uk/eca

Carbon Reduction Commitment

This is a new emissions trading scheme relating to direct and indirect CO₂ emissions from non-domestic energy consumption. The CRC will apply to you if you have an annual electricity consumption over 6,000MWh.

Find out more about the [CRC](#)

Renewable Obligations (RO)

The RO is the main support scheme for renewable electricity projects in the UK. It places an obligation on UK electricity suppliers to source an increasing proportion of their electricity from renewable sources.

Renewables Obligation Certificates (ROCs) are issued to Ofgem-accredited generators for any eligible renewable electricity they generate and supply within the UK. CHP fuelled by renewable fuel is currently eligible for ROCs, except where the scheme would be eligible for feed-in tariffs (see [page 11](#)).

When the RO began in 2002 one ROC was issued per megawatt hour (MWh) of electricity produced, with no incentive to reward renewable CHP over straight power generation. However, there are now bandings for various categories of power generation – where some or all of the fuel is solid biomass – which are eligible for additional ROC incentives if useful heat is recovered. This is shown in the *Figure 2*.

Figure 2 ROC bandings summary for thermal power generation/CHP involving solid biomass

Fuel	ROCs/MWhe	
	Power only	CHP
Dedicated biomass	1.5	2.0
Dedicated energy crops	1.0	1.5
(no CHP uplift)	2.0	2.0
Co-firing of biomass	0.5	1.0
Co-firing of energy crops	1.0	1.5
Waste-to-energy (biomass proportion)	0.0	1.0

Important info

It is important to note that Renewable Obligations, feed-in tariffs and the Renewable Heat Incentive are undergoing review, and in many cases policy is likely to change in the near future. It is therefore important to check the latest status with the organisations and websites referred to.

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Read the full legal statute 'The Renewables Obligation Order 2009' from the [Office of Public Sector Information](#)

Or you can read a more concise summary of bandings in the Ofgem document, '[Renewables Obligation: Guidance for generators](#)'

A summary relevant to CHP can also be found on the CHPQA website under [Guidance Note 44](#)

Under the current RO, there remains no additional incentive for heat recovery from dedicated energy crop-fuelled power generation, or liquid or gas renewable-fuelled power generation. However, this is likely to be eligible for the proposed Renewable Heat Incentive planned for April 2011.

Feed-in tariffs (FITs)

The FITs scheme was introduced on 1 April 2010 to incentivise small-scale (less than 5MWe) low carbon electricity generation by those not traditionally engaged in the electricity market. This 'clean energy cashback' will allow many people to invest in small-scale low carbon electricity, in return for a guaranteed payment – both for the electricity they generate and the electricity they export.

Of the thermal generating technologies applicable to CHP, only anaerobic digestion (AD) up to 5MWe and fossil-fuelled micro-CHP up to 2kWe are eligible for FITs. CHP fuelled by solid or liquid biomass and mature renewable gas technologies, such as sewage gas and landfill gas, continues to be supported under the RO at all scales. Under the FITs scheme there is no additional incentive for heat recovery from AD power generation, but this is likely to be eligible for the proposed Renewable Heat Incentive planned for April 2011.

Fossil-fuelled micro-CHP up to 2kW is eligible for FITs where fossil-fuelled power-only micro-generation is not. A domestic scale micro-CHP pilot will support up to 30,000 installations, with a review when 12,000 installations are completed. Micro-CHP projects supported through the pilot will have to use the [Microgeneration Certification Scheme \(MCS\)](#) in order for their eligibility for FITs to be confirmed.

Renewable Heat Incentive

The Renewable Heat Incentive (RHI) is expected to come on line in April 2011. Under the latest draft proposal, renewable heat-generating technologies – including heat from CHP fuelled by renewables – will be eligible for RHIs. The recent consultation proposed that no CHP will be eligible for simultaneous ROC uplifts and RHI. Instead, CHP uplifts will be removed at the next RO review in 2013. In addition, schemes installed under the current RO banding will have a choice – to be made during the period between the April 2011 and the 2013 reviews – of continuing with the uplift, or foregoing the uplift to gain eligibility for the RHI.

The recent consultation on RHI can be found on the [DECC website](#) where the mechanisms, values and interactions of ROCs, FITs and RHIs are explained in full.

Business rates exemptions

There are also business rates exceptions granted for CHP. For definitive guidance on Rating methodology, and how the Rateable Value of a Hereditament is determined, contact the Valuation Office Agency (Assessors Office, Scotland). You can also visit the CHPQA website and download [Guidance Note 43](#) for more information.



EU ETS

If you participate in the EU ETS, you will also see the benefits of having CHP on your site.

We are now in Phase II of the scheme, which runs from 2008-2012 to coincide with the first Kyoto commitment period. Under this phase, organisations with CHP schemes registered with CHPQA are given a greater carbon emission allocation than they would be without registration.

This is because a CHP plant emits more locally, but less globally, the longer it's in operation. So you will be given a bigger allocation to cover your on-site emissions, based on the fact that you are saving emissions on a global level.

As well as this direct benefit, the EU ETS indirectly enhances the economic benefits of CHP. This is because power stations are only allocated a proportion of their emissions and pass on the cost of the additional allowances to the consumers by increasing the price of electricity. Using CHP to generate power on-site avoids this increase.

Find out more about the [EU ETS](#)

Future policies

Proposed future policies that will benefit those with CHP include:

- Renewable Heat Incentive (RHI), anticipated April 2011. Under the latest draft proposal, renewable heat generating technologies, including any CHP fuelled by renewables, will be eligible for RHIs. However, it is likely that the RO policy would then be revised so that CHP schemes would not receive both RHIs and extra ROCs over and above power-only generators.
- The mechanisms, values and interactions of ROCs, FITs and RHIs are explained on [DECC's website](#)
- EU ETS Phase III, from Jan 2013. Under the latest draft proposal, the direct benefits to CHP are designed to be in direct proportion to the overall CO₂ saving, and credit for displaced gas in boilers awarded for CHP heat.

What is the EU ETS?

The EU ETS was introduced across Europe in January 2005 to tackle emissions of CO₂ and other GHGs and combat the serious threat of climate change. You will qualify for EU ETS if your business has combustion plant capacity of more than 20 megawatts (MW).

As part of the scheme, your business will have been given an allocation of CO₂ permits. Each year, your actual emissions will then be calculated, based on measured fossil fuel consumption and fuel type. If these exceed the allocation you'll need to buy more CO₂ permits and if it's less you can sell permits elsewhere.

You can find out more about the [EU ETS on DECC's website](#)

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- These draft proposals can be found on DECC's website under the title 'EU ETS Phase III (2013-2020)' at www.decc.gov.uk

- Unlike the EU ETS, off-site CO₂ emissions from imported/exported electricity and heat are attributed to the site. So if you are already within the EU ETS, your fuel will not incur CRC charges but your imported electricity will.

You'll be awarded credits if you export any heat and power created by CHP.

You can read the latest draft proposals for the CRC on DECC's website at www.decc.gov.uk

Case study

Pfizer

Pharmaceutical company Pfizer has seen significant cost and carbon savings from the two CHP plants it has installed at its site in Sandwich, Kent:

- a 6.2MWe gas-turbine CHP system, purchased in 1992
- a 7.5MWe gas-turbine CHP system, purchased in 2000.

The company decided to install the second plant after meeting the predicted four-year payback for the 6.2MWe unit. This coincided with a significant increase in the site's energy requirements in 2000, including the installation of 10MW of absorption chilling.

The second unit has also met all predictions for payback and savings.

Together, the two units provide 80% of the site's off-peak electricity requirements

20%

The amount Pfizer managed to reduce their energy costs

and 50% of its heat requirements from waste heat recovery.

They have also:

- reduced energy costs by over 20%
- both delivered a return on investment in four years
- achieved savings in line with internal projections and expectations.

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A better environmental performance

CHP improves a site's environmental performance because:

- the primary fuel consumption per unit of energy generated is lower
- fuels with high GHG emissions can be replaced with cleaner fuels
- electrical losses are reduced because the electricity is generated at, or close to, the point of use and is not transmitted over large distances.

By installing CHP, you can demonstrate your commitment to reducing energy consumption, improving sustainability and your awareness of environmental issues, all of which are of increasing interest to shareholders, customers and other stakeholders.

A more reliable and secure supply

CHP can enable you to generate power independently, helping you meet demand and reducing your dependence on electrical imports. It can be used to balance your maximum electrical demand and help you avoid penalty payments for exceeding your maximum agreed supply levels from the national grid.

If you use a synchronous generator (see [page 20](#)), CHP can also work completely independently of the mains supply, and provide emergency power in the event of a mains power failure. It can also be configured so your site can operate fully independently of the national grid, which means your energy supply is more secure.

The best time to consider installing CHP is at the design stage for a new installation or building, as it can be fully integrated into the design specification. However, it can also be successfully retrofitted into existing sites, particularly if you are upgrading energy plant (such as a boiler) that could feasibly be replaced by CHP.

CHP capacity

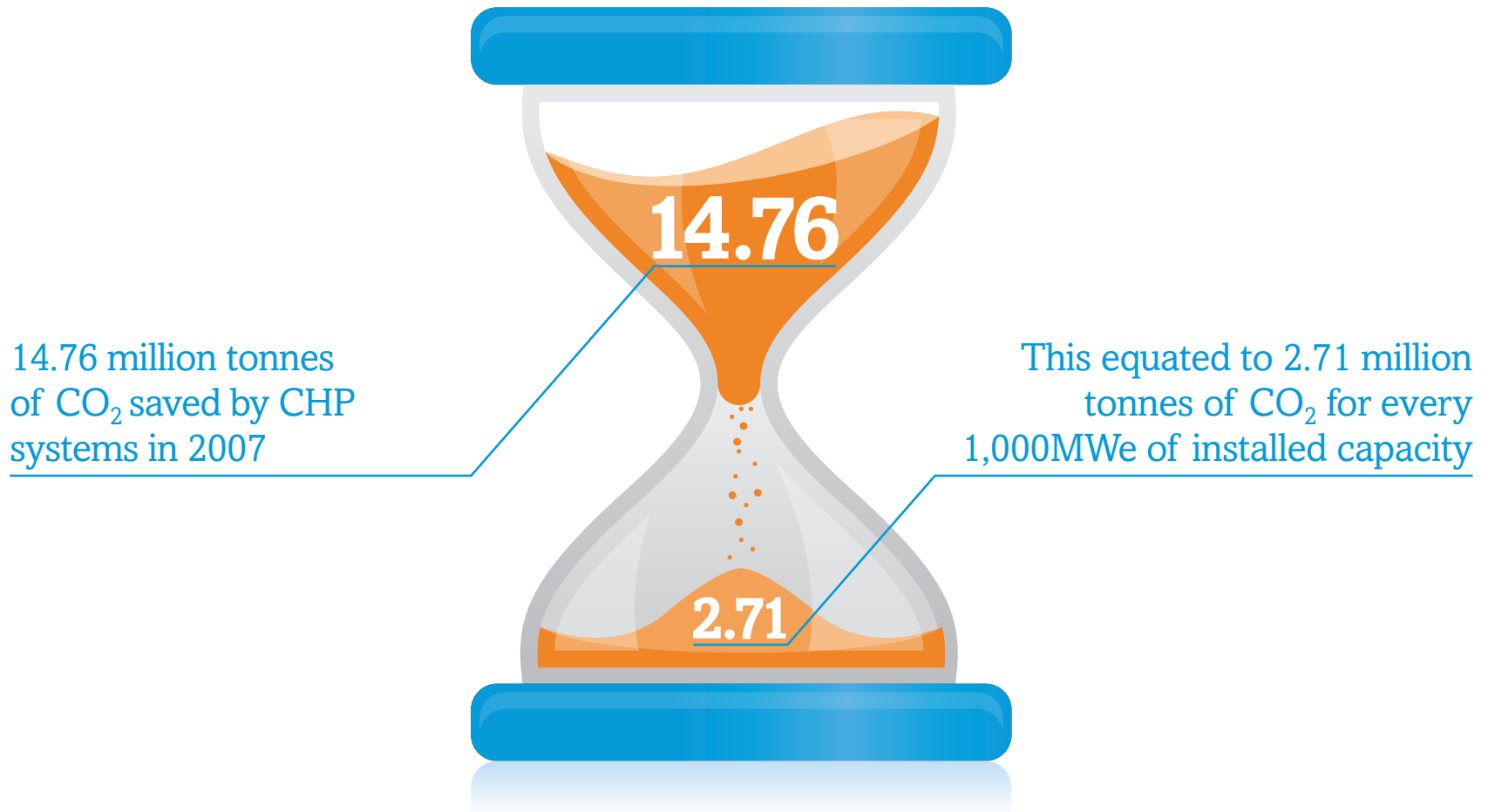
At the end of 2007, the total capacity of Good Quality CHP in the UK was 5,450MWe. This represents 6.6% of the total UK installed electricity-generating capacity (82,964MWe). There was due to be 5,469MWe of capacity by the end of 2008.



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Combined heat and power technologies

A CHP plant consists essentially of a prime mover, an electrical generator and equipment for recovering waste heat to be used. The type of prime mover used will vary, depending on whether the CHP plant is custom-built, small-scale or a micro-CHP scheme.

Basic elements

The basic elements of CHP plant are the prime mover, which provides the mechanical motive power, the electrical generator (where applicable) and the heat recovery equipment. The heat recovery equipment may include absorption chillers if the CHP is to provide chilled water.



Internal combustion engine CHP plant

The prime mover

There are five principal types of CHP prime mover:

Type of prime mover	Type of CHP in which it is found
1. Internal combustion engines	Packaged CHP
2. Steam turbines	Custom CHP
3. Gas turbines	Custom CHP (some, particularly microturbines, are packaged)
4. Combined cycle gas turbines (CCGTs)	Custom CHP
5. New and emerging technologies, such as Stirling engines, fuel cells, and Organic Rankine Cycles (ORCs)	Custom CHP or packaged CHP

Internal combustion engines

These use traditional spark-ignition engines (as used in cars and small electricity generators) to provide the motive power. In CHP these are converted to operate on natural gas or on compression-ignition diesel engines.

The electrical efficiency is typically 25-40%, with efficiency increasing with size. The heat produced is usually hot water, rather than steam, and they generally produce 1-2 units of heat for each unit of electricity, with the ratio of heat to power generally decreasing with size.

These engines are typically 70kWe-1,500kWe in size (but are available up to about 5MWe and down to 5.5kWe) and best suited to non-industrial smaller sites where most of the demand is for hot water.

- engine cooling circuit
- engine exhaust
- oil
- intercooler.

These use a steady stream of high-pressure steam generated in a boiler to drive the turbine.

The thermodynamic cycle is the Rankine cycle. The utility scale fully-condensing steam turbines used in large coal and nuclear power stations have average electrical efficiencies of about 36-38%. But in CHP applications, where the steam extraction reduces their electrical output, they have typical electrical efficiencies of 10.7-20%. Their overall efficiency ranges from 77.6-82.5%.

The electrical efficiency of steam turbines in CHP mode depends on the size of turbine and the pressure at which steam is extracted.
[See Appendix A](#) for a breakdown.



Steam turbine

- a. as medium-pressure steam between turbine stages ('pass-out') at the expense of a reduction in power generation
- b. as low-pressure steam slightly above atmospheric pressure exiting the final stage of the turbine ('back pressure')
- c. as low-grade hot water (about 30°C) recovered from the secondary cooling circuit in the condenser with no consequent loss of power. This is the most efficient option but is not common as such low grade heat is only of use in a few applications such as liquefied natural gas vaporisation.

Steam can also be diverted to the process before entering the turbine but, as mentioned earlier, this is not CHP, where the working fluid must first generate power.

Heat can then be used for process or space heating. Such turbines are particularly appropriate for CHP when steam is needed, or where the fuel available cannot be burned directly in the prime mover. They are typically suited to large-scale applications or where the amount of heat required is much greater than the amount of power.



Gas turbines

These use a steady stream of burning fuel to drive a turbine to generate the motive power. The heat from the turbine's exhaust gases can be recovered and used for space or process heating.

They are usually employed in large-scale custom-built schemes, larger than 1MWe, although there are small-scale 'mini turbines' of between 80kWe and 100kWe in some packaged CHP systems. Their electrical efficiency ranges from around 21% for mini turbines, to 25% for the smallest standard turbines of around 1MWe, and up to about 36% for very large turbines (above 100MWe).

Gas turbines have a higher electrical efficiency than steam turbines, as they operate at higher temperatures, but require a cleaner fuel (natural gas). Typically, they have lower electrical efficiencies than internal combustion engines but are smaller and require less maintenance.

Combined cycle gas turbine systems

These use the high temperature exhaust from a gas turbine to generate high-pressure steam which then passes through the steam turbines to generate more power. This combination provides very high power efficiencies of up to 55% (averaging around 52%) and is typically used in large-scale power generation.



Gas turbine

Heat can be recovered from the steam turbine cycle in the same way as with steam turbine only systems. All combined cycle turbine CHP schemes are custom-built.

New and emerging technologies

In addition to the more established types of prime mover, Stirling engine, fuel cell and ORC-based CHP are emerging in the UK market but are still essentially under development.

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Stirling engines

A Stirling engine is like a steam engine in that all its heat flows in and out through the engine wall. This is traditionally known as an external combustion engine, as opposed to an internal combustion engine where the heat input is by combustion of a fuel within the body of the working fluid.

Unlike the steam engine's use of water in both its liquid and gaseous phases as the working fluid, the Stirling engine encloses a fixed quantity of permanently gaseous fluid such as air or helium. As in all heat engines, the general cycle consists of compressing cool gas, heating the gas, expanding the hot gas, and finally cooling the gas before repeating the cycle.

Efficiencies in field trials have been found to range from 6-8% (nett system electrical efficiency). See the micro-CHP section on [page 23](#) for further details.

Fuel cells

A fuel cell is an electrochemical cell that directly generates electricity and some heat by electrochemically oxidising fuel. This process is often accelerated by a catalyst such as a transition metal or an acid solution. Fuel cells operating at high temperatures (>600°C) do not require catalysts.

These systems are more expensive than Stirling engines but offer higher electrical efficiencies of around 55%.

As with the other prime movers, waste heat is produced, which can then be recovered.

One notable fuel cell CHP scheme – the UK's first – is operated by Woking Council. Launched in 2003, it sits in Woking Park and provides power for the park's lighting, as well as the leisure centre and pool located there. Any surplus electricity is exported to the Council's nearby sheltered housing schemes.

ORC

An Organic Rankine Cycle (ORC) is based on the same principle as a steam turbine but uses a working fluid other than water, with either a lower or higher boiling point.

ORCs using a working fluid with a low boiling point can operate using low-grade heat to generate extra power. These can be driven by waste heat from conventional CHP or by boilers.

Recovering heat from the ORC cycle itself will not be practical in many cases, as the temperature of the condenser is around 20°C, which is too low for most applications. And recovering heat between turbine stages would reduce an already low cycle efficiency.

It is not CHP if heat from a boiler-driven ORC is diverted for use. But if the ORC is driven by a conventional CHP and some heat is recovered before entering the ORC this counts as CHP.

Some proposed ORCs use a working fluid with a high boiling point such as oil, so any heat recovered from the ORC condenser is more useful.



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Choosing the fuel

In general, the cost of a fuel is influenced by availability, flexibility of supply, storage and use.

CHP installations can be designed to accept more than one fuel, usually at an additional cost, which gives more flexibility and means supply is more secure. However, your fuel choice may be limited in practice by the emission requirements of an environmental permit.

The fuel for custom-built and packaged units is usually natural gas, though some can operate on other gases, such as stored propane, butane, LPG or biogas from sewage/landfill waste. Distillate fuels can also be used, but this is less common.

Steam turbines can burn cheaper fuels such as coal, heavy oils and waste materials, but there may be additional costs for handling, burning and meeting environmental standards. You may also need a back-up fuel – natural gas or oil – if you are burning a solid or waste product, either to bridge supply shortfalls or to initiate combustion.

Fuels such as natural gas and the lighter oils are of premium quality and value: they are generally more expensive to buy, but less costly to use.

The electrical generator

The generator converts the mechanical shaft power of the prime mover into electricity. Generators for CHP can be categorised as synchronous ('self-controlled') or asynchronous ('grid-controlled').

Synchronous generators can operate completely independently of the grid in what is known as 'island mode'. This means they are suitable for stand-by electricity generation if the grid power fails.

Asynchronous generators require a constant connection to the grid and will shut down in the event of a grid power failure. So they are not suitable for stand-by generation.

Below 100kWe size, synchronous generators are significantly more expensive than asynchronous generators because of the additional control equipment. So unless it's essential that a site has back-up, asynchronous generators are usually installed. Above 100kWe the cost differences are very small and so synchronous generators are usually employed.

The heat recovery equipment

Heat recovery equipment captures the heat from the prime mover either for process use (generally steam) or heating and hot water.

Generally, for internal combustion engines, the heat recovery equipment comprises plate heat exchangers, whereas for gas turbines the heat is recovered in a heat recovery steam generator (HRSG or HiRSiG). In some cases, the HRSG itself has additional fuel burned in it (called supplementary firing), in which case it's referred to as a 'fired HRSG'.

In systems with a steam turbine, the heat is usually used directly. However, in some cases, its pressure may need to be reduced before use.

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As mentioned on [page 4](#), there is large-scale and small-scale CHP, as well as micro-CHP, which refers to systems with an output below 50kWe. The three types will use different prime movers, depending on their size, power and application.

Custom-built CHP plant can range from 1MWe up to hundreds of MWe. The plant generally consists of large and complex systems installed on-site, although systems can be built for smaller power requirements.

The prime mover for custom-built CHP units up to about 40MW is most commonly a simple cycle gas turbine, or a steam turbine if solid fuel and oils are used. For units larger than 50MWe, a CCGT is often used.

In gas turbines, steam is then generated from the turbine exhaust. For pass-out steam turbines, or CCGTs with pass-out steam turbines, high-pressure steam is extracted from the turbine, causing a loss of power generation. The trade-off between heat and power depends on the size of the steam turbine and the pressure of the extracted steam.

You can find more information on custom-built schemes on DECC's CHP Focus website
www.chpfocus.com

Figure 3 Custom-built CHP system

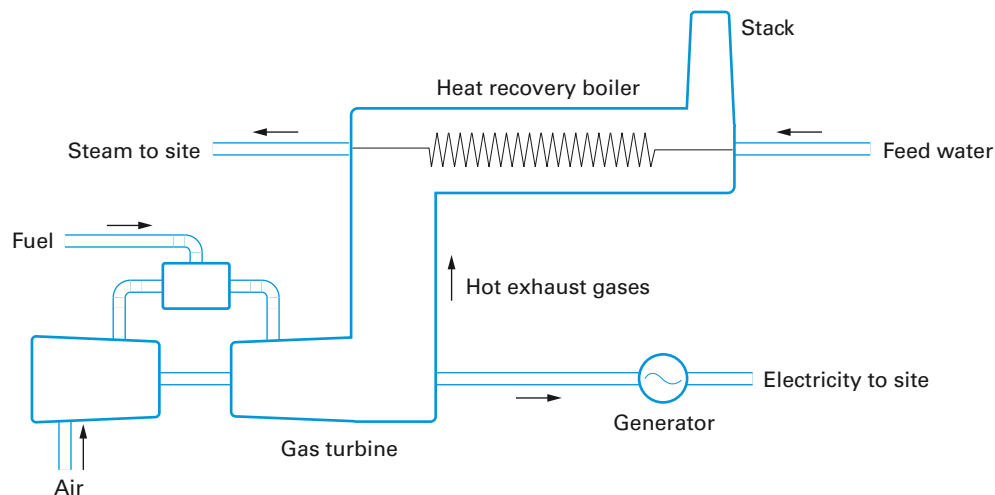


Figure 4 Example sizes for custom-built CHP units

	Gas-turbine CHP				CCGT CHP		
Electricity output (MW)	1.1	4.9	9.7	31.0	53.0	99.8	316.0
Heat output (MW)	1.8	7.2	14.5	36.5	40.5	99.3	205.3
Fuel input (MW)	4.3	16.3	34.0	96.1	134.3	271.6	686.4



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Small-scale, packaged CHP

Packaged CHP systems, typically ranging from 60kWe to 1.5MWe, are designed and supplied as complete units, selected to meet the requirements of the site and its energy demands. The package contains the engine, generator and heat recovery equipment, together with all the associated pipework, valves and controls.

The equipment is mounted on a steel structure and surrounded by an enclosure that reduces noise levels in the adjacent area. The enclosure normally contains a control panel that is accessible from outside the package. The package can also usually be easily dismantled to provide access for maintenance purposes. *Figure 5* shows how a packaged CHP works.

The prime mover for packaged CHP units is usually an internal combustion engine system. Heat is then recovered from the engine exhaust system and water jacket via suitable heat exchangers to provide a source of heat.

Alternatively, small-scale gas turbines (mini-turbines) are now available which have lower maintenance costs, but also lower electrical efficiencies.

Figure 5 A packaged internal combustion engine CHP

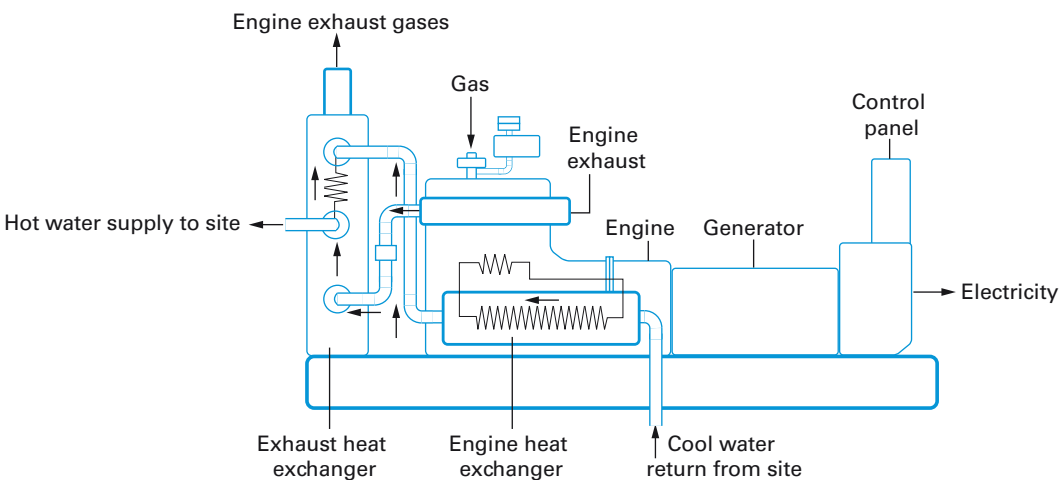


Figure 6 Typical sizes for packaged CHP units

	Gas-engine CHP					Small-scale gas turbine CHP	
Electricity output	60kW	100kW	300kW	600kW	1,000kW	60kW	100kW
Heat output	115kW	130kW	430kW	880kW	1,300kW	100kW	150kW
Fuel input	215kW	310kW	990kW	1,950kW	3,000kW	280kW	350kW



Micro-CHP

Micro-CHP is defined as systems with less than 50kWe. Systems with more than 5kWe are often referred to as mini-CHP.

Like small-scale CHP, micro-CHP systems are designed and supplied as complete units, and contain the engine, generator and heat recovery equipment, together with all the associated pipework, valves and controls.

Micro-CHP units can use internal combustion engines, micro-turbines or Stirling engines. Typical applications are in the domestic market, or in small commercial sites such as care homes or small leisure centres.



A cleaner alternative: biomass combined heat and power

Biomass CHP systems are even less carbon intensive than gas- or coal-powered plant, as they use a lower-carbon, more sustainable fuel source.

Although still quite uncommon in the UK, there are several hundred biomass-fuelled CHP plants in operation on the continent – the majority using solid biomass. Sizes vary, but most installations have a rated boiler output of more than 5MWth, with only a few generating at below 50kWe. These systems tend to use a mature combustion technology such as a steam turbine but systems using the Organic Rankine Cycle (ORC) are increasingly common.

There are also many plants in operation that use the gas produced by anaerobic digestion (AD) of liquid biomass (typically the methane produced at sewage treatment works) to operate a conventional internal combustion engine. These can operate effectively at smaller scales (down to 330kWe).

Other conversion technologies for biomass CHP include:

Gasification

This is a process of converting the biomass to a gas mixture – known as ‘syngas’ – by combining it at high temperatures with controlled amounts of oxygen or steam to create a reaction.

Pyrolysis

During this process the biomass decomposes, when heated in a controlled amount of oxygen, to produce a variety of products such as a fuel gas, char, bio-oil and tar – all of which can be used to generate heat and power.

Both of these technologies, however, are considerably less technically mature than steam or ORC conversion methods.

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Taking action

First carry out a scoping study to determine if your site's basic infrastructure is suitable for CHP. This should include an initial technical assessment. If this is successful, follow it up with a detailed feasibility study, to make sure it is definitely a viable option.

Your energy and facilities manager can complete the initial scoping study and technical assessment, but you may need help from a specialist consultant for the detailed feasibility study.

If the initial investigations show that CHP is a viable option, you can arrange for your CHP scheme to be designed and installed.



**Scoping study
including initial
technical assessment**



**Detailed feasibility
study**



Detailed design



**Installation and
commissioning**

Scoping study

The purpose of the scoping study is to determine whether installing a CHP system will be both technically and economically viable for your site.

Figure 7 Scoping study decision flowchart

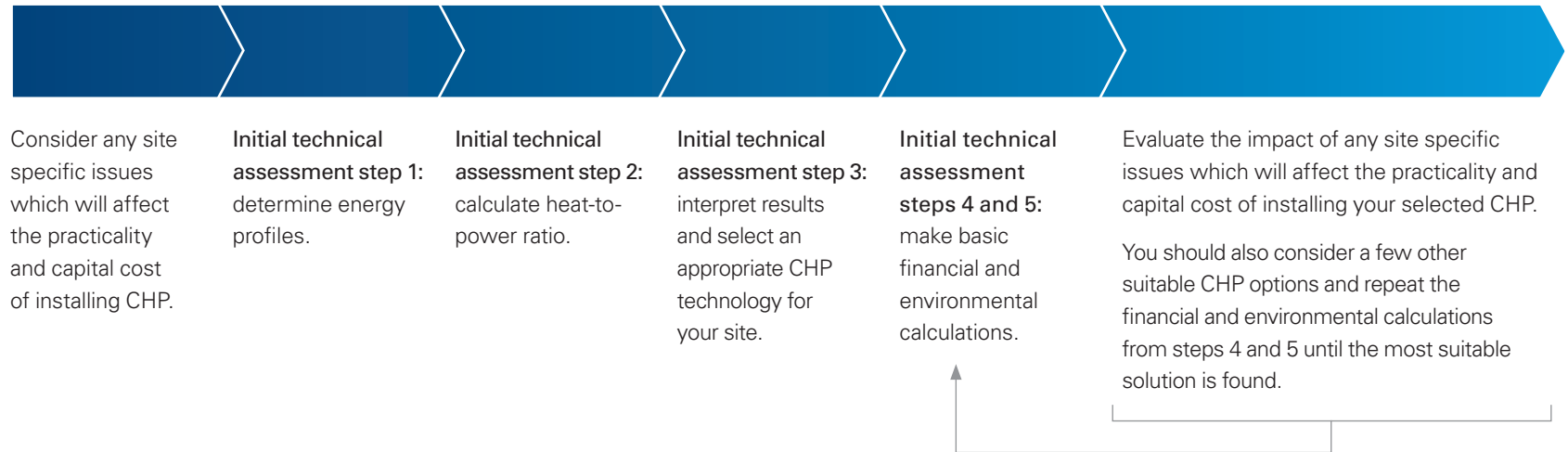


Figure 7 shows the key stages you should go through when carrying out a scoping study on your site, and we have explained what's involved in each further on in this section.



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Site specific issues

As part of your initial scoping study, it's important to check that your site is suitable for CHP – and that it's the right time to install it. If you are planning any other energy saving measures, you should consider CHP in the context of these, not independently of them.

Have all other energy efficiency measures been implemented?

Always carry out an energy audit before evaluating CHP. This will ensure that all energy saving measures have been implemented before calculating the size of a potential unit.

If you implement any energy saving measures after installing a CHP unit, you may find the CHP is then too big for the site, as it should always match your baseload consumption (see [page 32](#)).

Is the basic infrastructure in place?

Fuel supply

If you are planning to fire your CHP scheme on a fuel other than the one currently used on site, make sure you can get a steady, secure supply of the other fuel.

For example, if you're switching from oil to natural gas, check that there's a natural gas network available. Or, if you're planning to use a cleaner fuel such as biomass, make sure there's a local supplier.

Alternatively, even if the fuel is unchanged you need to check the current fuel supply is adequate. This is because CHP requires much larger quantities of fuel than boilers to produce your site's heat requirements.

For gas CHP you will need to check your pipework is large enough for the increased rate of gas required by the CHP, and also that there's enough pressure. Lack of pressure can be overcome by using a compressor, but it will be more expensive in capital outlay and running costs.

Electrical infrastructure

If, as is usually the case, the CHP is connected to the grid, you will need to check with your electricity supplier that their network (cabling, transformer, controls etc.) is capable of supporting the connection of your CHP and of exporting any electricity which might result. You will also need to show that your control system meets legal requirements such as G59, which states that your CHP must be disconnected from the grid in the event of a power cut for safety reasons.

Specialist advice

The Carbon Trust provides free, expert energy efficiency advice. Your company may qualify for a free energy efficiency survey from one of our qualified consultants.

Find out more at:
www.carbontrust.co.uk/freesurvey

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Is the site suitable?

Is there room in the existing boiler house for additional equipment and pipework? Are there any areas of the site that are not currently served by the central boiler house and which could be considered for connection to the new system?

Has the boiler recently been upgraded, or is it due to be?

If your boiler is scheduled for replacement in the near future, consider CHP as a replacement. This would help to offset some of the capital cost of the CHP.

On the other hand, if you have had boiler plant installed recently (within the last three to five years), it may be less economically viable to install CHP.

Are there any planned changes to your site's size or production levels?

To make sure that your CHP is future-proofed, take into account any plans that will affect your site's energy demand – such as expanding or reducing its size or production levels.

What existing energy contracts are in place?

Do you have existing energy contracts in place, particularly ones that commit you long-term to your current energy supplier?

This may affect the financial viability of a CHP system because you are committed to pay a predetermined price for your energy needs and use a specified supplier. So it would be difficult to recover the capital invested in developing CHP in terms of energy savings.

What control or building management systems are in place?

Is it feasible to integrate CHP into your existing plant control system? Or is there an opportunity to upgrade your system?

Depending on budget, these issues should form the basis of your initial technical assessment (see [page 28](#)).

Is there enough demand for CHP?

A CHP unit only generates economic and environmental savings when it is running. For this reason, it may not be viable unless there is a sufficient constant outlet for heat. A rule of thumb is there should be a heat load for at least 4,500 hours a year.

This equates to an average heat demand of about 17 hours a day for five days a week, throughout the year. In general, the greater the demand, the higher the cost savings.

However, this is just a rule of thumb. If your site has less than this, CHP may still be viable, so it is worth further investigation.

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Initial technical assessment

The main element of your initial scoping study is the initial technical assessment, which aims to determine if CHP will be appropriate for your site.

This should consider whether there is a suitable energy demand for heating/cooling and electricity and, if such a demand exists, the approximate size of the CHP unit you will need to meet it. The assessment should also look at the likely financial and environmental benefits of installing CHP.

Before the full assessment, it's worth doing a very simple analysis of the cost of CHP installation, as well as the annual cost savings and payback period. This should help you discount CHP early on if it is likely to be uneconomical.

Depending on budget, this assessment can be refined to consider how to overcome any potential barriers to CHP at your site.

An initial technical assessment generally comprises five stages. The first two can usually be done by your energy manager, but steps ③, ④ and ⑤ may require a specialist consultant, depending on how much your team know about CHP.

The five stages are:

- ① [Determine your energy profiles](#)
- ② [Calculate heat-to-power ratio](#)
- ③ [Interpret the results](#)
- ④ [Make basic financial calculations](#)
- ⑤ [Make basic environmental calculations](#)

Check the units

When analysing data, be sure to check the units used. Half-hourly consumptions measured in kWh must be doubled to convert them to the average instantaneous demand in kW.

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Is CHP right for your site?

When doing your initial scoping study, remember to check the following:

- have all other energy efficiency measures been implemented?
- is the basic infrastructure in place?
- is the site suitable?
- has the boiler recently been upgraded, or is it due to be?
- are there any planned changes to your site's size or production levels?
- what existing energy contracts are in place?
- what control or building management systems are in place?





1 Determine your energy profiles

You should produce energy profiles to evaluate the heat and power demands of your site. This will also give you an indication of what size of CHP unit you'll need.

To calculate these profiles, you need to collect data on how your site uses energy. There are two main ways to do this:

Building management systems (BMS)

Many buildings have some form of computer-controlled energy management system that keeps historical data of energy usage. Your energy or facilities manager will know if you have one.

It's an ideal source of data because it's the most accurate and likely to cover a number of years. This information should show how normal (average) demand profiles vary with:

- a. time of day (are there early morning and early evening peaks?)
- b. day of the week (are there different demand profiles at weekends?)
- c. season of the year (are there variations in demand for heating or cooling in certain months of the year?).

Monthly gas and electricity bills

You should be able to get these from your landlord or your energy manager for the last calendar year. But they may not be comprehensive records and there may be errors in the bills.

Alternatively, your electricity supplier may have information on consumption taken from half-hourly meter readings. This can be supplied electronically and can be analysed using a spreadsheet.

Ideally, it should cover one year and should be based on half-hourly measurements of heat and power consumption.

If you don't have enough information about energy consumption, you may need to estimate it. Your monthly fuel bills will provide an indication of seasonal variation, but you may need to do some short-term monitoring to determine the weekly and daily profiles. This will help you understand the operating patterns on your site – for both the building and any processes you carry out.

Get as close as reasonably possible to half-hourly consumption figures and avoid assessing demand from data averaged over long periods of time.

Degree days

The energy data should be normalised to estimate the demands in an average year, rather than the particular year in which the recorded energy was consumed. This correction needs to be applied only to the proportion of energy used for space heating, and so an estimate of this proportion is required.

The normalisation is done by carrying out a 'degree day analysis', where degree days are compiled for a specific location using historic temperature data. The amount of space heating required is broadly in proportion to the number of degree days, and so by comparing the number of degree days in an average year with those in the time period your energy data was gathered, an estimate of your energy demand for space heating in an average year can be estimated.

Degree day data can be downloaded from www.carbontrust.co.uk/degreedays

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Figure 8 Heat and electricity use

Average day in period	Winter Oct-Apr Mon-Fri (kW)	Winter Oct-Apr Sat/Sun (kW)	Summer May-Sep Mon-Fri (kW)	Summer May-Sep Sat/Sun (kW)
00:00				
02:00				
04:00				
06:00				
08:00				
10:00				
12:00				
14:00				
16:00				
18:00				
20:00				
22:00				

Compiling the data

Once you have got your half-hour consumption figures, you can generate your energy profiles. If you used a BMS, this may automatically generate them.

If not, you can create your energy profiles by completing the above tables for heat and electricity, either electronically or manually, using common units.

Figure 9 Typical annual demands

Month	Average demand (kWh)
Jan	
Feb	
Mar	
Apr	
May	
Jun	
Jul	
Aug	
Oct	
Nov	
Dec	

Figure 10 shows the daily heat load for a large supermarket, and gives an indication of how a heat profile might look. The curve would typically be more erratic for smaller sites but the difference between summer and winter profiles would typically be less pronounced.

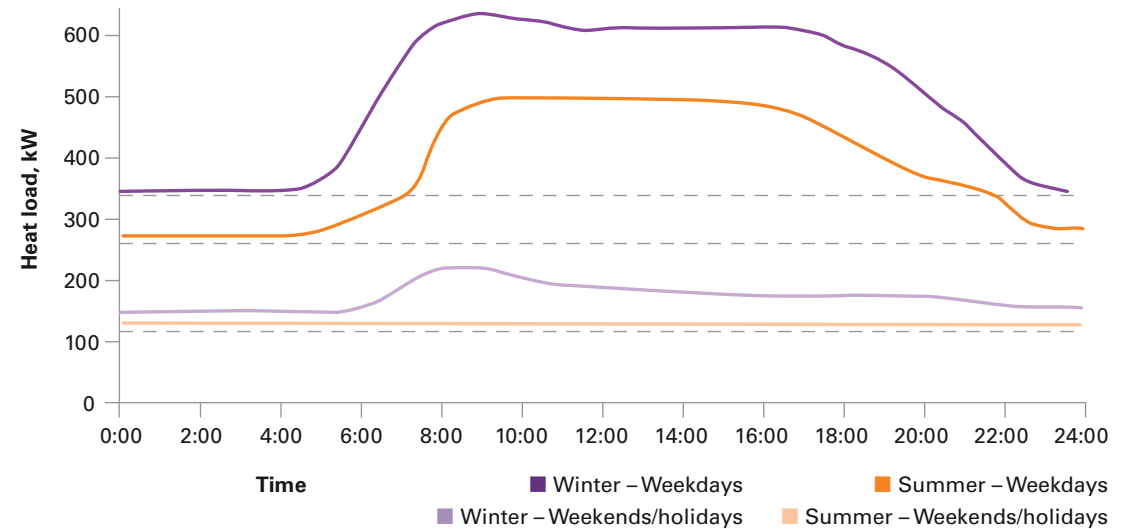
The dashed lines indicate the baseload for each particular case, which equals the minimum expected amount of energy the site needs to function.

Generally, where there is no electrical load for heating (for example, storage heaters or electric chillers), the seasonal variation for the electrical load will be smaller than the heat load.

Remember that if you are considering absorption chilling as part of the CHP scheme, the energy profiles will change as the electrical energy used to drive electric chillers will be replaced by heat energy for the absorption chillers.

This will reduce your annual electrical profile, but increase your heat profile.

Figure 10 Typical daily heat load for a large supermarket





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3 Interpret the results

Once you’ve calculated the energy demand and the heat-to-power ratio, it’s time to interpret the results.

Determine the constant outlet for heat

Use *Figure 11* to determine the annual average number of hours of heat at, or above, baseload. If this is above 4,500 hours a year, CHP may a viable option for your site.

If it’s less than that, CHP may still be worth further investigation, but you will need to take other technical considerations into account.

For example, you could include a facility to store heat when demand is low which can then be used when the heat demand increases. This is called ‘thermal storage’.

Select the right size and type of CHP unit

To maximise environmental and financial benefits, CHP generally needs to be sized to the heat load of a site as this will maximise heat recovery and, therefore, overall efficiency. Any excess electricity generated can then be exported to the grid and any shortfall can be imported.

If the CHP is sized to a site’s electrical load, there may be periods of high electrical demand when the heat demand is low and, therefore, some heat will need to be expelled to atmosphere. This wastes heat and lowers the overall efficiency of the CHP.

Usually, the most economically viable unit is one that is suited to the building’s lowest average heat demand (baseload) with the CHP acting as the lead boiler. Any further heat demand would be

picked up by the secondary boilers. This standard configuration also allows the secondary boilers to act as standby boilers when the CHP is down for maintenance. Based on the average mean electricity demand for summer and winter, *Figure 11* identifies whether the CHP unit should be sized above or below 1MWe. If the heat load is less than 600kWth, small-scale CHP may be appropriate.

In theory, a good CHP system will aim to use all the heat and power produced.

When the CHP plant has been sized, compare the financial and environmental benefits with those for a plant that is one size larger and one size smaller than that proposed. This will help you understand how sensitive the proposed plant might be to changes in energy use.

Figure 12 CHP prime movers have several characteristics due to the way they operate. These include their heat-to-power ratio and the grade of heat produced. The table below lists the different types of prime mover with the parameters that should be considered when choosing one

Prime mover	Heat-to-power ratio	Grade of heat	Scheme capacity	Space efficiency	Cost per kW _e capacity	Maintenance
Reciprocating engine	1.3:1	Low	Small	Average	Low	Relatively short intervals
Gas turbine	2.5:1	Very high	Large	Excellent	High	Long intervals



Determine what heat-to-power ratio the CHP needs to be

Using *Figure 11*, work out the heat-to-power ratio your CHP needs to be.

Heat-to-power ratios can range from 0.6:1 for an internal combustion engine with only exhaust-gas heat recovery, to 10:1 for a steam turbine.

Determine the type of prime mover to use for CHP

The size of CHP system when coupled with the heat-to-power ratio (both calculated as above) gives an indication of the type of prime mover to choose.

4 Make basic financial calculations

A basic financial viability check, when coupled with the calculations already carried out, will give you an indication of how economical it is to use a CHP scheme for a particular application.

The following are some of the things you should do as part of your calculations. Don't forget to consider current and future gas and electricity prices, as well as the capital and maintenance costs of CHP plant.

Determine the financial base case

The first step is to establish a financial base case (that is, existing energy costs) against which the proposed CHP scheme can be compared.

To do this, determine the current annual electricity and gas costs using the information collected in *Figure 11* to give an overall annual energy cost.

Calculate anticipated CHP running costs

Having sized the CHP unit from the energy demand figures, calculate the anticipated annual running costs of the CHP scheme. This should be based on estimated gas, electricity, operational and maintenance costs. The length and cost of CHP maintenance contracts vary greatly. Typical ranges are around 0.6p/kWh electricity generated for large gas turbines and CCGT above 40MWe, 0.8-0.9p/kWh for a gas turbine above/below 7MWe, and around 1.0-1.2p/kWh for a reciprocating engine above/below 1MWe.

Estimate the capital costs of the CHP scheme

This will vary from site to site, but for packaged CHP, average costs in 2008 were around:

- £2,000/kWe for 5kWe micro-CHP
- £1,250/kWe for 50kWe schemes
- £800/kWe for 1MWe schemes.

Custom-built CHP costs were around £1,350/kWe for a 1MWe gas turbine scheme falling to around £700/kWe for very large CCGT schemes above 200MWe.

Determine annual savings

Use the financial base case and the anticipated running costs to determine the annual savings you would see by installing CHP.

Compare this to the capital costs of the unit to determine whether CHP could be a viable and cost-effective option for your business.

Focus on finance

Alternative methods of financial appraisal – such as simple payback, discounted cash flow, net present value (NPV) and internal rate of return (IRR) – are covered in-depth in the [CHP Focus website's finance section](#).

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Getting the measure of CHP

Following is an example of a simple CHP sizer spreadsheet for a hypothetical site.

In this case, the table shows that a gas engine CHP would be most suitable, giving the shortest payback period of 3.8 years. If the payback of all options were high – e.g. well in excess of 12 years, the typical life of a CHP engine – then CHP would probably not be suitable for this site.

Remember this analysis is only indicative. A more detailed feasibility study might reveal other complications – such as heat and power demands being out of phase – which will increase costs and mean CHP is not a viable option.

Data input

Basic energy demand inputs

Site description	Test	
Annual electricity cost summer (May-Sep)	£20,000	£ (excluding standing charges)
Annual electricity cost winter (Oct-Apr)	£20,000	£ (excluding standing charges)
Annual electricity consumption summer (May-Sep)	200,000	kWh
Annual electricity consumption winter (Oct-Apr)	200,000	kWh
Annual fuel cost summer (May-Sep)	£4,500	£ (excluding standing charges)
Annual fuel cost winter (Oct-Apr)	£13,500	£ (excluding standing charges)
Annual fuel consumption summer (May-Sep)	150,000	kWh
Annual fuel consumption winter (Oct-Apr)	450,000	kWh
Seasonal boiler efficiency based on HHV input	75.00%	
Annual thermal demand period summer (May-Sep)	3,500	Hours (incl. hot water heating and absorption chilling if relevant)
Annual thermal demand period winter (Oct-Apr)	4,900	Hours (incl. hot water heating and absorption chilling if relevant)

Initial calculations and results

Period	Hours in period	Electricity purchases				Fuel purchases		Boiler eff (HHV)		75.00%	Site heat: power ratio
		£ (Excl SC)	kWh	p/kWhe	kWe	£ (Excl SC)	kWh (HHV)	p/kWhf	kWt		
May-Sep	3,672	£20,000	200,000	10.00	54	£4,500	150,000	3.00	31		0.56
Oct-Apr	5,088	£20,000	200,000	10.00	39	£13,500	450,000	3.00	66		1.69
Year	8,760	£40,000	400,000	10.00	46	£18,000	600,000	3.00	51		1.13

Period	Hours in period	Electricity purchases (variable costs)				Fuel purchases		Boiler eff (HHV)		75.00%	Site heat: power ratio
		£ (Excl SC)	kWh	p/kWhe	kWe	£ (Excl SC)	kWh (HHV)	p/kWh	kWt		
May-Sep production	3,500	£19,293	194,110	9.94	55	£4,500	150,000	3.00	32		0.58
Non-production	172	£707	5,890	12.00	34	£0	0	3.00	0		0.00
Oct-Apr production	4,900	£19,227	193,562	9.93	40	£13,500	450,000	3.00	69		1.74
Non-production	188	£773	6,438	12.00	34	£0	0	3.00	0		0.00
Year production	8,400	£38,521	387,671	9.94	46	£18,000	600,000	3.00	54		1.16
Year non-production	360	£1,479	12,329	12.00	34	£0	0	3.00	0		0.00
Year total	8,760	£40,000	400,000	10.00	46	£18,000	600,000	3.00	51		1.13
Net electricity generation 1st estimate, kW				16							
Maximum CHP operating hours				8,400							
Gas price, p/kWh				3.00							
Value of electricity generated, p/kWh				10.00							
Fired boiler efficiency, % (gross c.v.)				75.00%							

	Large open cycle gas turbine		Small gas turbine		Gas engine	
Output heat to power ratio	(Min 1.5 - Max 5.5)		(Min 1.5 - Max 5.5)		(Min 0.6 - Max 1.5)	
selected H:P ratio	2.17		2.17		1.54	
Heat recovery, kW	36		36		25	
CHP operation & maintenance (O&M), p/kWe	0.5		0.8		1.4	
Net generation efficiency, % (gross c.v.)	29%		29%		36%	
CHP availability, %	90%		90%		90%	
Net generation % of rated output	97%		97%		99%	
Actual CHP operating hours	7,560		7,560		7,560	
Rated electrical output of CHP, kW	20		20		20	
Annual power generated kWh	146,664		146,664		149,688	
CHP engine fuel input, kW	57		57		46	
CHP supplementary fuel input, kW	13		13		0	
Boiler fuel saving, kW	47		47		34	
Benefits and (costs)	p/kWhe	£/year	p/kWhe	£/year	p/kWhe	£/year
CHP engine fuel cost	-10.34	-£15,172	-10.34	-£15,172	-8.33	-£12,474
CHP supplementary fuel cost	-2.31	-£3,388	-2.31	-£3,388	0.00	£0
Operation & maintenance costs	-0.50	-£733	-0.80	-£1,173	-1.40	-£2,096
Boiler fuel cost saving	7.33	£10,757	7.33	£10,757	5.11	£7,647
Electricity cost saving	10.00	£14,666	10.00	£14,666	10.00	£14,969
Overall cost benefit	4.18	£6,129.10	3.88	£5,689.11	5.38	£8,046
Installed cost, £/kWe capacity		£3,429		£2,792		£1,528
Installed cost, £		£68,580		£55,840		£30,560
Simple payback period, years		11.19		9.82		3.80



5 Make basic environmental calculations

At the same time as you carry out your economic analysis, consider the environmental benefit of the CHP plant.

This is primarily the amount of CO₂ it saves, but can also include savings of other GHGs, such as methane (CH₄) and nitrous oxide (N₂O). If it includes other gases, the figure is known as the CO₂ equivalent (CO₂e).

Measuring the savings of other GHGs is less significant for schemes using standard fuels, but can be important for schemes with alternative fuels (such as biogas) that produce methane.

GHG emissions can be calculated by multiplying the fuel and electricity quantities by standard GHG emissions factors. The latest figures can be found on our website at www.carbontrust.co.uk/conversionfactors

To work out if a CHP scheme would deliver environmental benefits, compare its emissions for a certain fuel input to those produced by conventional electricity and a heat-only boiler for the same amount of fuel.

At the same time as you carry out your economic analysis, consider the environmental benefit of the CHP plant



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Detailed feasibility study

If the initial technical assessment suggests that CHP may be a viable option, you should carry out a detailed feasibility study.

This is a more thorough investigation of the technical and financial factors affecting the viability of CHP. These may include energy tariffs, hours of operation, plant availability and plant rating for heat and power at 100% output. The various components of the detailed feasibility assessment can be carried out by in-house staff, consultants, CHP suppliers or a combination of these. In practice, any assessment will require some in-house effort, even if the majority of work is done by consultants or suppliers.

For a small-scale CHP project, there may not be the budget for a consultant or much in-house resource, so CHP suppliers will normally offer some form of turnkey project and provide the system ready to use. Your staff can then evaluate these proposals, and the assumptions on which they are based, to see if they match expected business needs. However, the financial and the legal aspects may still require specialist external advice.

As each CHP scheme is different, your full feasibility study should include all the steps listed below. When you have completed all these steps, compare the costs with the base case costs to determine what savings you can achieve by installing and operating a CHP system.

Any assessment will require some in-house effort, even if the majority of work is done by consultants or suppliers

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1 Calculate site heat and power demands

The basic model is included in the initial technical assessment stage, but there are other elements to consider when doing the more detailed calculations.

For instance, consider whether you will need a connection to the grid to import any power. Also, think about any additional heat you might need, and what this would cost. Many units are not designed to meet the site's full demand, so you may need conventional boilers to provide additional heating in winter.

In practice, you can simplify the process by using a single calculation for periods with similar heat or power loads. For example, where there are steady loads overnight, make the calculation for one hour and then multiply the result by the total number of night hours.

2 – 5

The basic model for steps 2 – 5 is the same as in the initial technical assessment stage but will be more thorough at this stage.

2. Select CHP plant of an appropriate rating and type.

3. Assess the economic, energy and environmental benefits of the installation, taking into account all fiscal benefits and an environmental impact assessment.

4. Assess the capital costs of installation or the energy supply costs if an energy supply contract is being considered.

5. Assess the operating costs/savings when using the CHP plant.

The detailed feasibility study is a second iteration of the study carried out in the initial feasibility study. The initial feasibility study will show whether there is the potential for CHP on your site and provide some indication of the CHP configuration and what prime mover should be used, as well as the economic and environmental benefits.

You should use this information in any discussions with your supplier – which will help further refine the CHP configuration. After speaking to your supplier, you should have a more realistic model for the scheme, detailing the most suitable prime mover, the heat-to-power ratio and the overall CHP performance. If you decide on a different prime mover this may affect the capital and operating costs, and the viability of the proposed CHP.

If the detailed feasibility study shows that the proposed CHP is viable then you can proceed to step 6.

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6 Consider when, where and how the CHP unit will be installed and connected to fuel, heat and power systems

For example, you may need an adequate air supply for combustion and ventilation, plus a flue to remove the products of combustion and exhaust them safely to the atmosphere.

You may find it more cost-effective to introduce a CHP scheme if you are investing in other plant and infrastructure, such as a new boiler, or if there's an increase in your site's heat demand.

7 Decide on your financing options

The type of financing you use will depend on the capital you have available and the level of risk you're willing to accept.

The options are:

- equipment supply finance
- capital purchase
- energy supply contract.

These are explained in more detail in the following section.

8 Think about delivery options (if financing is by capital purchase)

Should your scheme be delivered by a contractor who you pay (on completion) for the design, specification, construction and commissioning?

Or should you carry out the design, specification, construction and completion yourself, subcontracting out individual elements if needed?

9 Check if you need any permits or consents

Depending on the location and nature of the scheme, you may need planning permission from the Local Authority, Pollution Prevention and Control (PPC) or Environmental Permitting (EP).

You might also have to get permission to connect the generator to the local electricity supply network.

Find out more

Get more information on the initial assessment and detailed feasibility from the CHP Focus website www.chpfocus.com

You may find it more cost-effective to introduce a CHP scheme if you are investing in other plant and infrastructure

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Finance options

Your financing options for CHP can be divided into two key groups – those that appear on your balance sheet and those that don't.

Capital purchase or 'on balance sheet' financing

Financed by:

- internal funding
- debt finance
- leasing.

Operating lease or 'off balance sheet' financing

Financed by:

- equipment supplier
- energy services company
- Private Finance Initiative.

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On balance sheet

If you make a capital purchase of CHP plant, it will appear on your balance sheet as a fixed asset. A capital purchase is generally funded using internal sources, external finance (debt) or a mixture of both. Another option is to lease a CHP scheme rather than purchase it.

Internal funding

With internal funding, you provide the capital for your CHP installation.

The level of risk varies depending on what type of installation you choose. For instance, if you place the work with a turnkey contractor, the contract terms may reduce the risk by placing more of it on the contractor. Similarly, the terms of contracts with consultants, equipment suppliers and subcontractors can be designed to minimise the investment risk.

Of course it's not always easy to find funding for CHP. It will often have to compete with other potential business projects that are closer to your core business activities. What's more, it may have to compete with short-term investments, even though it's for the long-term. So getting approval for CHP as a self-financed project may prove a problem.

Even if you pool all your existing sources of finance, and so can't distinguish which one has been used to fund which new project, each form of capital nevertheless has a cost associated with it. Therefore most companies calculate a composite rate that represents the average cost of capital weighted according to the various sources of finance. This rate is known as the weighted average cost of capital (WACC).

Financing CHP yourself?

Don't forget to register it with the CHPQA, and you can claim a 100% tax allowance as part of the ECA scheme.

Visit the CHPQA website and download **Guidance Note 42** for more information, or visit www.carbontrust.co.uk/eca



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Debt finance

Another option is to purchase the new plant by using new debt plus some internal funding.

With new debt, you can match an appropriate source of capital to a specific project. In particular, the borrowing timescale can be matched to the requirements, so you can get short-term finance for short-term cash needs and long-term finance for long-term needs such as a CHP plant.

For example, if you intend to generate a flow of savings/income from CHP over a period of 15 years, try to finance the plant over the same period.

If this is not possible, the borrowing timescale should be at least as long as the payback period for the project, plus the period required for recovering the 'cost of money'. This means the repayment schedule can be financed out of the savings/income generated by your CHP system.

Leasing

Leasing is a financial arrangement that allows you to use an asset over a fixed period.

There are two main types of arrangement that will appear on your balance sheet:

- hire purchase
- finance lease (also known as 'lease' or 'full pay-out lease').

There is also operating lease, also known as 'off balance sheet' lease, which is covered in the next chapter.

Hire purchase

Under a hire purchase agreement, you become the legal owner of the equipment only once you've made all agreed payments.

Although you don't technically own the equipment before you have finished the payments, you are responsible for maintenance and insurance. And for tax purposes, you are the owner of the equipment from the start of the agreement.

Looking for a loan?

We offer unsecured, interest-free loans with no arrangement fee. These can help provide upfront capital to invest in energy efficient technologies, such as CHP.

You can borrow from £3,000 to £100,000. The payback period will depend on the amount borrowed, and the likely savings from the new technology.

Visit our website for more information and details on how to apply.

www.carbontrust.co.uk/loans

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Finance lease

With a finance lease arrangement you pay regular rentals to the leasing organisation over the primary period of the lease. This allows the leasing company to recover the full cost – plus charges – of the equipment.

Although you don't own the equipment, it appears on your balance sheet as a capital item and you are responsible for maintenance and insurance.

At the end of the primary lease period, you can either take out a secondary lease – with much reduced payments – or sell the equipment second-hand to a third party, with the leasing organisation retaining most of the proceeds of the sale.

With finance leasing, the leasing organisation gets the tax benefits. These are passed back to you, in part, in the form of reduced rentals. In principle, the rental can be paid out of your energy savings, thereby assisting cash flow.

With this route, your level of financial and technical risk is similar to that of a self-financed project.

Figure 13 What's the best 'on balance sheet' financing option for you?

Type of financing	Pros	Cons
Internal funding	You retain full ownership and control of the project and should reap the maximum potential benefits.	You bear a considerable element of technical and financial risk.
Debt funding	You retain the full ownership, control and benefits of the installation.	You will accrue interest on any borrowed capital.
	The financial risk is spread over time.	As with full internal financing, you retain the technical and financial risks, apart from those that lie with suppliers and contractors.
Hire purchase	The financial risk is spread over time.	You don't own equipment until it is paid for but you are still taxed for it and responsible for operation costs.
		You will usually need to pay an interest charge.
Finance lease	As with debt financing, the financial risk is spread over time.	Although you never own the equipment, you are responsible for maintenance and insurance – and for tax purposes you are the owner of the equipment.
	May have tax advantages over internal and debt financing if you have insufficient taxable profits to benefit from the tax allowances available on capital expenditure.	



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Off balance sheet

Common arrangements of off balance sheet financing for CHP plant are via equipment supply finance, an Energy Services Company (ESCO) and a Private Finance Initiative (PFI).

Equipment supplier finance

An equipment supplier may, as an alternative to outright purchase, offer a leasing package for CHP. Under this arrangement, it will normally design, install, maintain and sometimes operate the CHP system.

A common commercial arrangement is for the energy to be supplied at prices that incorporate agreed discounts on the open market price. This means you pay for the fuel and buy the electricity and/or heat generated from the CHP at the agreed price.

To assure the equipment supplier of a continued income throughout the 5-10 year contract period, you may be required to pay a substantial standing charge, a lease payment or a high 'take or pay' volume of the energy supplied.

This form of financing arrangement is often used to finance small, packaged engine-based CHP systems.



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Is a turnkey arrangement right for you?

A turnkey project is one in which a single contractor – for example, an equipment supplier – takes responsibility for implementing the whole project. That includes the detailed design, purchasing and installation, as well as commissioning and testing. This means you have less influence over selecting your plant, and how it is configured, and it's your contractor's responsibility to ensure that all the plant items work together.

When the project has been completed, the contractor will hand the plant over to you; you pay for it and own it from that point onwards. You may decide to operate and manage the plant yourself – assuming responsibility for plant performance and reliability, and also retaining all of the cost savings. Or you could appoint an integrated energy services company (ESCO) to operate and manage the plant on your behalf.

Energy services company (ESCO)

An ESCO is a company set up to provide a total energy supply service, taking responsibility for provision, financing, operation and maintenance of energy facilities.

An ESCO arrangement can vary widely. In some instances, the ESCO contractor will design, install, finance, operate and maintain a CHP plant on your site. In other cases, you might subcontract only the operation and maintenance of CHP plant that has been installed by other contractors, under a design and manage or turnkey arrangement.

In both cases, the ESCO contractor supplies heat and power at agreed rates. The ESCO contractor may also take responsibility for buying fuel and for your other on-site energy plant.

From a financing point of view, the basis of this type of agreement is that the CHP plant capital and operating costs are transferred from the end user to the ESCO contractor – together with all the technical and operating risks of CHP.

Your savings when funding a CHP plant through an ESCO arrangement will normally be less than under a capital purchase arrangement because the ESCO contractor needs to recover the cost of the capital investment and cover operating costs, overheads and profit.

However, under certain circumstances, the savings can be greater. For example, your ESCO contractor may be able to size a CHP plant to meet your heat requirement and produce surplus electricity that can be exported and sold. You will still receive only part of the value of the energy savings but, because the energy savings are greater, your share may have a value greater than the savings you would have got under a smaller capital purchase scheme.

The ESCO contractor will also be able to increase the benefits compared with an in-house solution by avoiding the learning curve costs.

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Different ESCO contractors may produce widely differing proposals, depending on your requirements and their objectives. Questions to be answered include:

- who will operate the plant on a day-to-day basis and, therefore, bear the performance risk?
- who will maintain the plant?
- who will own the plant at the end of the initial agreement period of 10-15 years and at what ongoing cost?

Any transaction with an ESCO contractor still involves a long-term commitment.

Your audited accounts should contain a summary of this commitment, and you will need to satisfy your auditors that the arrangement is an operating lease and not a finance lease. If it is implied or stated in the contract that ownership of the plant will transfer to you, the arrangement must appear on your balance sheet.

Remember that an ESCO contract and finance are not intrinsically linked. You can enjoy the core benefits of an ESCO arrangement – reducing the cost and transferring the risk – irrespective of the finance route you choose.

In some cases the organisation hosting the CHP can also be part of the ESCO.

Private Finance Initiative (PFI)

The PFI applies if you are a public sector organisation hosting CHP plant.

Under this arrangement, you sign a contract with a private sector consortium, technically known as a Special Purpose Vehicle (SPV), and usually formed for the specific purpose of providing the PFI.

The PFI is owned by a number of private sector investors. It usually includes a construction company for building and refurbishment projects (of which CHP often forms a part), a CHP supplier and often a bank as well. The consortium's funding will be used to build the facility and to undertake maintenance and capital replacement during the life cycle of the contract.

If you are installing a CHP in an existing building you should consider a PFI arrangement. Where a new building is being proposed, explore the possibility of installing a CHP scheme within a wider PFI for the building.

An ESCO contract and finance are not intrinsically linked. You can enjoy the core benefits of an ESCO arrangement irrespective of the finance route you choose

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Figure 14 What's the best 'off balance sheet' financing option for you?

Type of financing	Pros	Cons
Equipment supplier financing	This arrangement transfers most of the technical risk to the equipment supplier.	Your savings are significantly lower than under a capital purchase arrangement. You retain the risks relating to fuel price fluctuations.
ESCO	This arrangement transfers most of the technical risk to the equipment supplier. Your savings can be higher than under a capital purchase arrangement as you can install a larger scheme.	For a given size of scheme, your savings are usually lower than under a capital purchase arrangement. You also retain the risks relating to fuel price fluctuations.
PFI	Puts the risk of time and cost overruns in installation onto the private sector through agreement of a fixed price and completion date. Puts the risk of the ownership, management and performance of the facility onto your private sector partner. The facility will be maintained to a predetermined standard for the duration of the contract term.	Can be time consuming to finalise the documentation. The public host takes on a long term commitment to the private sector.



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Next steps

Step 1

Investigate CHP/carry out a scoping study

If you have a constant outlet for heat, investigate the potential for CHP and carry out a scoping study. Gain support from senior management, identify resources needed to proceed.

Step 2

Carry out initial technical assessment

1. Determine heat and power demands.
2. Select CHP size and type.
3. Assess operating costs/savings when using CHP plant.

This can be done internally using this guide, by using our other publications or by talking to us directly.

Step 3

Decide whether to proceed

Gain support from senior management, identify resources to proceed. Don't forget financial investment is needed to carry out detailed feasibility study.

Step 4

Carry out detailed feasibility study

1. Determine where/how CHP will be installed.
2. Assess capital costs of installations or energy supply costs.
3. Assess economic, energy and environmental benefits of installation.
4. Assess nature of other relevant issues such as any permits or consents required.

This study will need to involve consultants, CHP contractors and internal staff.

Step 5

Decide whether to proceed

Gain support from senior management, identify resources needed to proceed.

Step 6

Proceed with project

1. Prepare project specification.
2. Issue invitations to tender for equipment and its installation.
3. Analyse tenders.
4. Place contract.
5. Plant installation.
6. Plant commissioning and handover.

Step 7

CHP plant operation and management

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Glossary

Absorption chiller

Equipment that uses heat energy to produce chilled water in air conditioning. Often uses spare CHP heat in the summer when buildings require cooling.

Alternator

A machine, the shaft of which is driven by an engine or turbine and converts rotating mechanical energy into alternating current (AC).

Back pressure steam

The steam exhausting from the low-pressure end of a steam turbine.

Baseload

The minimum expected amount of energy a site needs to function.

Building energy management system (BEMS)

An electronic control system for building services, usually linked to a central computer system.

Building services

The utilities/services required for operation of a building. Building services include cold water, space heating, domestic hot water, air-conditioning, lighting, small power and electricity.

Capital purchase

A funding option where the business buys CHP equipment using its own funds or own structured loan.

CHP engine

Type of CHP engine, spark ignition or compression ignition internal combustion engine fuelled by gas or oil.

Climate Change Levy (CCL)

An environmental tax on energy supplies applicable to businesses and introduced in April 2001. It is intended to help the UK meet its commitment to reduce greenhouse gas emissions.

Combined heat and power (CHP)

Simultaneous generation of electricity and production of heat using a source of mechanical and thermal energy (e.g. internal combustion engine, gas turbine or steam turbine).

Compression ignition

Ignition of the fuel in an engine using compression on the principle of a diesel car engine.

Condensing steam turbine

The steam turbine mode whereby steam surplus to site requirements is expanded to the lowest practicable pressure (vacuum stage) to generate more electricity, then exhausted to a condenser where the latent heat in the exhaust stream is removed by cooling water and resulting condensate is returned to the boiler.

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**Contract energy management (CEM)**

A service providing technical, financial and management resources to implement an energy saving project. Remuneration for the service is often by retention of a proportion of the savings. The CEM contractor can also bear a higher proportion of the financial risk of any investment.

Cost of money

The cost of borrowing money and servicing the debt incurred.

Domestic hot water

Hot water used on site for day-to-day purposes, such as for catering, baths and showers, cleaning, etc.

Efficiency

The percentage of energy input that results in useful energy output.

Energy services contract

The same as CEM, but in this case the supplier is contracted to maintain pre-determined conditions in buildings, and accepts responsibility for the entire heating system up to the point of delivery. Energy services contracts may be worded to define the outcome of the service provided, temperatures and light levels, rather than how much energy is to be supplied.

Energy services company (ESCO)

Companies offering a total energy supply service who take responsibility for provision, financing, operation and maintenance of energy facilities.

Enhanced capital allowances (ECA)

A government scheme to encourage businesses to invest in low carbon technologies. The scheme enables businesses to claim 100% first year capital allowances on investments in energy saving technologies and products. Businesses can write off the whole cost of their investment against their taxable profits of the period during which they make the investment.

Equipment supplier finance

A funding option whereby the CHP equipment supplier designs, installs, finances, operates and maintains the CHP equipment; supplies the site with free heat; and sells the electricity generated to the site.

Typically the site purchases the fuel for the CHP, and additional electricity from the grid, in the usual way.

Export electricity

Electricity generated in excess of site demand which can be sold to the electricity supply company if suitable metering and contract conditions exist.

Gas turbine

A type of CHP, with an operating principle similar to a jet engine, fuelled by natural gas.

Good quality CHP

CHP which meets the threshold criteria in the combined heat and power quality assurance (CHPQA) programme standard. The standard is intended to ensure that the energy efficiency and environmental performance of a CHP scheme are superior to the generation of the same amounts of heat and power by separate conventional means.

Heat customer

The site that has a demand for heat.

Heat dump

A means by which excess heat from CHP equipment can be transferred to the atmosphere when not required for utilisation on-site, usually in the form of a radiator with powered fan to drive external air over it.

Heat load

The heat demand from the heat customer.

Heat-to-power ratio

The amount of usable heat for each unit of power generated.

**Heat recovery**

Recovery of heat from the exhaust gases and cooling system of CHP equipment.

HHV (higher heating value)

The total heat available in complete combustion including the latent heat of the steam in the exhaust. It is an alternative phrase for gross calorific value.

Island mode operation

Mode in which CHP can function despite a failure of mains electricity from the grid. May be used in conjunction with standby generation to maintain full operating service.

Low temperature hot water (lthw)

Water, typically at 70 – 80°C and which may or may not be pressurised. Low pressure hot water (lphw) is the term sometimes used when water is not under pressure.

Medium temperature hot water (mthw)

Water at temperatures between 120 and 133°C and pressure between 200 and 300kPa.

MWe

Megawatt of electricity, equivalent to 1000kW of electricity.

Packaged CHP

Self-contained CHP equipment with all necessary equipment, often in a sound-insulated casing.

Primary energy

Chemical energy contained in oil, natural gas, coal, etc., which is used to provide secondary power (such as electricity and heat).

Prime mover

Engine or turbine used in a CHP plant to convert fuel to mechanical shaft power (usually to generate electricity) and heat.

Remote monitoring

A CHP control system which reports performance and problems automatically via telephone to the maintenance contractor.

Secondary energy

Energy (such as electricity or heat) provided through the conversion of a raw source (such as, oil, natural gas and coal).

Spark ignition

Ignition of the fuel in an engine, using spark plugs on the principle of a petrol car engine.

Stack or flue

Chimney or flue through which waste gases are exhausted from CHP equipment or conventional boiler.

Standby

Generation capacity on-site which provides electricity (or other building services during supply failure).

Thermal storage

The storage of heat, usually hot water in a buffer tank so that a CHP sized to meet the baseload heat demand can meet occasional peak heat demands.

Utilisation

The percentage of time that the CHP equipment is operated at full output (or equivalent).

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Appendix – steam turbine efficiencies

The following table was produced for DECC in generating the CHPQA standards for steam turbines.

Figure 14 Turbine efficiencies at various sizes and extraction pressures

Steamcycle CHP – efficiency and primary energy saving					
Representative of size range	5-10MWe	10-25MWe	25-50MWe	50-150MWe	>150MWe
Pressure of steam to site, psia	55	55	55	55	55
Temperature of steam to site, deg F	300	300	300	300	300
Sp enthalpy of steam to site, Btu/lb	1,184	1,184	1,184	1,184	1,184
Percent of boiler steam to site %	100	100	100	100	100
HP steam pressure, psia	615	915	1,515	1,515	2,265
HP steam temperature, deg F	720	820	980	980	1,050
HP steam sp enthalpy, Btu/lb	1,361	1,406	1,478	1,478	1,499
Reheat duty, Btu/lb				0	30
Boiler thermal efficiency, % net c.v.	87	88	89	92	92.5
Sp boiler fuel, Btu/lb steam	1,399	1,434	1,499	1,450	1,497
Efficiencies, % gross c.v.					
Electrical efficiency, % gross c.v.	10.7	13.2	16.9	17.5	20.0
Thermal (heat) efficiency, % gross c.v.	66.9	65.3	62.4	64.6	62.5
Overall efficiency, % gross c.v.	77.6	78.5	79.3	82.1	82.5

MWe = Megawatt of electricity, equivalent to 1,000kW of electricity. Deg F = Degrees Fahrenheit. Btu/lb = British Thermal Units of heat per pound weight. Psia = pounds per square inch absolute pressure, as opposed to gauge pressure which is relative to atmospheric pressure. % net c.v. (% net calorific value) = efficiency based on energy output divided by net calorific value fuel energy input – the latter being the total heat available in complete combustion excluding the latent heat of the steam in the exhaust. % gross c.v. (% gross calorific value) = efficiency based on energy output divided by gross calorific value fuel energy input – the latter being the total heat available in complete combustion including the latent heat of the steam in the exhaust.



Further information

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Carbon Trust website

You will also find more information about CHP on our own website.

Visit www.carbontrust.co.uk

Combined heat and power quality assurance

You can read information about CHP, and also find out how to get your system certified, on the combined heat and power quality assurance (CHPQA) website.

Visit www.chpqa.com

CHP Focus

CHP Focus is a DECC initiative to support the development of CHP in the UK. On the website you will find comprehensive information on all aspects of CHP, whether you are new to CHP or looking for specific information.

There is also free helpline support provided on 0845 365 5153, where experts can provide guidance to those who require it.

Visit the CHP Focus website at www.chpfocus.com



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Go online to get more

The Carbon Trust provides a range of tools, services and information to help you implement energy and carbon saving measures, no matter what your level of experience.

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Carbon footprint calculator

Our online calculator will help you calculate your organisation's carbon emissions.

➔ www.carbontrust.co.uk/carboncalculator

Interest-free loans

Energy Efficiency Loans from the Carbon Trust are a cost effective way to replace or upgrade your existing equipment with a more energy efficient version. See if you qualify.

➔ www.carbontrust.co.uk/loans

Case studies

Our case studies show that it's often easier and less expensive than you might think to bring about real change.

➔ www.carbontrust.co.uk/casestudies

Action plans

Create action plans to implement carbon and energy saving measures.

➔ www.carbontrust.co.uk/apt

Carbon surveys

We provide surveys to organisations with annual energy bills of more than £50,000*. Our carbon experts will visit your premises to identify energy saving opportunities and offer practical advice on how to achieve them.

➔ www.carbontrust.co.uk/surveys

Publications

We have a library of free publications detailing energy saving techniques for a range of sectors and technologies.

➔ www.carbontrust.co.uk/publications

Events and workshops

The Carbon Trust offers a variety of events and workshops ranging from introductions to our services, to technical energy efficiency training, most of which are free.

➔ www.carbontrust.co.uk/events

Need further help?

Call our Customer Centre
on 0800 085 2005

Our Customer Centre provides free advice on what your organisation can do to save energy and save money. Our team handles questions ranging from straightforward requests for information, to in-depth technical queries about particular technologies.

* Subject to terms and conditions.



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The Carbon Trust is a not-for-profit company with the mission to accelerate the move to a low carbon economy. We provide specialist support to business and the public sector to help cut carbon emissions, save energy and commercialise low carbon technologies. By stimulating low carbon action we contribute to key UK goals of lower carbon emissions, the development of low carbon businesses, increased energy security and associated jobs.

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