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Using Micro Cogeneration Technologies to Enhance the Sustainable Built Environment

Esam Elsarrag and Yousef Alhorr
Gulf Organisation for Research and Development
Qatar Science and Technology Park, Doha
Qatar

1. Introduction

The accompanying CO_2 and other greenhouse gas emissions have been identified as a primary cause of global warming and the demand for electricity is expected to rise sharply within two decades. New energy-efficient, environmentally friendly power systems are, therefore, urgently required to ensure a sustainable built environment and also to meet the current building regulation standards.Buildings, new and old account for 50% of global energy consumption and related emissions. As citizens of the world, we have to reduce our reliance on ever dwindling supplies of fossil fuel. The imperatives for this are energy security and climate change. Estimates of the cut needed within our lifetime range 60% to 80% of current demand. Although, energy resources are more depleted and fossil fuel cost is increasing in addition to the effect of burning these fuels on the environment. The accompanying CO_2 and other greenhouse gas emissions have been identified a primary cause of global warming and the demand for electricity is expected to rise sharply within two decades. Different green building certification schemes are deployed in different countries including LEED in USA, BREEAM in UK, ESTIDAMA in Abu Dhabi, QSAS in Qatar, etc. to encourage creating a sustainable built environment and encourage the adoption and application of green building practices.
New building regulations are enabling new regimes of distributed power generation, to which fuel cell systems are ideally suited.
Conventional electricity generation is inherently inefficient, using only about a third of the fuel's potential energy. In applications where heating or cooling is needed as well, the total efficiency of separate thermal and power systems is still only about 45%, despite the higher efficiencies of thermal conversion equipment.
The recent development of efficient thermal prime movers for distributed generation is changing the focus of the production of electricity from large centralized power plants to local generation units.
Micro Combined Heat and Power (micro-CHP) technologies use fuel, e.g. natural gas, but provide electricity as well as heat. The two main systems use either reciprocating engines or Stirling engines, see Fig. 1. The size of the European Union (EU) market of domestic micro-CHP (1 to 10 kW) exceeded the 90 millions of units deploying about 6.2 millions of new installations per year with a development plan for 2020 shows a quick evolution of micro-

CHP solutions to a higher efficiency comparable to condensing boilers. CHP was assessed in field tests in Germany, the UK and some other EC countries [1].

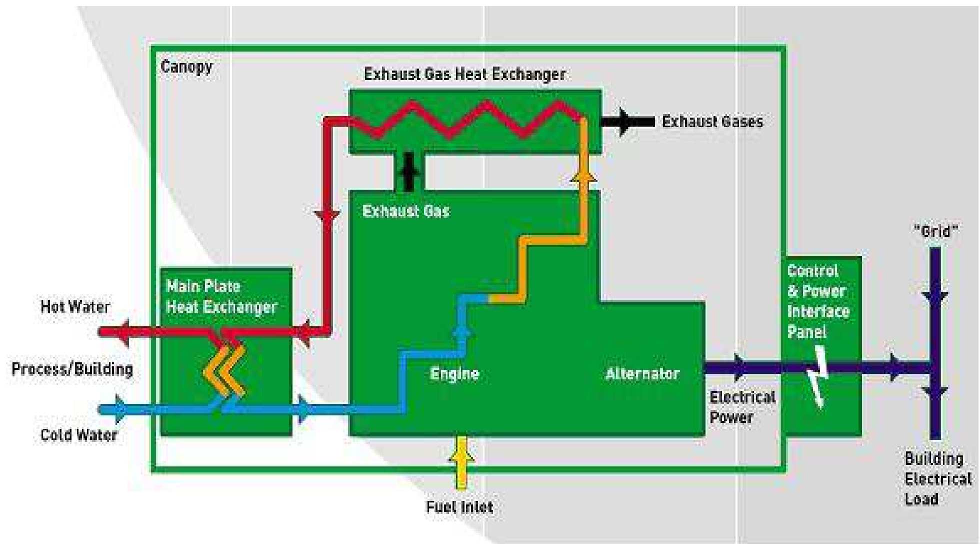


Fig. 1. Prime mover CHP diagram

Fuel cells, e.g. PEMFC, are also an alternative source of power; they provide a means of supplying electricity and heat and improving the built environment [2].

The current European policy pathway on the energy savings will enhance and accelerate this evolution with the implementation of highly efficient systems like the Proton Exchange Membrane Fuel Cells (PEMFC) and Solid Oxide Fuel Cells (SOFC) [3].

Fuel Cells are used primarily for transportation applications and some stationary applications due to their fast start-up time, low sensitivity to orientation, and favourable power-to-weight ratio. They have recently passed the test or demonstration phase and have partially reached the commercialization stage due to the impressive worldwide research effort [4]. They are different from batteries in that they consume reactant, which must be replenished, while batteries store electrical energy chemically in a closed system. Additionally, while the electrodes within a battery react and change as a battery is charged or discharged, a fuel cell's electrodes are catalytic and relatively stable.

Fuel cells also have an environmental advantage over batteries, since certain kinds of batteries require special disposal treatment. Fuel cells provide a much higher power density, packing more power in a smaller space.

Despite the currently promising achievements and the plausible prospects of PEMFCs, there are many challenges remaining that need to be overcome before they can successfully and economically substitute for the various traditional energy systems. With the many promising research efforts in overcoming these challenges, the most important tools for the commercialization will be the technical data and information from a real PEMFC application test [5].

The largest deployment of micro-CHP is in Japan at the year 2009, where over 90,000 units are in place where six Japanese energy companies launched the 300 W -1 kW PEMFC. In the UK, it is estimated that about 1,000 micro-CHP systems were in operation as of 2002. These are primarily Stirling and reciprocating engines [6]. Of the 24 million households in the UK, as many as 14 to 18 million are thought to be suitable for micro-CHP units.

Current building regulations enforce building designers to consider micro cogeneration as an alternative means of supplying energy especially. This chapter explores the importance of running a CHP plant to achieve maximum reduction in CO_2 emissions. A range of constraints, design and technical issues, is currently affecting the wide-scale deployment of microgeneration. Idle plant accrues no benefits, so it is important that the CHP plant operates for as many hours as possible. Such issue makes the design of a micro cogeneration technology is not quite as straightforward. The site heat and electricity demand must be properly assessed to prevent a CHP plant from being incorrectly sized.

Building designers are left with several questions; how to size a CHP plant? Does the integration of absorption chillers require over sizing the CHP unit? How much a CCHP plant contributes to carbon reduction? How to integrate a CHP or CCHP plant with other renewable sources such as biomass boilers to achieve a maximum reduction in CO_2 emissions in a development?

Section 2 of this chapter reviews the application of current micro cogeneration, the combination with district heating and incorporation of CHP into a trigeneration scheme. Section 3 assesses the use of a CHP unit when coupled to absorption/electric chillers, as well as the interactions with biomass boilers, to allow for setting up multi-generation systems for combined local production of different energy vectors. It investigates through a detailed study the maximum carbon reduction that could be achieved in a mixed use development. Section 4 examines the use of commercially available low-cost PEMFCs in dwellings to provide power for lighting in a dwelling and shows the advantages on both energy and carbon reduction when using the technology in dwellings.

2. Micro cogeneration review

Combined Heat and Power, CHP, have demonstrated superior efficiency for years in industrial plants, universities, hotels, hospitals and mixed use developments. They can be employed over a wide range of sizes, applications, fuels and technologies [7]. The resulting electricity can be used either wholly or partially on-site. It is particularly efficient when employed as a source for district heating to provide hot water, space heating and electricity for a number of linked buildings. Figure 2 shows the typical percentage of electricity and heat from a prime mover CHP.

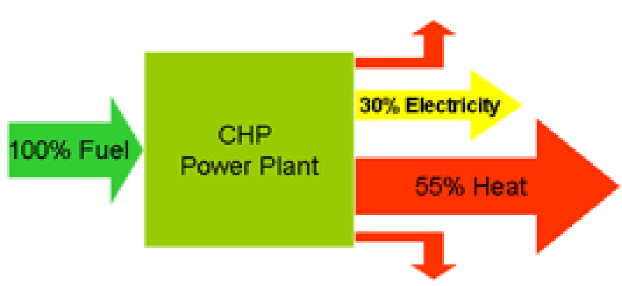


Fig. 2. Typical percentage of electricity and heat for a prime mover

The combination of cogeneration and district heating is very energy efficient. A thermal power station which generates only electricity typically converts 30 % of the fuel input into electricity. The major part of the energy is wasted in form of heat and dissipated to the environment. A cogeneration plant recovers that heat and can reach total energy efficiency beyond 85%. The heat is often obtained from a cogeneration plant burning fossil fuels but increasingly biomass, although heat-only boiler stations, geothermal heating and central solar heating are also used.

CHP can be incorporated into a trigeneration scheme to provide cooling alongside heat and power from the same energy source, see Fig. 3. Here excess heat produced is cooled by absorption chillers linked to the CHP system. This provides chilled water for cooling to be circulated around a building or community. This is particularly useful for schemes that require a large amount of air conditioning. This is also known as combined cooling, heat and power (CCHP) [8].

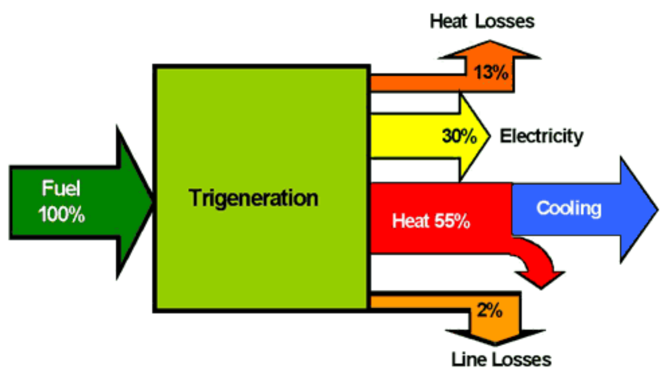


Fig. 3. Trigeneration diagram

CCHP could be combined with district or central cooling systems, as any system which provides building cooling through the distribution of chilled water, hot water or steam from a central plant. Thus, cooling achieved through distribution of district hot water or steam to drive absorption chillers located in buildings is also considered district cooling.

Usually space heating and hot water storage tanks serve as a heat sink for reasonable waste heat utilization. In summer, the heat demand is much lower but the heat of the electric generation process can be transformed into cooling energy by an absorption chillers. The absorption cycle, see Fig. 4 uses a heat driven concentration difference to move refrigerant vapours from the evaporator to the condenser.

The high concentration side of the cycle absorbs refrigerant vapours. Heat is then used to drive off these refrigerant vapours thereby increasing the concentration again.

Lithium bromide is the most common absorbent used in commercial cooling equipment, with water used as the refrigerant. Smaller absorption chillers sometimes use water as the absorbent and ammonia as the refrigerant. Heat fired absorption chillers can be provided from a central plant or by local heat fired absorption chillers connected to the district heating network.

The trigeneration is of concern and attraction of a lot of researchers in terms of application, economic and performance. In the application fields, an investigation in a typical supermarket for cooling, heating and power requirements was described and a number of CCHP options involving the use of different cooling and engine technologies were reviewed [9]. The investigation calculated and compared the energy savings of the different options against typical conventional supermarket technology. Typical energy demand profiles and economical proposals of trigeneration plants for an airport and typical results for a large airport was presented [10].

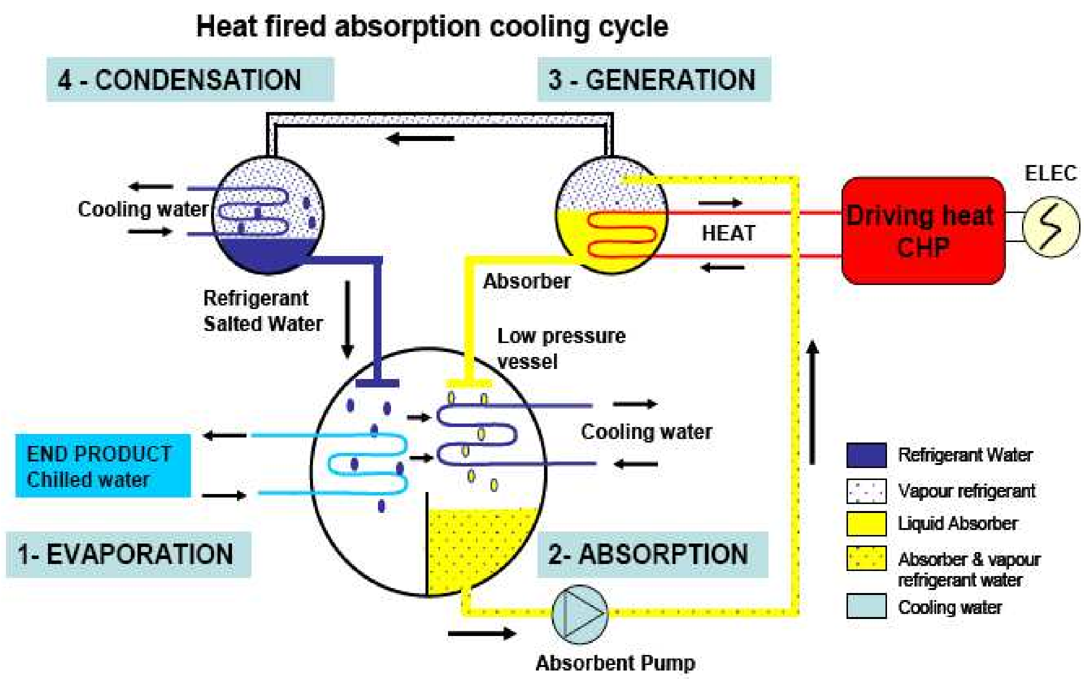


Fig. 4. Absorption cooling cycle

The evaluation of the energy efficiency and economic feasibility of a small scale trigeneration system for CCHP with a Stirling engine showed that a CCHP system saves fuel resources and has the assurance of economic benefits [11]. A study [12] proposed a modified exergo-economic optimisation overcoming the difficulties encountered when applying the traditional ethodologies to CCHP plants serving civil buildings, characterised by irregular demand-profiles.

The performance of CHP and CCHP systems was carried out by several researchers including static calculation methodology for evaluating the primary energy consumption for CCHP and separate productions and analysis of energy saving performances of various types and sizes systems in heating and cooling modes and improving energy use in cogeneration systems [13]. Investigations on the potential of CHP and CCHP systems for reducing the energy use and the emission of hazardous greenhouse gases were carried out [14-16]. In the experimental tests to evaluate the performance and emissions of a diesel engine generator and the performance of the trigeneration system the CO_2 emissions per unit kWh of useful energy output from trigeneration were reduced by 67.2–81.4% compared to those from single generation [15]. A study suggested the inclusion of an additional gas boiler and calculated the prices of the energies produced from such a trigeneration system [17].

Residential and small-scale commercial fuel cells are now becoming available to fulfill both electricity and heat demand from one system. Fuel cell technology in a compact system converts natural gas, propane, and eventually biofuels into both electricity and heat. Fig. 5 shows the chemical process for different fuel cells [18].

There is much interest in proton exchange membrane fuel cells (PEMFCs). There have been pre-commercial demonstrations for stationary power and CHP applications in Canada and Germany of small 3 kWe systems and larger 250 kWe systems. PEMFCs deliver high power density and offer the advantages of low weight and volume, compared to other fuel cells. PEMFCs, see Fig. 6, use a solid polymer as an electrolyte and porous carbon electrodes containing a platinum catalyst. Materials used include a fluorocarbon polymer backbone,

similar to Teflon, to which sulfonic acid groups are attached. The use of a solid polymer electrolyte eliminates the corrosion issues associated with liquid electrolyte fuel cells.
They need only hydrogen and oxygen from the air to operate and do not require corrosive fluids like some fuel cells. They are typically fuelled with pure hydrogen supplied from storage tanks or onboard reformers.

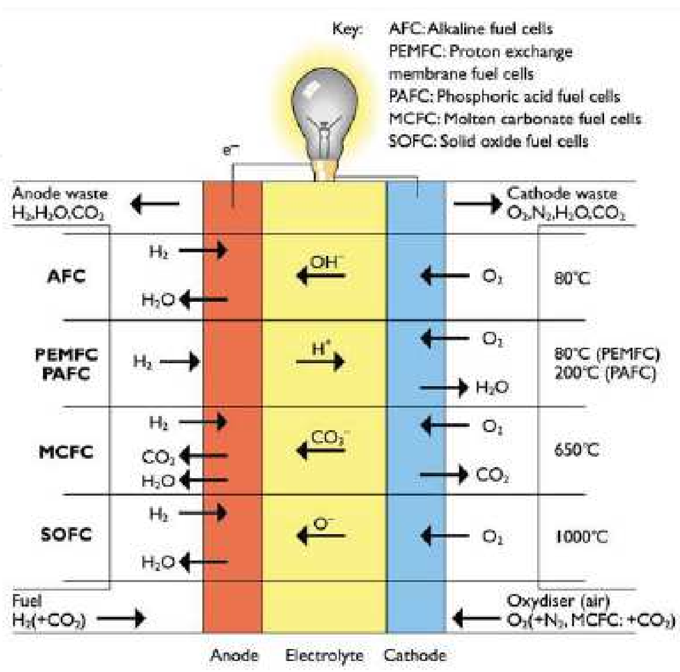


Fig. 5. Chemical process for different fuel cells

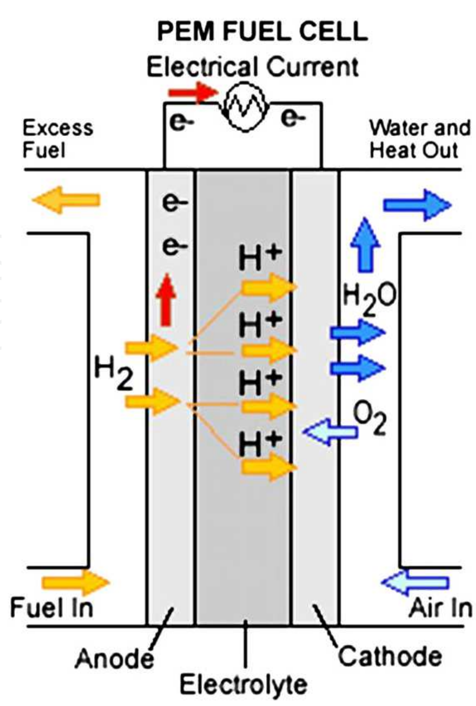


Fig. 6. The proton exchange fuel cell

Because the proton exchange membrane fuel cell uses a solid electrolyte, a significant pressure differential can be maintained across the electrolyte. This allows the operation of the fuel cell with low-pressure fuel and high-pressure air in order to optimise performance. In practice there is a trade-off between the energy and financial cost associated with compressing air and the improved performance. They operate at relatively low temperatures, around 80°C (176°F) which allows them to start quickly and results in less wear on system components, resulting in better durability. However, they require that a noble-metal catalyst (typically platinum) be used to separate the hydrogen's electrons and protons, adding to system cost. The platinum catalyst is also extremely sensitive to CO poisoning, making it necessary to employ an additional reactor to reduce CO in the fuel gas if the hydrogen is derived from an alcohol or hydrocarbon fuel. This also adds cost. Developers are currently exploring platinum /ruthenium catalysts that are more resistant to CO [18].

Fuel cell systems are presently the focus of intense research efforts among industrial, academic, and government organizations, but this work is primarily concentrated on technical hurdles to fuel cell commercialization.

A description, detailed design, energy savings and an economic analysis proving the technical and economical feasibility of the installation of the design of a laboratory-scale high-pressure electrolyser was investigated by researchers [19]. An examination of the performance of a PEM water electrolysis cell using $Ir_xRu_yTa_zO_2$ anode electro-catalysts showed that the best cell voltage they achieved was 1.567 V at 1 Acm^{-2} [20].

Fuel cells have a heat to power ratio of roughly 1:1 with overall efficiencies of around 80% when fired on hydrogen. Fuel cells powered with pure hydrogen have potential power efficiencies up to 45% i.e. 45% of the hydrogen is converted into electrical energy. However, when we add a reformer to convert other fuels to hydrogen, this can drop significantly. Fuel cell systems can maintain high efficiencies at loads as low as 50%, exhibiting characteristics that are ideal for use in buildings where much of the time is spent at low load [21].

3. Application of micro cogeneration in a mixed use development

Deploying CHP and CCHP systems in mixed use development or any application requires more attention and proper design by engineers. This section will provide analysis of deploying the proper size of CCHP and biomass for maximum carbon reduction in a mixed use development.

The development is residential flats and offices. Figure 7 below shows the annual energy demand by percentage of different mixed use development based on the percentage net internal floor area. It can be observed that the hot water demand decreases with the increase of the offices area but the cooling demand percentage remains approximately constant. The carbon emission produced from the thermal load decreases with the increase of the offices area, Fig. 8.

Atypical case study of 50% offices and 50% residential, by area, will be discussed and analysed. A district heating plant is proposed for the development as they can provide higher efficiencies, diversity of fuel type, and better pollution control than localised boilers. It will distribute the heat generated in a centralized location for the residential and commercial heating requirements such as space and water heating. The core element of a district heating system is usually a cogeneration plant, CHP, or a heat only boiler station. Both have in common that they are typically based on combustion of primary energy

carriers. The difference between the two systems is that, in a cogeneration plant, heat and electricity are generated simultaneously, whereas in heat only boiler stations - as the name suggests - only heat is generated.
In this study a CHP is coupled to absorption/electric chillers, as well as the interactions with renewable sources, to allow for setting up multi-generation systems for combined local production of different energy vectors such as electricity, heat, cooling power.
The main objective of adopting composite multi-generation systems as it may lead to significant benefits in terms of higher energy efficiency, reduced CO_2 emissions, and enhanced economy.

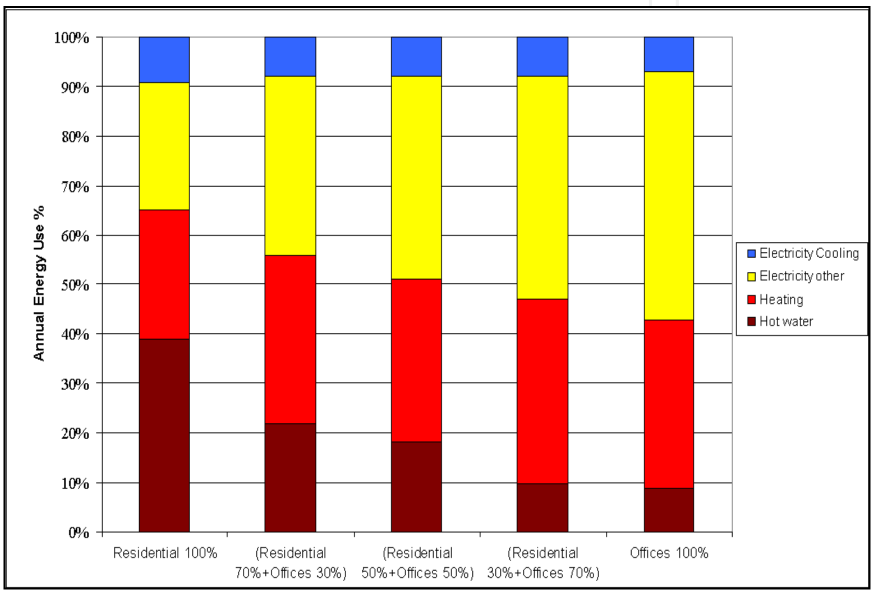


Fig. 7. Annual energy percentage for different mixed schemes

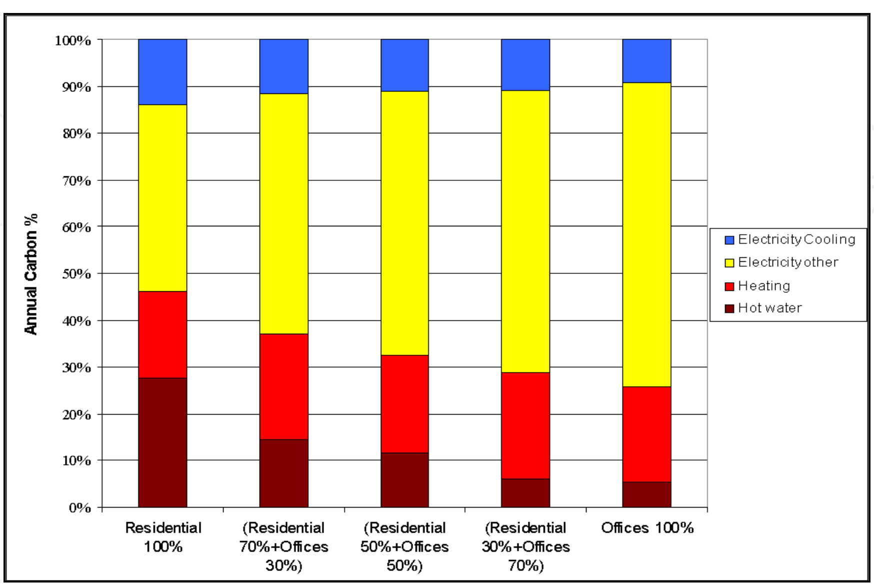


Fig. 8. Annual CO_2 emissions percentage for different mixed schemes

Biomass boilers are also proposed to be used in the development. They use a biological material derived from living, or recently living organisms, as the fuel. In the context of biomass for energy this is often used to mean plant based material, but biomass can equally apply to both animal and vegetable derived material. Energy produced from biomass residues displaces the production of an equivalent amount of energy from fossil fuels, leaving the fossil carbon in storage. Whereas fossil fuels are becoming increasingly expensive, some forms of biomass fuels are sustainable, renewable and almost carbon-neutral. This makes biomass a very sensible and economically viable option for many heating projects in relation to homes, communities, offices and industry. A typical biomass fuel is wood, in the form of logs or wood chips, but other energy crops such as straw can be used to fire biomass boilers. All of these biomass input fuels are renewable and almost carbon-neutral, in that the CO_2 which is released via the combustion process is cancelled out by the CO_2 which is absorbed by the plant when it is growing. Consequently, biomass could replace much of our current use of fossil fuels, in several different forms.

The proposed heating and cooling strategy for the proposed development is shown in the diagram below, Fig. 9. The main fuel is natural gas and the CHP is the lead boiler, top up by the biomass and then the gas boiler to meet the peak demand. The electricity produced by the CHP will be connected to the grid.

In summer; the heat produced by the CHP is used to meet the hot water demand and portion of the cooling need.

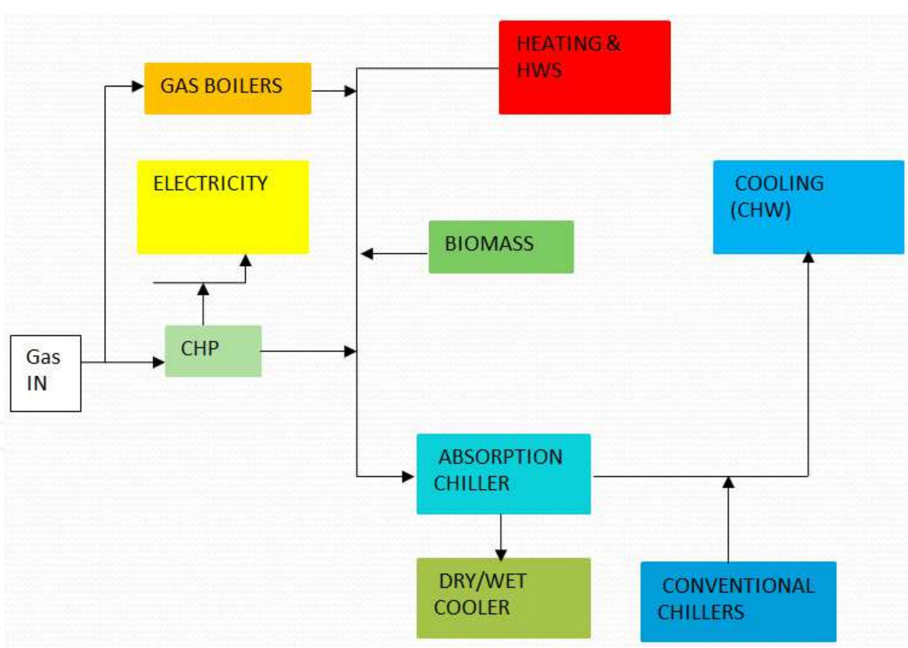
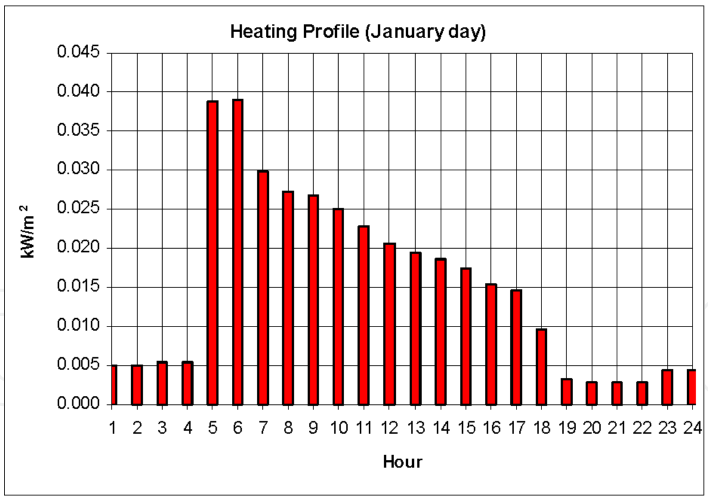
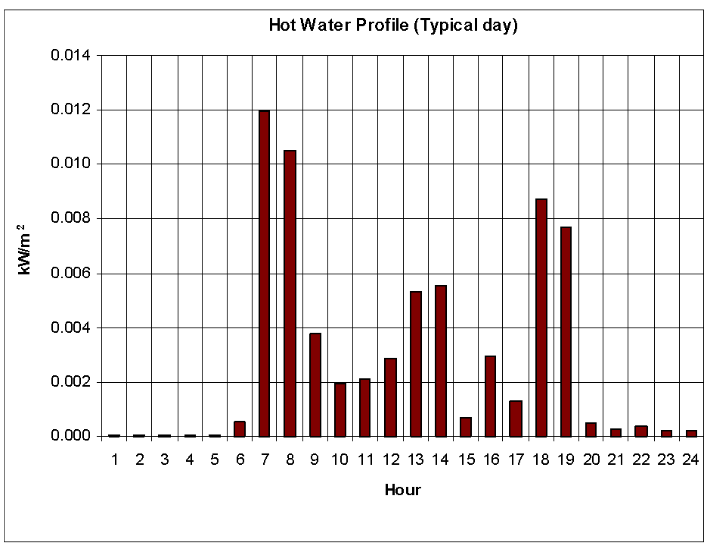


Fig. 9. Schematic diagram of the proposed district plant

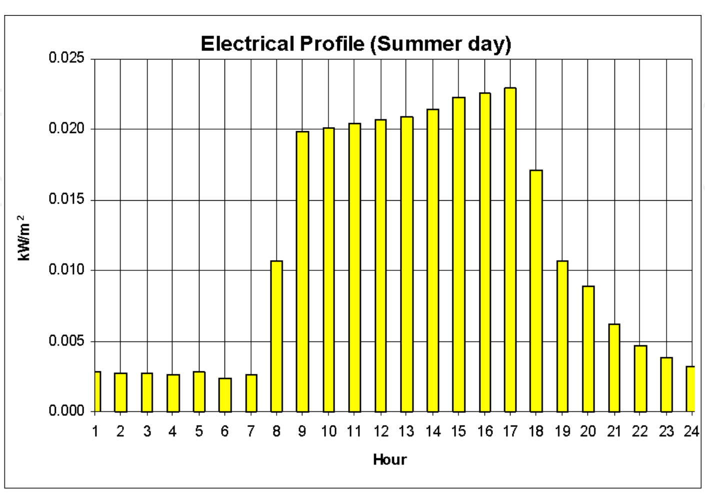
The key to a successful building gas CCHP plant selection exists in that the detailed building heat, cool and power load status and appropriate unit capacity to ensure high hourly operation and waste heat recovery. Fig. 10 shows the combined hourly heating, hot water and power load for office building and residential building (50% of the floor area each) in a typical winter day in London.



Heating



Hot water



Power

Fig. 10. Hourly profile for a typical winter day

3.1 Carbon emission calculation

3.1.1 Carbon reduction from CCHP

The carbon reduction from a CHP plant can be calculated from the simplified formula below developed by the authors.

$$R_{CHP} = \frac{G \times CHP_{th}\%}{HPR} \times \left(CF_g \times HPR \times \left(1 - \frac{1}{\eta_b} \right) + \left(CF_e - CF_g \times \eta_b \right) \right) \quad (1)$$

Where R is the carbon reduction kg/year; G is the total gas energy in the base building, kWh/year; HPR is the heat to power ratio generated by the CHP; $CHPth\%$ is the percentage of heating demand met by CHP, CF_g is the carbon factor for gas; CF_e is the carbon factor for electricity and η_b is the boiler efficiency.

The percentage carbon reduction, $R_{CHP}\%$ can be defined as the ratio of the carbon reduction obtained by the CHP, $RCHP$, to the total carbon from the base building generated by natural gas, G, and electricity, E.

$$R_{CHP}\% = \frac{R_{CHP}}{CF_g \times G + CF_e \times E} \quad (2)$$

The absorption cooling percentage, $AC\%$, is calculated considering the domestic hot water demand in summer. The carbon reduction achieved from using the absorption chiller, R_{AC}, is calculated by:

$$R_{AC} = AC\% \times C \times (CF_e - COP_{cc} \times (\frac{ACCF}{COP_{AC}} + CF_e \times Par\%) \quad (3)$$

Where $ACCF$ is the carbon dioxide burden of the heat supply to the absorption chiller, $kgCO_2/kWh$; η_e is the CHP electrical efficiency; η_{th} is the CHP thermal efficiency; COP_{cc} is the seasonal energy efficiency ratio of the conventional chiller; COP_{AC} is the coefficient of performance of the absorption chiller; and $Par\%$ is the percentage of the parasitic power used by the absorption chiller.

$$ACCF = (\frac{CF_g}{CHPe\%} - CF_{re}) \times Ratio \quad (4)$$

The total CO_2 reduction, R_{CCHP}, is the sum of the carbon reduction due to the operation of the CHP and absorption chiller.

$$R_{CCHP} = R_{AC} + R_{CHP} \quad (5)$$

The percentage of total CO_2 reduction, $R_{CCHP}\%$, is given by:

$$R_{CCHP}\% = \frac{R_{CHP} + R_{AC}}{CF_g \times G + CF_e \times E} \quad (6)$$

3.1.2 Carbon reduction from biomass boiler

The percentage contribution of the annual thermal load by biomass, $Bio\%$, is the difference between the maximum percentage, $Max\% <100\%$, and the CHP percentage.

$$Bio\% = (Max\% - CHP\%) \tag{7}$$

$$R_{Bio} = (CF_g - CF_{bio}) \times Bio\% \times G \tag{8}$$

$$R_{Total}\% = \frac{R_{CHP} + R_{AC} + R_{Bio}}{CF_g \times G + CF_e \times E} \tag{9}$$

Where CF_{bio} is the carbon factor for biomass, R_{Bio} is the carbon reduction for biomass and R_{Total} is the total carbon reduction.

3.2 Results

Table 1 shows the case study development area assumptions used for the proposed development and substituted in equations 1 to 9. The results are depicted graphically in figures 11 to 15. Figure 11 shows the annual and monthly energy consumption. The heating and domestic hot water demand is about 50% of the annual demand.

	Residential	Offices
Area weight	50%	50%
Gas Benchmark kWh/m^2	75	82
Electricity Benchmark kWh/m^2	30	98
Cooling Benchmark kWh/m^2	10	14
DHW%	60%	11.4%
CHP η_e	30%	
CHP η_{th}	45%	
Heat to power Ratio HPR	1.5	
Conventional Chiller COP	3	
Absorption Chiller COP	0.68	
Carbon dioxide factor for conventional boiler $kgCO_2/kWh$	0.194	
Carbon dioxide factor for grid electricity $kgCO_2/kWh$	0.422	
Carbon dioxide factor for displaced grid electricity $kgCO_2/kWh$	0.568	
Maximum thermal percentage Max%	80%	

Table 1. The mixed use development

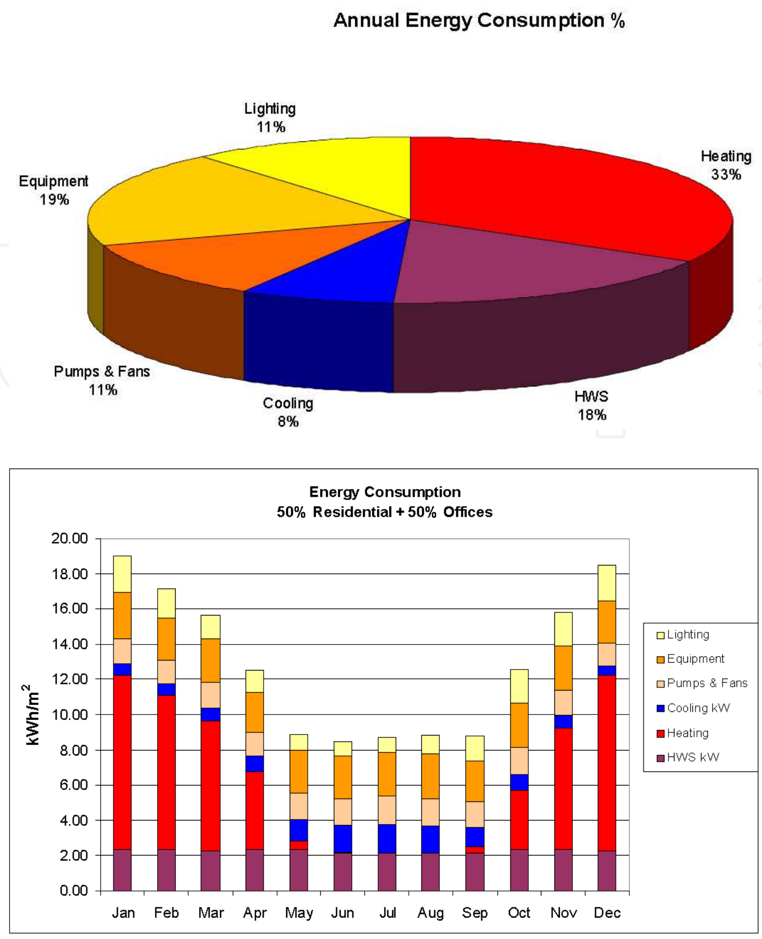


Fig. 11. Annual and monthly energy consumption

The relation between the peak load and annual thermal demand for the mixed use development is shown in Fig. 12. It can be observed that 80% of the annual thermal demand can be attained by 40% of the peak heating load.

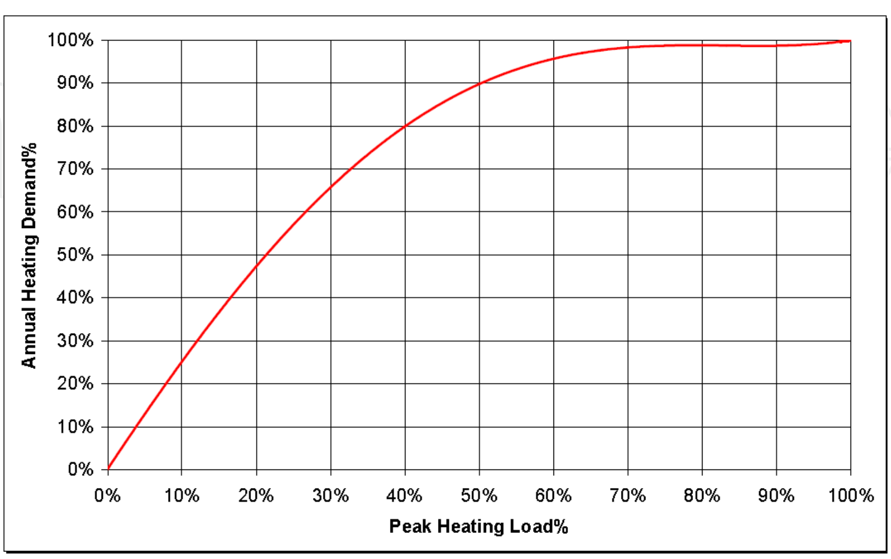


Fig. 12. Demand duration curve

For maximum carbon reduction the thermal load should be met by low carbon source. The operational condition of CCHP system with cooling and heating network interconnecting in one typical day in summer is illustrated in Fig. 13. It can be observed that by maximising the CHP more waste heat is generated in summer and using CCHP system will recover the waste heat in an absorption chiller.

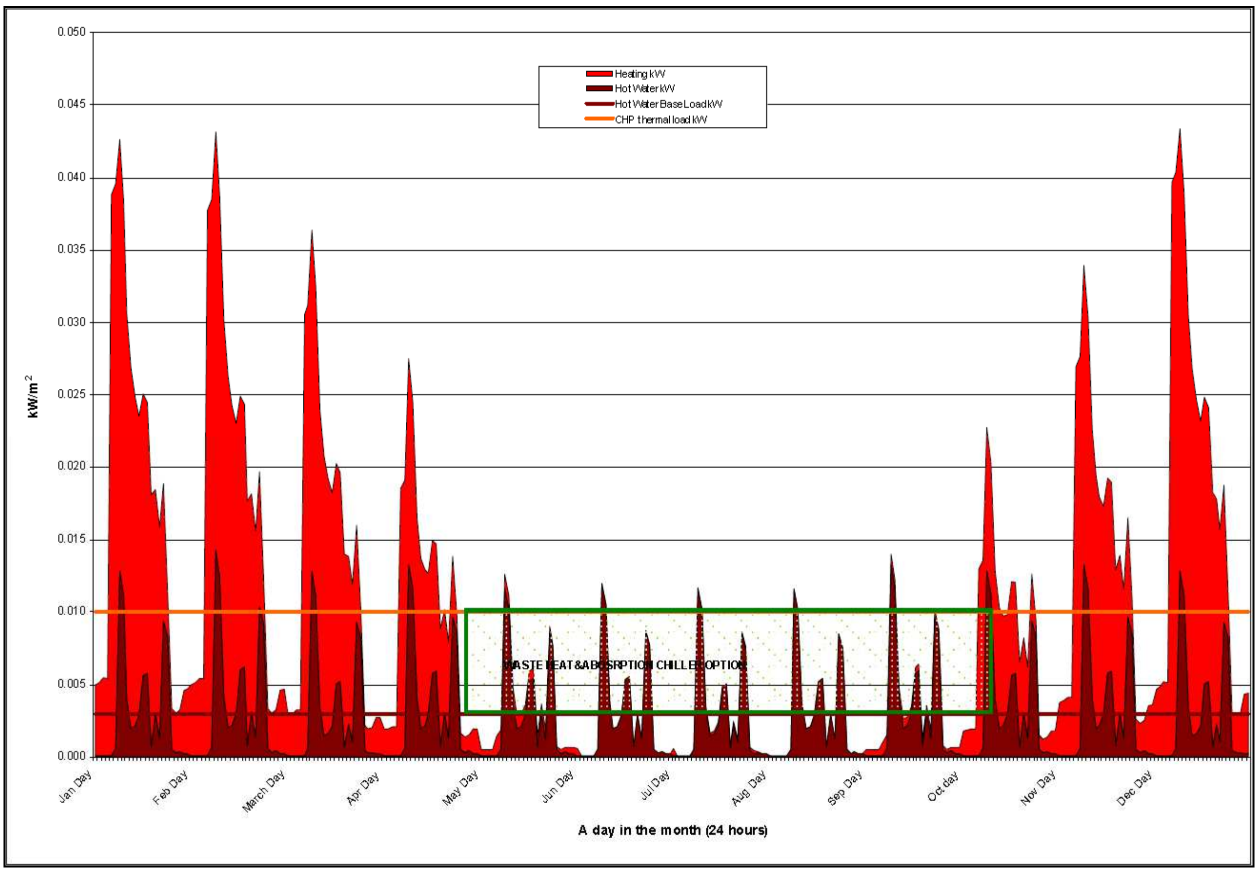


Fig. 13. Waste heat in summer

Equations (6) to (9) are depicted graphically in Fig. 14. As shown the maximum thermal load contribution by the CHP and/or biomass is limited by 80%. The maximum CO_2 reduction obtained by the CCHP is 26.0% however; the absorption cooling does not exceed 1.5% reduction attributable to the total emissions mainly because of the parasitic power used by the absorption chiller and the low coefficient of performance compared to modern vapour compression machines.

The use of a biomass boiler will reduce the CO_2 emissions from the development by 27.5% which supplies 80% of the annual thermal demand. However, unlike most gas fired boilers, wood boilers are limited in their ability to rapidly modulate heat output.

Therefore sizing should be considered to meet the base load and provide more responsive plant, such as gas-fired boilers, to meet peaks in demand. On another hand, the duty of the CHP plant is limited by the demand for heating so that normally only a small fraction of the electrical demand can be produced by the CHP without dumping heat. Therefore the point of intersection could be considered as the optimum operation of the CHP and biomass boiler. At this point 50% of the CO_2 emissions reduction is from the CCHP (42% of the annual thermal load) and the other 50% from the biomass boiler (38% from the annual

thermal load). The total CO_2 reduction is about 26%. However, at this point the contribution of absorption cooling in CO_2 reduction does not exceed the 0.5%.
The contribution of the CHP and biomass as a percentage of the annual thermal load is shown in Fig. 15.

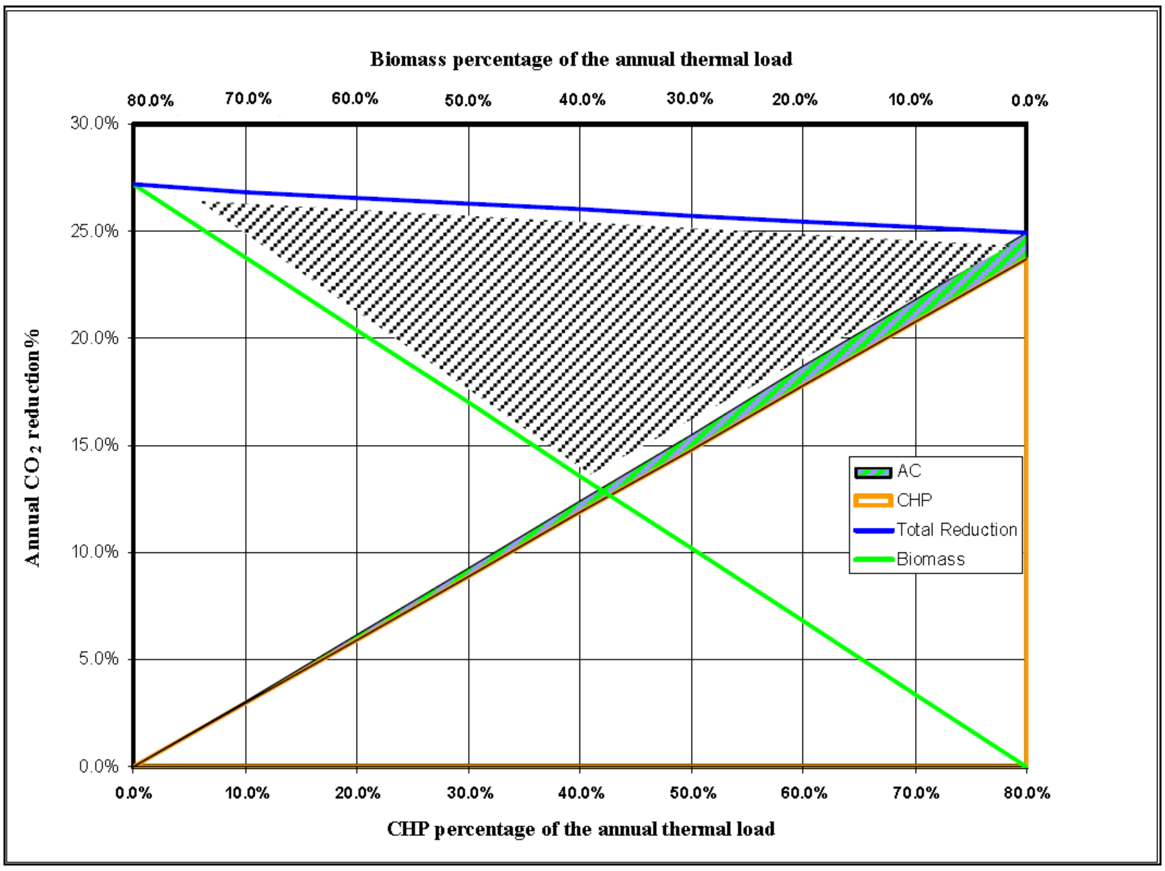


Fig. 14. Optimum CHP-biomass boiler

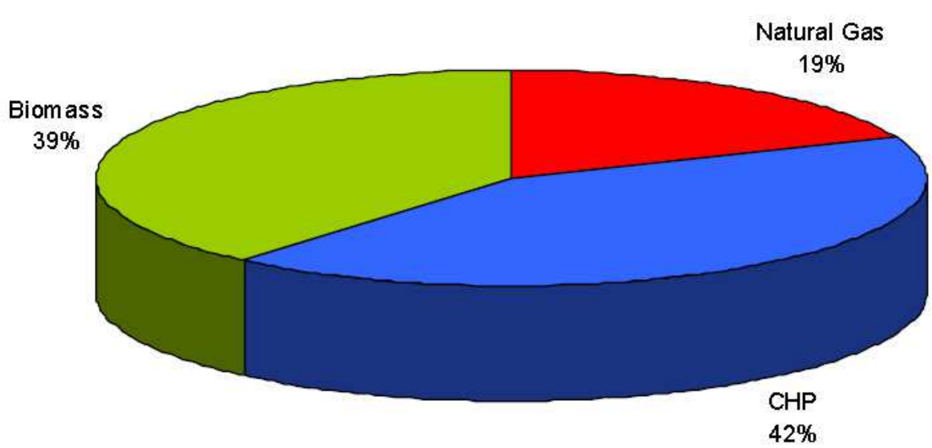


Fig. 15. Contribution of CHP and biomass as percentage of the annual thermal demand

4. Application of using fuel cells in dwellings

The main purpose of this study is to examine the use of commercially available low-cost PEMFCs in dwellings. The PEMFC will be used to provide power for lighting in a dwelling. The dwelling under study has an area of 150 m². The calculation of lighting use in a dwelling is based on the proportion of fixed low energy lighting outlets installed, and on the contribution of daylight.

4.1 Energy and CO_2 lighting calculations

Allowing for fixed low-energy outlets In UK houses, the average energy consumption for lighting is taken as 9.3 kWh/m² annually if no low-energy lighting is used [21].

$$E_B = 9.3 \text{ kWh} / \text{m}^2 \tag{10}$$

The Standard Assessment Procedure, SAP 2005calculation takes account of fixed lighting outlets with low energy lamps, by including a correction factor C_1 [22]:

$$C_1 = 1 - 0.5 \times \frac{N_{LE}}{N} \tag{11}$$

Where N_{LE} is the number of fixed low energy lighting outlets and N is the total number of fixed lighting outlets.
Analysis of typical house types gives the following approximate correction factor, C_2, for lighting energy use depending on the ratio of glass area to floor area, glass transmittance and light access factor.

$$C_2 = 52.2G^2 - 9.94G + 1.433 \text{ if } G \le 0.095, \ C_2 = 0.96 \text{ if } G > 0.095 \tag{12}$$

$$G = \frac{\sum 0.9 \times A_w \times g_L \times FF \times Z_L}{TFA} \tag{13}$$

Where *FF* is the frame factor, A_w is the area of a window, m², *TFA* is the total floor area m², g_L is the light transmittance factor, Z_L is the light access factor. The annual energy used for lighting in the house, E_L kWh/year, is then:

$$E_L = E_B \times TFA \times C_1 \times C_2 \tag{14}$$

The reduction in lighting energy, kWh/year, use due to low energy lights is:

$$\Delta E_L = E_B \times TFA \times (1 - C_1) \times C_2 \tag{15}$$

The power and hydrogen consumed is calculated by [23]:

$$P = Vc \times I \times n \tag{16}$$

$$H_{used} = 1.05 \times 10^{-8} \times I \times \frac{T}{\rho_h} \tag{17}$$

Where *P* is the power in Watts, V_c is the cell voltage in Volts, *I* is the current in mA, *n* is the number of cells, H_{used} is the hydrogen used in Litre, T is the time in seconds and ρ_h is hydrogen density in kg/m³.

4.2 Results

The energy reduction due to the use of 50% energy saving light fittings is about 25%, as shown in Fig. 16. The calculated energy and CO_2 emissions after using the low energy light fittings are shown in Fig. 17. The results show that the annual electrical energy demand is 4,500 kWh, the percentage of the lighting energy of the total electrical energy is about 26%.

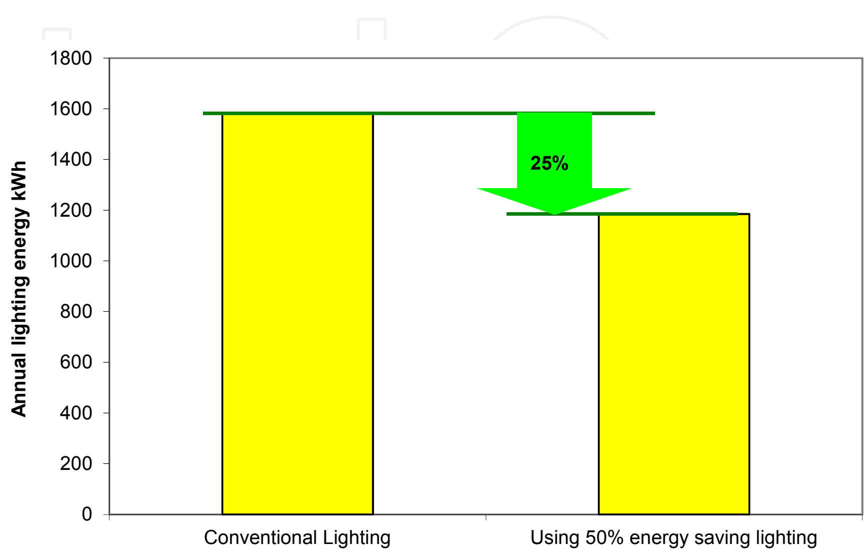


Fig. 16. Lighting energy consumption

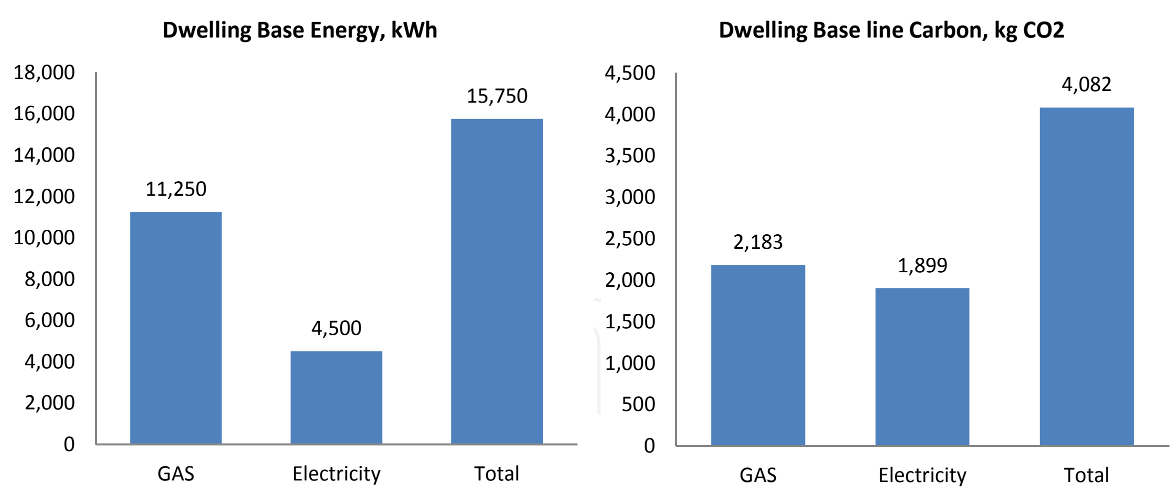


Fig. 17. Dwelling energy consumption and carbon emissions

The use of 100W PEMFC, as baseline, to generate electricity for the lighting will reduce the dwelling energy and CO_2 emissions. The calculations require finding out the annual demand that will be served by the PEMFC. The annual energy demand calculated from Eq. 14 is used to produce the hourly profile shown in Fig.18 [24]. The percentage of electrical demand met by the PEMFC is about 11% and reduces the annual CO_2 emissions by 8.7% as shown in Fig. 19. The results encourage the use of fuel cell in dwellings.

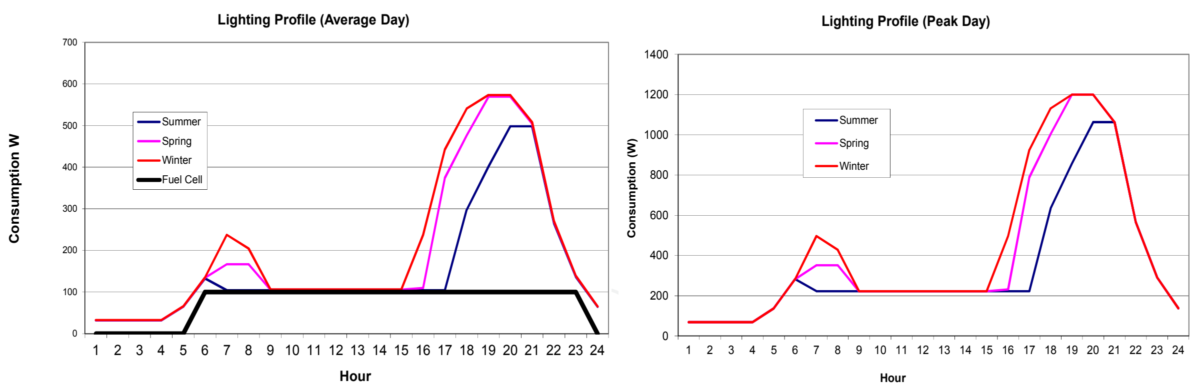


Fig. 18. Lighting energy consumption profile

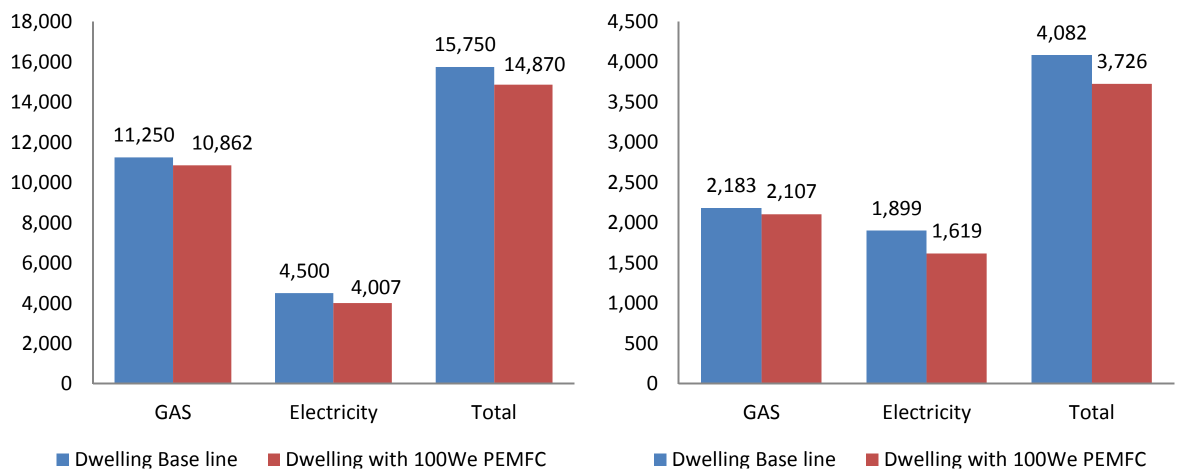


Fig. 19. Dwelling energy and carbon emissions reductions

5. Conclusions

Commercial building's heat and power demand is the most recently developed, both from the market perspective as well as in terms of the technology itself. The amount of power produced in a commercial building's cogeneration system can be less than, equal to, or greater than the local demand. The heat obtained from the system is generally used for heating large volumes of water destined for a variety of uses, including absorption cooling. CHP systems can be employed over a wide range of sizes, applications, fuels and technologies. The resulting electricity can be used either wholly or partially on-site. It is particularly efficient when employed as a source for district heating to provide hot water, space heating and electricity for a number of linked buildings. This chapter discussed the consideration of CHP as a leading option and alternative means of supplying energy. A full CHP feasibility study was carried out. However, before CHP assessment was done, all passive design and energy efficiency measures were conducted. The development heating and hot water demands were assessed to prevent the CHP from being incorrectly sized.

It is assumed that the electricity generated is utilised on site or exported back to the electricity grid and this can be worthwhile, particularly where on-site demand is low. The current electricity incentive, supplying electricity to the grid, means matching CHP capacity to heat load although the most cost effective solution often involves some modulating capability and/or heat storage. The CHP was sized using daily demand profiles in order to accurately determine the actual amounts of heat that can be supplied to the building. Thermal store has been considered to smooth the demand profiles as it has a significant effect on the overall performance of the CHP system and its contrbution in reducing CO_2 emissions.

This chapter investigated the contribution of micro combined heat and power and renewables into CO_2 reduction in a mixed use development and dwellings and provided guidance to the designers of employing energy waste and low equipment usage in a traditional combined cooling, heating and deploying CCHP and biomass heating technologies for both energy efficiency and carbon reduction in different applications.

Here, the micro CHP operates as the lead boiler to maximise savings. The biomass boiler tops up the heating energy demand and the gas boiler will meet the spike and peak loads.

Detailed energy demand daily and monthly profiles for heat are established to accurately sizing CHP. In order to increase the size of the CHP further analyses have been developed to identify alternative conditions that would improve the viability considering the energy profile of the development and thermal store size in winter and the feasibility of using heat-driven absorption chilling plant, CCHP, to extend the base load heat demand into the summer months.

The mixed use development case study showed that the use of absorption chillers will result in additional small reduction in CO_2 and the maximum reduction did not exceed 1.5%. The maximum CO_2 reduction obtained by using the combination of CHP and biomass boilers was about 26%. The study suggests a careful consideration when sizing CCHP and biomass technologies and provides a methodology to estimate the contribution of each technology into carbon reduction. In this study the CHP unit size was considered to meet the base load and provide more responsive plant, such as gas-fired boilers, to meet peaks in demand.

The current study also encourages the use of fuel cells in dwellings and other application as it will have a significant impact on reducing carbon emissions. For instance, the study, showed that the use of 100W PEMFC in a dwelling for lighting power reduced the electrical demand by 11% and the dwelling CO_2 emissions by 8.7%. The results give important pointers to how micro cogeneration technologies can be used in residential, commercial and other applications in tandem with other energy-saving technologies.

Adopting composite multi-generation systems will lead to significant benefits in terms of higher energy efficiency, reduced CO_2 emissions, and enhanced economy considering that the duty of the CHP plant is limited by the demand for heating so that normally only a small fraction of the electrical demand can be produced by the CHP without dumping heat. The limitations of cogeneration technology in the commercial sector such as low power requirements have been overcome by the incentive programs which encourages deploying CHP and CCHP plants in such regions when applicable.

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The failure of the UN climate change summit in Copenhagen in December 2009 to effectively reach a global agreement on emission reduction targets, led many within the developing world to view this as a reversal of the Kyoto Protocol and an attempt by the developed nations to shirk out of their responsibility for climate change. The issue of global warming has been at the top of the political agenda for a number of years and has become even more pressing with the rapid industrialization taking place in China and India. This book looks at the effects of climate change throughout different regions of the world and discusses to what extent cleantech and environmental initiatives such as the destruction of fluorinated greenhouse gases, biofuels, and the role of plant breeding and biotechnology. The book concludes with an insight into the socio-religious impact that global warming has, citing Christianity and Islam.