Combined heat and power (CHP) in universities

‘Every university should consider the financial and environmental benefits that combined heat and power can provide,’

Professor Peter Toyne, chair of the committee on ‘Environmental responsibility: an agenda for further and higher education’.
INTRODUCTION

OBJECTIVES
The objectives of this Guide are to:
- introduce the concept of CHP and identify opportunities for its use
- help you decide whether there is an initial case for CHP
- describe how CHP schemes can be progressed, and the responsibilities of different management levels
- report on four existing CHP schemes
- provide essential information, explain jargon, and suggest an initial action checklist.

COMBINED HEAT AND POWER
CHP is plant which consumes fuel to produce electricity and useful heat. It is usually located in a boiler house, and supplies heat to the heating system as from a normal boiler. The electricity generated is fed into the electrical supply system, thus reducing the need for purchased electricity. CHP can also provide electricity during mains failures (see box ‘Stand-by power’, page 4).

The best time to consider CHP in existing buildings is when the heating plant is being replaced, so that the CHP unit can be integrated with the heating system.

The commercial value of the electricity and heat produced by a CHP unit is greater than the cost of the fuel consumed. In particular, the value of a unit of electricity can be up to five times that of a unit of heat. In order to maximise savings from the initial capital investment, running hours should be as long as possible (at least 4000 hours per year).

Finance and contract options
CHP schemes may require an initial capital investment and management resources for supervising the installation and maintenance of the equipment (see box ‘Contract types’, page 4).

Maintenance
CHP plant requires specialist maintenance which can be managed by the university, by the CHP supplier, or by a specialist company. Effective long-term maintenance is crucial to achieving cost savings and trouble-free operation. For some contract types maintenance is the responsibility of the supplier (see box ‘Contract types’).

Electricity and fuel contracts
The savings obtained from operating CHP depend on the price of its fuel and the value of the electricity and heat generated, so energy pricing is an important part of evaluating and improving the financial case for CHP.

Help with negotiating suitable contracts is available from the local electricity supplier, CHP suppliers and other sources (see ‘Getting help’, on back cover).
THE ENVIRONMENTAL BENEFITS OF CHP

Heat and electricity from CHP plant are produced with typically 50% savings in emissions of the greenhouse gas carbon dioxide (CO₂), and 30% savings in consumption of primary energy (a measure of energy which includes the fuel consumed by power stations), compared to conventional boiler plant and electricity supplies.

The more efficient use of fuel:
- reduces emissions of the principal greenhouse gas CO₂, thus helping to reduce the risk of global warming
- reduces the emission of sulphur dioxide (SO₂), the major contributor to acid rain
- helps to conserve the world's finite energy resources.

Further details are provided in Good Practice Guide 115, 'An environmental guide to small-scale combined heat and power’ (GPG 115) and Good Practice Guide 176 'Small-scale combined heat and power for buildings' (GPG 176), available from BRECSU (see back cover for address information).
THE ROLE OF CHP IN A UNIVERSITY

CHP can serve a vital role in a university’s environmental and energy strategy. It should be considered as part of the university’s energy management programme to reduce energy consumption and cost. Highly cost-effective measures such as loft insulation and control improvements should generally be carried out first, after which more costly measures, including CHP, should be considered.

Major building plans should be taken into account when considering CHP because they may have a considerable effect on base loads.

STAND-BY POWER

In addition to providing normal power and heat, CHP can generate electricity during mains supply failures, so acting as a stand-by power supply for essential loads. If the site has an established need for stand-by power, then using CHP to produce it can be highly cost effective, especially if there is existing generator plant which needs replacing.

When action is being considered on site heat mains - either major refurbishment of the main or changing to local boilers (decentralisation) – care should be taken so that the opportunity for central CHP is not lost without due strategic thought. York University (see Case Study 2, page 8) provides an example of the strategic assessment of options.

Detailed investigation and design is required to ensure that the CHP installation integrates with other plant. There should be sufficient space for the CHP unit in the central boiler house, or a dedicated enclosure may be required. Some on-site maintenance is usually necessary.

Smaller packaged units are suitable for individual buildings or small groups of buildings, for example, a sports facility or residential halls. These units can be connected directly to most local heating systems. They operate automatically and often include a telephone link to the CHP supplier to advise of potential problems before operation is affected.

ARCHIVED DOCUMENT

CONTRACT TYPES

Different universities have differing requirements for funding and managing the installation and maintenance of CHP systems. A wide range of contract types is available, and common arrangements are given below.

Outright purchase
The university pays for the installation of the CHP plant and associated work such as plant housing and energy supplies, as well as any feasibility, design and training costs. It is normal for a maintenance contract to be taken out, often with the equipment supplier (see Case Study 4, page 10).

Loan finance
The installation is financed by a loan to the university which is paid off from savings produced by the CHP plant (see Case Study 1, page 7).

External funding – equipment supplier finance (ESF)
Installation and maintenance are entirely at the CHP supplier’s cost with the university paying only for the fuel used by the CHP unit and an agreed reduced price for electricity (see Case Study 3, page 9).

Energy services
An energy services arrangement can provide a wide range of building and systems services including the finance, installation and operation of CHP plant.
ASSESSING THE CASE FOR CHP

There are two primary technical requirements for CHP.

- There must be sufficient need for heating and electricity on the site for CHP plant to operate, typically for over 4000 hours a year (equivalent to 11 hours a day throughout the year, or 17 hours a day for eight months of the year).
- CHP plant is compatible with most heating systems, but a site which has high temperature or steam heating can restrict the options.

The amount of heating required in milder weather is critical for individual buildings or small groups of buildings with local heating systems. Ideally, there should be year-round loads, such as extensive hot water heating for residential blocks or changing facilities, or specific heating requirements such as that for swimming pools.

AN INITIAL CASE FOR CHP

The following indicate promising sites.

For larger CHP installations:
- a central heat main, also preferably with a single electricity supply
- local heat mains serving accommodation buildings with a heat load for at least eight months a year.

For smaller CHP installations:
- residential buildings or buildings with extended heating needs for showers or a swimming pool.

Management and technical guidance can be found in the following Good Practice Guides available from ETSU (see back cover for details).

GPG 1  Guidance notes for the implementation of small scale packaged combined heat and power
GPG 3  Introduction to small scale combined heat and power
GPG 43  Introduction to large scale combined heat and power

Longer term plans

Plans to add extra buildings to the heat or electricity mains served by CHP plant should be considered as these may improve the base loads and hence the economics of the system.

Decentralisation of central plant into local boiler plants will greatly reduce, or even eliminate, the case for large central CHP plant. Care should be taken to evaluate such options within an overall technical strategy including energy costs, for example, the availability and benefit of interruptible gas.

TECHNICAL ISSUES

- There must be available space for the CHP plant. Modern boiler plant is generally much smaller than older plant and space may be found in existing boiler rooms.

Packaged CHP units can be located in special enclosures (see Case Study 3), where one unit is in an existing boiler house and the other is sited in an enclosure on a covered car park.

- Noise has to be carefully considered and, if necessary, limited in the design (see Case Study 2). Most smaller packaged units are fully sound-insulated.

- Flueing CHP units should not be a problem, but care in siting flues is needed to avoid unexpected costs if relocation is needed.
THE STEPS TOWARDS A CHP INSTALLATION

The steps below are generally necessary for all CHP installations. For smaller installations the level of finance is lower and more responsibility can be taken by the supplier which shortens the procedure, although most steps are still necessary in principle. Good Practice Guides that are available to support particular steps are indicated.

1. Generate initial interest. This ideally comes from the most senior levels. A preliminary case for CHP can be established without significant research.
   - GPG 176 Small-scale combined heat and power for buildings

2. Assess initial technical and economic feasibility. This can be achieved by in-house teams using published guidance such as the Department of the Environment’s Best Practice publications, through consultation, or by inviting initial proposals from CHP suppliers or energy services companies. It should identify the initial costs and benefits of the options, and should assess strategic options such as decentralisation, new building plans, replacement and maintenance of main plant, and energy efficiency programmes.
   - GPG 182 Heating system option appraisal – a manager’s guide
   - GPG 187 Heating system option appraisal – an engineer’s guide for existing buildings

3. Consider finance and management resources. The source of finance and the university’s ability to manage installation and maintenance should be considered. Both of these can be made the responsibility of the CHP supplier or energy services company.
   - GPG 161 Finance options for small-scale combined heat and power

4. Initial committee stage. Summarise and assess CHP prospects at relevant committees and, if appropriate, obtain commitment in principle. Allocate funds for a detailed feasibility study.

5. Commission a detailed technical feasibility study. Include technical and financial assessment of any relevant decentralisation and new building or refurbishment plans.


7. Tender stage. Tender evaluation should encompass all issues raised by investigations.

8. Assess funding and maintenance options. Confirm suitability of contract procedures, funding and maintenance arrangements, and energy supply contracts. Consider staff information and training needs.

9. Installation and associated works. Any major works may need coordinating with the university timetable.
   - GPG 1 Guidance notes for the implementation of small scale combined heat and power
   - GPG 3 Introduction to small scale combined heat and power
   - GPG 43 Introduction to large scale combined heat and power

10. Commissioning and initial operation. Ensure that suppliers/contractors are fully committed to this stage. GPG 1, GPG 3, GPG 43

11. Maintenance and management. Obtain monthly or quarterly financial performance, including maintenance costs. Review annually. GPG 1, GPG 3, GPG 43

The financing of all these stages can be made the responsibility of the CHP supplier or energy services company (see box ‘Contract types’, page 4), but the university should monitor proposals.

GPG 161 (from ETSU)
CASE STUDY 1 – LIVERPOOL UNIVERSITY

LARGE CENTRAL CHP PLANT – LIVERPOOL UNIVERSITY

In 1985, Liverpool University’s buildings and estates department, which was responsible for all utility billing and payments, was given a target to reduce costs by a further £150,000. CHP was suggested by the energy manager, and a feasibility study was commissioned. The study indicated that the site was suitable, providing that the heat main and the electricity network were upgraded.

The director of the buildings and estates department produced a business plan which was presented to various committees.

The University agreed to support the proposals providing that commercial finance could be obtained. The estates director then obtained a commercial loan from the University’s bankers for £1.6M. In addition the University provided £500,000 funding for heating and electrical network upgrades.

The project was approved in November 1985. The University set up a wholly-owned company, University of Liverpool Electricity Company (ULEC), to manage the installation. The scheme was inaugurated by the Secretary of State for Education and Science in December 1986.

Operating experience

The operating company and the University are pleased with the performance of the installation. The plant has operated reliably for nine years and has consistently achieved substantial annual savings for the operating company ULEC and hence for the University. The original commercial loan has been repaid, so there are no debt servicing costs and any profits now realised accrue to the University.

The installation has attracted considerable attention, including regional and national energy awards. The turbine installation is visited by, among others, University of Liverpool students, with regular tours being requested.

KEY POINTS

- The large central installation makes savings of £400,000 a year.
- The scheme was largely funded by a commercial loan, so it imposed little burden on university finances.
- Works included an upgrade of the ageing electricity network and heat main.
- The installation is owned and operated by a separate management company, which is in turn wholly owned by the University.
- Dual fuel gives energy supply flexibility.

SUMMARY

- **Size and type**: 3600 kWe dual fuel gas turbine
- **Buildings served**: Site heat and electricity mains serving 30 buildings
- **Source of finance**: Commercial loan guaranteed by the University
- **Maintenance**: Managed by the University
- **CHP supplier**: Turbine supplier: Centrax
- **Commissioned**: October 1986
- **Running hours**: 5000 hours per year
- **Initial cost**: £2.1M (in 1985/86)
- **Annual savings**: £416,000 (no finance costs)
- **Payback period**: 5 years

The Right Honourable Kenneth Baker QC MP, the then Secretary of State for Education and Science, opens the Liverpool University CHP plant.
CASE STUDY 2 – YORK UNIVERSITY

MEDIUM/LARGE PACKAGED CHP PLANT – YORK UNIVERSITY
The University’s energy management initiative was well advanced before the introduction of CHP. Boiler replacements, lighting, and local heating control measures and a site-wide building energy management system (BEMS) were already installed, and helping to make significant savings.

The University engineer had expressed an interest in CHP from the early 1980s, and provided a summary report each year to the working party for energy conservation. In the early 1990s, the prospects for CHP improved as medium-sized packages became available, and the engineer commissioned a feasibility study of central and local CHP options.

An associated condition appraisal of the heating main, together with a heating decentralisation study, were also undertaken. These allowed life-cycle cost comparisons to be made of CHP and alternatives. The appraisal showed that the condition of the heating main and use of CHP was acceptable and funding approval was gained.

In February 1995, a CHP scheme rated at 1030 kWe was commissioned. This provides 60% of the campus electrical demand and 20% of the annual heat requirement, including all heating and hot water needs from June to October.

The CHP unit is located inside the main boiler house. Stringent noise standards have avoided any increase in noise levels.

KEY POINTS
- CHP was investigated as part of an extensive energy management programme.
- A thorough investigation was carried out of the ageing heat main and the prospects for decentralising to local boiler rooms.
- Heat is provided at up to 127°C from a reciprocating engine CHP unit.
- Noise levels were restricted to 1dB increase in the centre of the main boiler house, and no increase outside the boiler house.
- The CHP plant is saving 14% of the annual energy bill.

SUMMARY
- Size and type
  1030 kWe packaged gas engine unit
- Buildings served
  Campus buildings via heat and electricity mains
- Source of finance
  University
- Maintenance
  Annual contract with CHP suppliers
- CHP supplier
  Baseload Systems
- Commissioned
  February 1995
- Running hours
  Projected 7900 hours per year
- Initial cost
  £520 000
- Annual savings
  Projected £150 000
- Payback period
  3.5 years

The CHP unit at York University

Operating experience
Installation was straightforward. Initial operating experience in the period since February 1995 has shown that the unit is reliable with over 97% availability achieved during the first 9 months of operation, at an average load factor of 85%.
TWO MEDIUM PACKAGED
CHP UNITS – COVENTRY UNIVERSITY

The estates director and energy conservation officer were enthusiastic about CHP. In the late 1980s there were various approaches from British Gas, suppliers and consultants regarding the installation of CHP.

Using a student’s final year project and an assessment by British Gas, the estates director and energy conservation officer concluded that there was a potential case for CHP.

Limited funding was put forward for a study by British Gas, which was seen as an independent body. The study supported the case for CHP, and capital funding of £250 000 was earmarked for a unit. However, this amount only covered one installation. The University therefore chose to fund two units under a discounted energy purchase (DEP) scheme, with the option of buying the units later.

There are six boiler rooms on the campus, and a residential site was identified with seven day use, together with kitchens. A second site was also identified, which incorporated the original six buildings of the Lanchester College of Technology, Students Union and laboratories.

Coventry University had also negotiated an advantageous electricity supply contract because of the site’s electricity load pattern. The contract was not affected by CHP use.

Operating experience
Savings were £20 000 for both units in the first year. These are expected to rise to £32 000 a year, with no finance costs because the units were funded by the CHP supplier. If the University purchases the units, savings (before finance costs) increase to £60 000 a year each. The University is delighted with the performance of the units. Minor problems have been overcome and have not affected the scheme’s attractiveness.

KEY POINTS
- Two medium sized units provide significant contribution (600 kWe total) to energy demand, while retaining the advantages of smaller packaged systems.
- The supplier-financed contract includes maintenance.
- The automatic operation is trouble-free, with on-board diagnostics managed by CHP suppliers.
- Packaged units are located in a boiler room and a car park area.
- This is a flexible arrangement. The University may subsequently purchase units and benefit from higher savings.
- The stand-by power capability from one unit avoided cost of replacing ageing stand-by generator.
CASE STUDY 4 – BANGOR UNIVERSITY

SUMMARY

- **Size and type**
  75 kWe packaged gas engine unit
- **Buildings served**
  Four residential student blocks and amenity buildings
- **Source of finance**
  University
- **Maintenance**
  Initial period included in purchase cost
- **CHP supplier**
  Combined Power Systems Ltd
- **Commissioned**
  January 1992
- **Running hours**
  5900 hours per year
- **Initial cost**
  £63 000
- **Annual savings**
  £15 000 excluding finance costs
- **Payback period**
  4 years

**SMALL PACKAGED CHP UNIT – BANGOR UNIVERSITY**

Initial interest in CHP resulted in investigations of various applications within the estate, and a student accommodation site was identified as suitable for a packaged installation. The availability of a comprehensive contract, including maintenance and on-board diagnostcics, allowed the University to proceed as in-house maintenance management was not considered possible.

**Operating experience**

Installation was straightforward and there were no problems connecting to the local heating and electrical systems. The CHP contract has run satisfactorily alongside a site energy services contract which encompasses 160 boiler houses.

The three year initial maintenance period is short by the standards of current good practice (usually five years including the first major overhaul). However, a new contract has successfully extended the initial maintenance arrangement.

The availability of the CHP unit has been high, over 90%, and the unit has achieved 5900 running hours a year. The University is very pleased with the installation which has prompted interest in further CHP installations in its estate.

**KEY POINTS**

- The automatic operation is trouble-free, with on-board diagnostics and remote monitoring.
- The contract was all-inclusive, including a period of full maintenance by the supplier.
- The scheme was financed by the University and repaid internally from the energy budget.
- The scheme operates alongside the existing site energy management and maintenance contract.
WHAT NEXT?

The Vice Chancellor should:
- establish commitment to evaluate the case for CHP
- action the estates department to consider CHP options
- consider use of CHP in marketing the University
- consider CHP within the University’s overall policy for environment and energy.

The Estates Director should:
- consider the preliminary case for CHP
- establish commitment at all levels
- involve the finance department in proposals
- obtain information on long term plans eg decentralisation
- request initial feasibility study
- investigate and visit existing schemes
- take responsibility for achieving approvals.

The Finance Director should:
- explore various contract types for value for money.

The Engineer or Energy Conservation Officer should:
- investigate large and small sites for CHP
- obtain key information such as energy usage data
- discuss with CHEEP, CHPA etc
- contact potential suppliers via CHPA
- contact electricity and gas supply companies to discuss supply contracts and tariffs.

JARGON LIST – A BRIEF GUIDE TO SOME COMMON TERMS IN THIS DOCUMENT

**Availability:** the percentage of time that a CHP unit is able to be used. Availability is reduced below 100% by maintenance time (scheduled down-time) and breakdowns (unscheduled down-time).

**Decentralisation:** changing to local boilers in place of existing central boiler plant and heat mains. The decision to decentralise encompasses the cost of maintaining heat mains and the benefit of interruptible gas which is normally only available for central plant. The opportunity for central CHP should also be considered.

**Energy services:** provision of a wide range of energy management and other services including funding, installation, operation and maintenance of buildings and plant. Introduces private sector skills and finance in keeping with the Private Finance Initiative.

**Equipment supplier financing (ESF):** a type of contract whereby the CHP supplier installs equipment at its own cost. The CHP supplier is paid by the customer, at a discounted cost, for electricity generated.

**Export electricity:** electricity generated by CHP plant which is in excess of the site demand at any time and which can be sold to other users or back to the electricity supplier if suitable contract and metering arrangements exist.

**Interruptible gas:** gas supplies that can be interrupted by the gas supplier, in contrast to firm gas contracts. The site has to store oil or some other fuel for occasional use, and the plant must be able to use the stored fuel. (Usually significantly cheaper than firm gas.)

**kWe:** the capacity of CHP plant to generate electricity, measured in kilowatts of electrical power.

**Packaged CHP:** a self-contained CHP unit with all the necessary equipment in a casing or box which is usually sound-insulated.

**Public electricity supplier:** a company that supplies electricity to customers. Includes the 12 regional electricity companies and the two Scottish supply companies.

**Reliability:** the percentage of time the CHP plant is able to be used, without penalising for maintenance time (scheduled down-time).

**Remote diagnostics and monitoring:** an extra control system for CHP plant which diagnoses any problems and reports them automatically via a telephone link to the CHP supplier.

**Stand-by power:** generation capacity on site which provides electricity for selected essential services during mains failures.

**Turbine:** larger CHP plant sometimes uses a gas or oil fired turbine to drive the generator. While providing higher temperature heat and greater flexibility in operation, turbine technology requires more specialist installation and maintenance arrangements.
GETTING HELP

The organisations listed below can help in different ways.

- For Good Practice Guides and many other useful publications contact BRECSU or ETSU.
- For lists of suppliers, contractors and consultants, contact the Combined Heat and Power Association (CHPA), the Institute of Energy or the Energy Systems Trade Association.
- To find out more contact the CHPA.
- To view existing installations, contact ETSU, BRECSU or one of the case study universities in this Guide.

Combined Heat and Power Association (CHPA)
35-37 Grosvenor Gardens, London SW1W 0BS
Tel 0171 828 4077
Fax 0171 828 0310

DOE ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

Further details on investigating and implementing CHP are available from BRECSU and ETSU (see below).

**Good Practice Guides**

1. Guidance notes for the implementation of small scale packaged combined heat and power
2. Introduction to small scale combined heat and power
3. Introduction to large scale combined heat and power

**Consortium for Higher Education Energy Purchasing (CHEEP)**
FAO Mr Graham E Manning
Queen Mary & Westfield College
London E1 4NS
Tel 0171 975 5101  Fax 0171 975 5500

**Energy Systems Trade Association**
PO Box 16, Stroud, Gloucestershire GL6 9YB
Tel 01453 886776  Fax 01453 885226

**Institute of Energy**
18 Devonshire Street, London W1N 2AU
Tel 0171 580 7124  Fax 0171 580 4420

**Utility Buyer’s Forum**
PO Box 526
Ingatestone, Essex CM4 9TP
Tel 01277 353399  Fax 01277 353989