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MODULE 10
THE CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME APRIL 2010

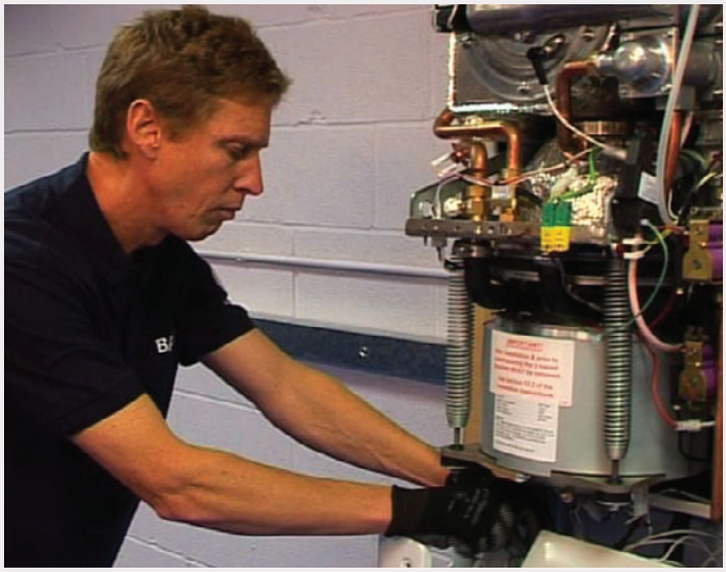
CURRENT THINKING ON...

SMALL-SCALE COMBINED HEAT AND POWER

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Combined Heat and Power (CHP) or sometimes referred to as cogeneration converts a singe fuel into both electricity and heat in a single simultaneous process at the point of use. CHP is well proven highly energy efficient technology and as well as supplying power, it can deliver positive financial and environmental benefits.

CHP can be utilised in a range of industrial and commercial applications or in district energy schemes. By generating electricity and heat at the point of use the requirement for centrally generated grid-electricity and on-site heat production is reduced thereby offering the potential for significant cost savings and reductions in carbon emissions.



CHP is the prime mover

In its simplest form CHP plant is a prime mover driving an electrical generator with the heat generated utilised in applications such as industrial heating, building heating and district heating schemes. CHP plant is commonly categorised by its size in terms of electrical output.

CHP with an electrical output greater than 1MWe is categorised as large scale CHP and most often uses turbine or compression engine prime movers. Small scale CHP covers a size range of 50kWe to 1MWe and commonly comes as packaged plant, often based on gas-fired reciprocating engines, with the components assembled ready for connection to the building's heating circuit and electrical distribution system. In recent years there has been considerable interest in the micro-scale CHP (outputs up to 50kWe) for domestic and small commercial applications. This CPD module, however, focuses on small-scale reciprocating engine based CHP.

CHP converts around 30 per cent of the energy in the fuel into electricity and up to another 55 per cent into to usable heat giving an overall efficiency of up to 85 per cent. This compares with a combined primary energy efficiency of around 55 per cent for centralised grid based power generation and transmission and heat generation with on-site boiler plant.

The UK's centralised grid electricity system has a delivered efficiency of around 40 per cent; in other words, up to 60 per cent of the energy in the input fuel is lost as heat at the power station and from the electricity transmission and distribution systems. Even combined cycle gas turbine stations only achieve a delivered efficiency of 45 to 55 per cent.

A well-designed and operated CHP scheme will always achieve a higher level of primary energy efficiency than centralised power generation and on-site heat generation through boiler plant and this is reflected in a reduction in the overall site energy bill. The actual level of savings achieved will depend upon the relative value of the electricity generated and the cost of the CHP fuel. This is referred to as the "spark-ratio" and a rule of thumb often quoted is that if the ratio value is greater than 2.8:1 CHP is worth considering.

Environmental benefits

The high efficiency of CHP results in significant environmental benefits because less primary fuel is consumed per unit of energy generated. Every unit of energy produced by natural gas engine CHP reduces the level of carbon dioxide emitted by around 35 per cent compared with the current mix of centralised generation.

Savings are achieved because the value of the electricity and heat produced by the CHP is greater than the cost of the fuel consumed and the cost of plant maintenance. CHP has a high capital cost and to be viable the savings need to be sufficient to repay the installed cost within an acceptable period and to cover on-going operation and maintenance costs. In order to maximise savings running hours should be as long as possible.

The economic case for CHP is improved by exemption from the Climate Change Levy (CCL) provided the CHP plant qualifies as "Good Quality" under the CHP Quality

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Assurance (CHPQA) scheme. "Good Quality" CHP is also eligible for Enhance Capital Allowances, which means any company investing in CHP can write-off the whole cost of the investment during the first year of its operation. The resulting tax benefit can be seen as a small but significant capital cost discount.

Fundamental criteria

For a site to benefit from an investment in small scale packaged CHP it will typically need to meet fundamental criteria:

- there should be a simultaneous requirement for heat and power for at least 5,000 hours/year (i.e. for 12 hours/day and 7 days/week). CHP can sometimes be cost-effective with fewer operating hours but in general the greater the annual period of demand the higher the cost savings;
- there must be a reasonable confidence in the future demand for heat and power over the life of the CHP plant;
- there must be an adequate supply of a suitable fuel.

CHP is not only relevant to existing sites. Incorporating CHP as an integral part of the energy supply arrangements for new sites and major refurbishment can be particularly beneficial and should be considered at an early stage.

The fundamental components of a packaged CHP unit are:

- prime mover – engine;
- an alternator;
- heat recovery system;
- a control system;
- an enclosure for protection and noise attenuation.

The electricity generated by the CHP unit is normally consumed on site but can be exported to the grid at times of low site demand. Heat is recovered from the engine exhaust and the jacket water and oil cooling circuits. Heat is normally recovered in the form of hot water, although steam can be generated from the engine exhaust, and supplied to the site for process or building space heating. The heat output from the CHP unit usually supplements that from boiler plant with the CHP unit being controlled as the lead heat provider.

The energy balance in the form of a Sankey diagram for typical gas engine CHP indicates that the overall efficiency is around 78 per cent (based on gross calorific value).

Fig 1: Schematic of a typical gas engine CHP plant

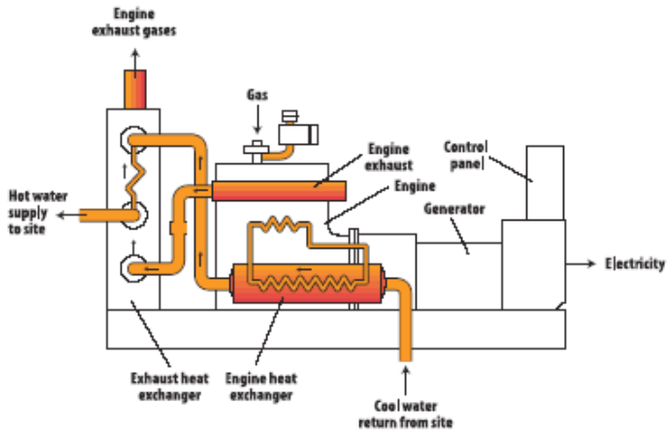
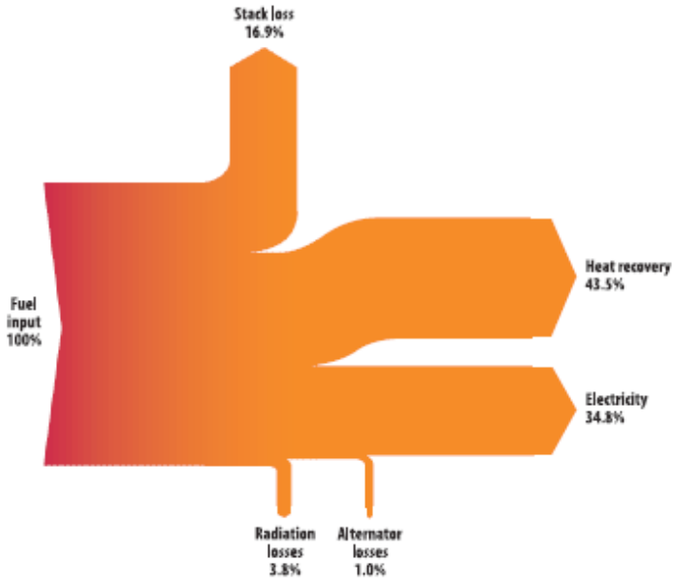


Fig 2: Energy balance for a typical gas engine CHP



Fuel options

Very often small-scale packaged CHP units are fuelled by natural gas although other fuel options include LPG, biogas from sewerage or landfill waste and to a lesser extent distillate fuels.

The reciprocating engine is the most common prime mover found in small-scale packaged plant.

The reciprocating internal combustion engines used in packaged CHP are similar to the diesel engines in widespread use in the transport industry. They have lower compression ratios, employ spark ignition and are usually designed to operate on natural gas.

The useable heat to power ratio ranges from about 1:1 to 2:1 and shaft efficiencies are up to 35 per cent. Engines are available up to about 4MW.

Heat produced by the engine can be recovered at different temperatures:

- engine exhaust – at around 4000C;
- engine water jacket and lubricating oil cooling systems – hot water, typically at 800C.

Compression-ignition (diesel) engines are used for larger CHP and are available from about 1MW to 15MW with efficiencies between 35 and 45 per cent. Cooling systems are more complex than on spark ignition engines and temperatures are lower thereby limiting the scope for heat recovery. The exhaust excess air levels are high which means that supplementary firing is practicable.

The engine must not be permitted to overheat so engine modulation or heat dumping is employed when the site heat demand is less than that being developed by the engine.

Gas and steam turbines are widely used in larger-scale, custom-built industrial CHP schemes. While at the other end of the scale micro-CHP based on technologies including internal combustion and sterling engines, fuel cell, rankine cycle and gas turbines is an area of considerable technical and commercial development primarily for the domestic market. These are not further considered in this CPD Module.

Absorption chiller

A site with a cooling demand could consider the use of an absorption cooling rather than electricity based chilling. The absorption chiller uses heat from the CHP unit to generate chilled water for the building or process.

This approach reduces the site's demand for electricity and increases the useful heat demand on the CHP unit. In some cases, using heat for cooling can turn a marginal CHP case into a viable option after the additional cost for the absorption chiller is included.

This type of system for electricity and heating/cooling is often known as trigeneration.

Most small scale packaged CHP plant is connected in parallel with the grid system and is not designed to meet the site's full power demand. As the site electrical demand varies any power requirement in excess of that provided by the CHP unit will be

automatically drawn from the grid.

When the CHP generation output exceeds site demand it is possible for surplus power to be exported to the grid. However, for small-scale CHP this is not common because additional cost and complexity outweighs the export revenue available.

CHP represents a large capital investment and there are two main alternatives for funding:

- capital purchase. The site owner purchases and installs the plant but often contracts out maintenance. The owner bears all the costs and risks but accrues all the benefits.
- energy supply contract. An energy or equipment supplier owns, installs, operates and maintains the plant. The site owner pays a contract tariff rate for the energy supplied and benefits from reduced energy costs for minimal capital outlay. The financial advantage to the site owner is less than with capital purchase, but so are the risks, which are usually shared between the two parties.

The basic steps for assessing the feasibility of a CHP scheme can be summarised as:

- determine site heat and power demands.
- select CHP plant of an appropriate rating and type.
- consider fuel, heat and power connections.
- assess operating costs and savings.
- obtain installed costs or contract costs if an energy supply contract is being considered.
- evaluate the economic, energy and environmental benefits.

Varying heat demand

A good understanding of the site's varying heat and power demand profiles is vital before the optimum size CHP unit can be selected.

Information on electricity consumption might be available from the electricity supplier's half hourly metering. Heat demand data are rarely as comprehensive and where information is sparse some degree of estimation is required. Monthly fuel bills will provide an indication of seasonal variation but might have to be supplemented by short term monitoring.

The objective is to establish the level of simultaneous heat and power demand (i.e. the base load demand) that the CHP unit would experience over 5,000 hours/year or more together with the site heat to power ratio. From this a CHP package of an appropriate type and output can be identified.

Few sites have a heat to power ratio that perfectly matches any particular CHP unit so it is important to consider sizing and control options:

- select a unit that matches the site's electrical demand. Make up any deficiency in heat demand using boilers. If there is too much heat, modulate the unit or dump excess heat;
- select a unit that matches the site's heat demand. Make up any deficiency in electricity demand from the grid. If too much power is generated, modulate the unit or if viable export the excess power.

The capital cost of any CHP plant (measured as £/kWe output) depends on its size and there are a number of issues that should be taken into account including:

- small-scale CHP seldom produces electricity more cheaply than purchasing from the grid supply. However, the additional benefit of using the "free" heat makes it economically worthwhile;
- CHP can be more cost-effective than other forms of energy supply when the heat output is used effectively. However, where CHP power generation produces heat that remains unused the financial benefit drops off;
- economies of scale do exist. As the size of a CHP plant increases capital and installation costs, expressed as £/kW, both fall. Maintenance cost per unit of electricity generated also decease with increasing unit size;
- the CHP Quality Assurance Scheme discourages the dumping of significant quantities of heat;
- electricity export is seldom an economic option for small-scale units;
- CHP provides cost savings only if there are sufficient heat and power demands throughout the forecast life of the plant. Consideration must be given to possible changes in future demand patterns such as planned energy efficiency measures or changes to the business.

Comparing costs and savings

CHP plant is a capital-intensive investment and a rational method of comparing costs and savings should be employed to arrive at the optimum solution. This is often best completed using a spreadsheet so that variations and sensitivities can be quickly studied.

The first step of the appraisal is to determine the electricity and heat base load (ideally based on time periods to match the site's electricity supply contract/tariff). The next step is to calculate the cost to meet the heat and power demands from conventional sources and the CHP plant. The third step incorporates a cost estimate for maintaining the CHP plant. This will vary by operating hours and type of plant but will be in the range 0.6 to 1.6p/kWe generated.

The cost savings can then be calculated and set against the cost of installation to determine the simple payback. With the long-term nature of CHP projects more sophisticated analysis using for example Internal Rate of Return is preferable. It is often beneficial to test the sensitivity of the financial savings for the scheme against a range of possible fuel and electricity price rises and CHP operational hours.

Installed cost can be obtained from suppliers and will typically lie between £800 and £1,250/kWe depending upon unit size.

The installation of a combined heat and power (CHP) plant can result in considerable financial and environmental benefits for sites where there is a significant and simultaneous demand for both heat and electricity.



There are numerous opportunities for industry, commerce and the public sector to invest in CHP including:

- industrial sites/process;
- hotels;
- leisure centres;
- the health care sector - hospitals and residential premises;
- universities;
- horticulture;
- airports;
- community heat schemes.

References:

GPG388 Good Practice Guide – Combined heat and power for buildings. Carbon Trust.

Web sites:

- The Carbon Trust www.thecarbontrust.co.uk/energy
- CHP Quality Assurance Scheme (CHPQA) www.chpqa.com
- CIBSE www.cibse.org
- The Combined Heat and Power Association www.chpa.co.uk

PROMOTING ENERGY EFFICIENCY www.eibi.co.uk
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How to obtain CPD accreditation



Energy in Buildings and Industry and the Energy Institute are delighted to have teamed up to bring you this Continuing Professional Development initiative.

This is the last of ten modules in the seventh series and focuses on small-scale combined heat and power. It is accompanied by a set of multiple-choice questions. To qualify for a CPD certificate readers must submit at least eight of the ten sets of questions from this series of modules to ***Energy in Buildings and Industry*** for the Energy Institute to mark. Anyone achieving at least eight out of ten correct answers on eight separate articles qualifies for an Energy Institute CPD certificate. This can be obtained, on successful completion of the course, for a fee of £15 (for members) or £25 (for non-members).

The articles, written by a qualified member of the Energy Institute, will appeal to those new to energy management and those with more experience of the subject. A new series of modules will begin in the next issue ***Energy in Buildings and Industry*** and will focus on the CRC Eneregy Efficiency Commitment.

If you have missed any of the modules in the series (the previous modules focused on the Carbon Emissions Reduction Commitment, biomass heating, building management systems; solar thermal; thermal imaging; free cooling; water management, underfloor heating; and air conditioning) let *EiBI* know (mark.thrower@btinternet.com) and we will send you the missing modules in 'pdf' format to you either by e-mail or on a CD.

The previous 60 modules from the first six series are also available free of charge on CD.

MARK THROWER, MANAGING EDITOR

PLEASE COMPLETE YOUR DETAILS BELOW IN BLOCK CAPITALS

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Completed answers should be mailed to:
The Education Department, Energy in Buildings & Industry,
P. O. Box 825, GUILDFORD, GU4 8WQ



Questions

Please mark your answers on the sheet below by placing a cross in the box next to the correct answer. Only mark one box for each question. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet in ink, return it to the address below. Photocopies are acceptable.

1. A CHP unit generates?
- ☐ air conditioning
- ☐ heat
- ☐ electricity
- ☐ heat and power simultaneously

2. CHP plant converts how much of the input fuel to usable heat and power?
- ☐ 25 per cent
- ☐ 50 per cent
- ☐ 85 per cent
- ☐ 100 per cent

3. What is the average efficiency of the UK's central electricity generation system?
- ☐ 40 per cent
- ☐ 50 per cent
- ☐ 60 per cent
- ☐ 70 per cent

4. Which of the following three statements is not true?
- ☐ CHP is a carbon efficient technology for the production of on-site heat and power.
- ☐ CHP units have a capital cost about the same as standard boiler technology.
- ☐ Maintenance costs of the CHP unit are important in the economic feasibility of any CHP scheme
- ☐ CHP can reduce costs

5. What is the typical CO_2 reduction for gas fired CHP compared with current centralised generation?
- ☐ 25 per cent
- ☐ 35 per cent
- ☐ 50 per cent
- ☐ 60 per cent

6. Typically how many hours would a site require simultaneous heat and power to make CHP viable?
- ☐ At least 1,500/annum
- ☐ At least 2,500/annum
- ☐ At least 3,000/annum
- ☐ At least 5,000/annum

7. What is not a key component of a packaged CHP unit?
- ☐ Prime mover
- ☐ Heat recovery system
- ☐ Alternator
- ☐ Gas burner

8. Which of these is likely to improve the financial benefit of CHP?
- ☐ Falling electricity prices
- ☐ Rising electricity prices
- ☐ Rising gas prices
- ☐ None of these

9. To qualify for CCL exemption and ECA a CHP unit must:
- ☐ Qualify as good quality under the CHPQA scheme
- ☐ Use a gas engine
- ☐ Have an output less than 1MW
- ☐ Have an output greater than 2MW

10. What is the typical range of installed cost for packaged CHP?
- ☐ £100 – £250/kWe
- ☐ £300 - £650/kWe
- ☐ £800 - £1,250/kWe
- ☐ £1,500 - £2,000/kWe