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ELSENHAM ECO-TOWN

INTERIM ENERGY ASSESSMENT

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TABLE OF CONTENTS

1 INTRODUCTION

This report provides an outline of an initial broad brush energy assessment carried out for Elsenham Eco-town. It considers the policy requirements and associated standards of meeting the Eco-town intent set forward in the CLG's Prospectus. That is, "to create a complete new settlement to achieve zero carbon development and more sustainable living using the best new design and architecture." This energy assessment responds to the key criteria outlined with regards to CO_2 emissions and the built environment.

The concept driving the energy assessment can be described as an 'Energy Patchwork', which reflects the use of a suitable combination of heat and power generating technologies that fit the scale and location within the development, whilst also meeting the ambitions of the Eco-town standards. This concept leads to technologies and systems that are responsive to character area and are integrated with phasing and predicted energy demand.

Our assessment considers the need to provide a zero carbon development based on the 5,000 dwellings proposed as part of the Elsenham Eco-town schemes. Within this initial assessment five scenarios are analysed, incorporating different technology mixes, all of which have the potential, in technical terms, to be able to meet the zero carbon standards for the development. The principle purpose is to demonstrate the potential for the development to achieve zero carbon in a number of different ways. The final scenario choice will be dependent on further feasibility investigations.

2 STANDARDS

The Eco-town process seeks to ensure that very high levels of sustainability are met in the selection and development of an Eco-town.

Where,

> *"Eco-towns are considered to be a major opportunity for local authorities, house builders, developers and registered social landlords to come together to build small new towns. Eco-towns should be well designed, attractive places to live, with good services and facilities, and which connect well with the larger towns or cities close by. Uniquely, they offer an opportunity to design a whole town – business and services as well as homes – to achieve zero-carbon development, and to use this experience to help guide other developments across the country.*
>
> *The essential requirements that should be met are:*
>
> - *Eco-towns must be new settlements, separate and distinct from existing towns but well linked to them. They need to be additional to existing plans, with a minimum target of 5,000–10,000 homes;*
> - *The development as a whole should reach zero carbon standards and each town should be an exemplar in at least one area of environmental sustainability;*
> - *Eco-town proposals should provide for a good range of facilities within the town – a secondary school, a medium scale retail centre, and good quality business space and leisure facilities;*
> - *Affordable housing should make up between 30 and 50 per cent of the total through a wide range and distribution of tenures in mixed communities, with a particular emphasis on larger family homes;*
> - *A management body which will help develop the town, provide support for people moving to the new community, for businesses and community services."*

[Draft Planning Policy Statement: Eco-town Consultation, CLG, 2008]

The Eco-town has developed its own definition of zero carbon which is that 'living a greener future: progress report' outlines that "planning applications will be expected to demonstrate that over a year the net carbon dioxide emission for ALL energy use within the buildings on the development are zero or below."

The PPS outlined that the calculation of emissions should take account of:

- Emissions associated with the use of locally produced energy
- Emissions associated with the production of energy imported from centralised energy networks
- Emissions displaced by exports of locally produced energy to centralised energy networks.

The energy strategy scenarios explored in the following sections illustrate ways to meet net zero CO_2 emissions, based on the above carbon emissions principles.

3 ENERGY STRATEGY PRINCIPLES

3.1 ENERGY HIERARCHY

The energy strategy at Elsenham will follow a three step hierarchical principle, commonly defined by the ' Be Lean, Be Clean, Be Green' mantra. The first step involves the consideration of energy demand reduction, by applying passive design principles and energy efficiency measures, to achieve a 'Lean' design.

The ways to introduce efficient supply technologies are investigated in order to achieve best practice and efficient use of fuels where applicable. This is typically by using waste from power generation by applying decentralised generation.

Once demand reduction and efficient supply technologies has been applied, appropriate combinations of renewable energy technologies are assessed. This hierarchy will applied at Elsenham eco-town with due consideration of technical and commercial feasibility as well as long term operation and management.

These energy hierarchy principles are summarised in the followed table and diagram.

Actions	How	Means
1. Use less energy		
Be Lean	Reduce energy consumption	Energy efficiency measures: • Increased air tightness • Improved building fabric standards • Ventilation systems incorporating heat recovery systems • More energy efficient heating and lighting systems with advanced controls
Be Clean	Supply energy efficiently	Decentralised energy generation: • CHP / CCHP • Community heating system
2. Use renewable energy		
Be Green	Supply renewable energy	Building-integrated or centralised renewable energy technologies: • Aquifer thermal energy storage • Ground source heat pumps • Biomass/waste/biogas heating • Biomass CHP/CCHP • Solar water heating • Photovoltaic panels • Wind turbine

Table 1 - Strategic Energy Hierarchy Methodology

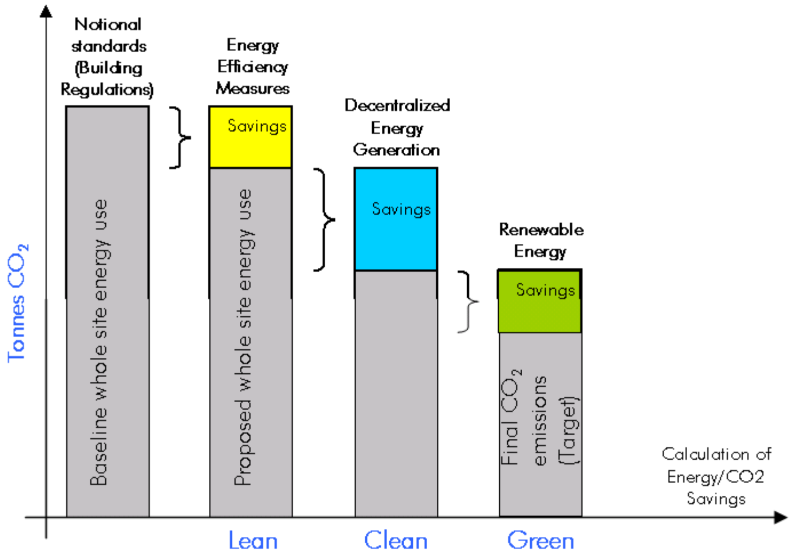


Figure 1 - Energy Analysis Methodology

3.2 INTEGRATED APPROACH

An inclusive and iterative design approach will be fundamental to a successful outcome for the Eco-town aspiration. An integrated approach to infrastructure, building design, CO_2 emission reduction and other urban design aspects will be therefore applied. The following efficiencies of scale; use of waste heat; potential sharing of resources via import and export with surrounding villages and the national grid; potential use of other waste products. The following will all be considered in careful balance to derive an optimised final approach: critical mass.

The importance of considering scale and density is outlines in the following section.

3.2.1 Critical Mass and Efficiencies of Scale

Many sustainable infrastructure features (such as site-wide energy, waste and water strategies) require a certain number of dwellings or floorspace, with an appropriate amount of diversity in the demand; to allow for an optimised efficiency and effectiveness to be reached in their operation and economics. This development principle is often referred to as a 'critical mass'. The main function of critical mass is to provide stability, limit risk and allow for a greater range of options to be considered.

Principle of Critical Mass

The principle of critical mass, as applied to a development, is understood through its scale, type and the number of units within. Sub-features include: peak and overall demand of resources, and the type of resources required. Critical mass can be used as an indicator of a development's ability to provide sufficient demand to broaden the palate of applicable sustainable technologies. Some technologies are most cost effective and energy efficient at higher densities. There is an understanding in environmental planning policy that the more concentrated and mixed use the form of development, the more it will facilitate successful adoption of certain energy conservation measures.

3.3 DESIGNED FOR LIFE

In evaluating design options the choice of system is driven by short term considerations such as initial cost and design restrictions. This can lead to systems that during their actual operation have much higher environmental, social and financial impacts than other alternatives.

The situation tends to occur where the parties responsible for the initial decisions are not the same as those who are responsible for their operation.

This tendency can be addressed by considering the whole life of a system, including its operators and users, in the initial decision making.

For Elsenham Eco-Town Life-cycle and whole-life costing assessments will be included into the process for major decisions; to allow the consideration of operation and maintenance issues.

Thought will be given to the organisations responsible for the ongoing operation and maintenance of systems, as well as the requirements of the end users.

Management through a cooperative model (Elsenham Cooperative Ltd; ECL) will be explored a partner organisations (ESCOs/MUSCOs) to provide energy and other utility services, under the umbrella of ECL. The energy service provider, via ECL, could potentially also be responsible for maintenance of all of the equipment; including that within the homes.

Ways to encourage the end user's interaction with their service provision will be explored involving local residents.

3.4 ENERGY AND URBAN DESIGN

The following is an outline of general sustainable design principles that will be used throughout the consultation and design process. They embody practical principles for each level of the development, from site wide and location to street scale.

3.4.1 Energy and Location

The location of the development will provide opportunities and constraints for particular technologies and design practice. For example:

Urban Locations

Higher densities have the potential to reduce energy used in transport, providing the development is of mixed-use.

Building-integrated renewable technologies, such as solar; may be suitable.

Urban areas are ideal for developing community heat, cooling and power networks supplied by low and zero-carbon technologies. Economies of scale are more easily achieved in urban areas given the higher densities involved.

Suburban Locations

Medium density developments may increase the energy used for transport and movement, thus a public transport system must be flexible in its ability to capture users.

There is greater scope for technologies such as biomass and medium to large wind turbines given the lower density and more availability of open space.

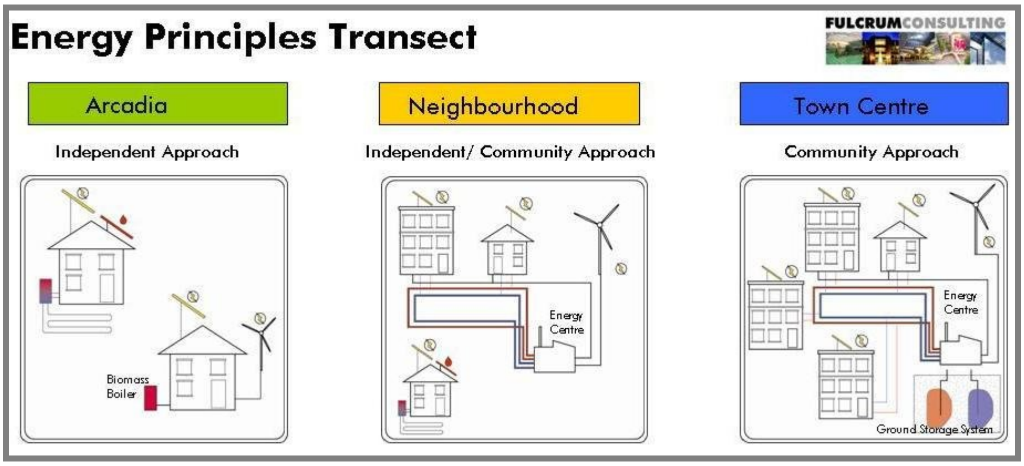
Rural-urban Fringe Locations

Densities at the lower end of the scale have increased potential for detached building integrated renewable technology.

The availability of open space increases the opportunity to provide locally grown biomass and may generate income for areas of arable land

Sustainable energy networks can supply groups of buildings or homes but will need to transmit over longer distances.

The following diagram illustrates these principles.



3.4.2 Settlement Scale

Design tools will be employed for the analysis of the city or district climate (e.g. relative humidity, temperature, precipitation); the predominant wind paths, solar irradiation, overshadowing, and land type.

Daylighting will be assessed in order to inform the design process. A solar orientation of ± 30° of south will allow for 80% of dwellings to have an unobstructed access to sunlight.

Taller buildings may be located to the north of a site to maximise solar access and reduce over-shadowing.

Wind sheltering and compact built form will be considered to avoid wind tunnelling in and around the site.

Building-integrated technologies are likely to be easier to install in larger buildings and on larger and more accessible roof spaces.

3.4.3 Street Scale

Sustainable design at street scale will be based on a detailed analysis of the site and its microclimate; with land use and density studies making way for consideration of the uses within individual blocks and streets.

Vegetation, drainage, massing, overshadowing

- Deciduous vegetation may be used to reduce overheating during the summer whilst allowing solar gain during the winter.
- Green spaces and green roofs could operate as sustainable urban drainage systems to help attenuate water, as well as providing shading, and mitigating heat island effect.

- Massing may be used to reduce energy demand; for example with taller buildings positioned to the north to minimise overshadowing.

Character, place and space-making

- The requirements of solar orientation and wind sheltering will be balanced with the need for place-making, space and character of the development.
- Sustainable urban design will also provide attractive sunlit amenity spaces at ground level.

Block sizing, orientation

- The design of the roofscape is critical to maximise the potential for south-facing solar panels .
- Orientation and solar access will also be a consideration in the planning of the courtyards and street axis.
- Energy demand for dwellings can be reduced with the use of daylight within the dwellings, reducing the need for artificial lighting.

3.5 DEMAND REDUCTION AND EFFICIENT SUPPLY

As noted earlier the principle of energy demand reduction and energy efficiency will be applied throughout the development.

It is important to address energy demand reduction in buildings and infrastructure design in order to reduce CO_2 emissions, achieve greater efficiency of use, and achieve cost benefits. Demand reduction measures should be applied, and with standards set for reduction prior to the consideration of energy supply sources and renewable energy technologies.

By reducing the demand for energy, the amount of infrastructure and equipment required to serve a development is reduced. This has benefits not only in terms of the embodied energy of the equipment and infrastructure, but importantly also enabling greater cost efficiency for the infrastructure.

Although there is a capital cost associated with increasing the specification of building design in order to deliver demand reduction, demand reduction can be more cost effective to apply than renewable energy technologies. Greater life-cycle carbon emissions reduction can be achieved through applying investment in passive demand reduction than from the same investment in renewable energy technologies, as the reductions are achieved through the whole building life and are not limited by supply technology operation, maintenance and replacement.

In terms of efficient supply generating electricity on site in there are significant efficiencies that can be made by comparison to using grid derived electricity. In general, the principle of generating energy as close as feasible to the point of use (proximity principle) will be considered and also balanced against the advantages of having a critical mass of development that enables cost-effective delivery of energy and carbon emissions reductions. Future-proofing for managed incorporation of new low-carbon technologies, introduced over time, is also an important consideration.

Demand reduction design considerations Elsenham Eco-town are likely to include:

- The relationship between orientation and energy use
- Application of passive design principles to avoid solar overheating in summer and avoid heat loss in winter
- The potential effects on occupant behaviour of smart metering and use of visible renewable technology
- Window specification of at least double-glazed with low emissivity coating. Achievement of U-values better than current Building Regulations minimum standards
- Achievement of air-tight construction with carefully planned ventilation Potential for air tempering via earth tubes or labyrinths
- Inclusion of effective thermal mass in construction, with environmental strategies to make use of thermal mass provided (e.g. secure night time ventilation). Thermal mass exposed internally where feasible.
- Inclusion of high-efficiency heat recovery in all instances where mechanical ventilation is applied
- Installation of energy efficient appliances wherever domestic appliances are installed
- Specification of energy efficient light fittings. This should include internal lighting, external lighting to building and street / public realm lighting

4 ACCOMMODATION ASSUMPTIONS

The following table outlines the assumed accommodation schedule for Elsenham Eco-town and has been used to inform the energy demand calculations described later in this report.

Type	Number of Buildings/ Area
Domestic	
Flats and houses	5,000 dwellings, 40% Affordable Housing
Non-Domestic	
Offices	11,400 m^2
Retail - Food	1,850 m^2
Retail - Non Food	6,300 m^2
100 Bed Hotel	1,000 m^2
B1 Floorspace	31,000 m^2
Primary School	1500 m^2
Secondary School	1,000 m^2
Library	575 m^2
Health	790 m^2
B2 Industrial	10,600 m^2
Other B1 employment including R&D and light industry	31,000 m^2

Table 2 - Elsenham Eco-town Accommodation Schedule Assumptions

5 ENERGY DEMAND

5.1 GENERAL

To establish options for achieving zero carbon, first the energy demand is estimated in terms of kWh and this is then converted to CO_2 emissions using a carbon co efficient for each type of fuel used. Therefore the initial sections below concentrate on a prediction of energy in kWh and the later sections relate to conversion to CO_2 emissions.

5.2 DOMESTIC ENERGY DEMAND ASSUMPTIONS

The baseline energy demand used to compare the CO_2 emissions savings for the proposed development with Code requirements is based on the methodology used in SAP, and modelling undertaken using NHER[1] software.

SAP considers the CO_2 emissions of notional dwelling that is compliant under Building Regulations – known as the target CO_2 emission rate (TER) – and compares them to the proposed dwelling's CO_2 emission rate (DER). The DER reflects any enhanced energy and carbon saving measures built into the dwelling (i.e. good building fabric performance, efficient heating systems, etc). The methodology uses Part L 2006 standard CO_2 fuel emission factors. It is also worth noting that there are a number of limitations to the type and magnitude of energy saving measures accounted for under the SAP assessment methodology.

Due to the early stage of design, and given that the development mix is yet to be confirmed, it is considered appropriate that a 'notional dwelling' is used to represent an average dwelling at the Elsenham development.

The dwelling type used as the notional dwelling is a 3-bedroom, 5 person, semi-detached house. This dwelling type is selected to assist the assessment of the energy strategy options appraisal, as its energy demands could be considered representative of a median unit type.

It is assumed in the energy assessment that all dwellings achieve a heat loss parameter of 0.8W/m^{2}K, as is required by the current definition of zero carbon under the Code for Sustainable Homes. This means that all dwellings will be highly insulated and have very low heat losses, approximately equivalent to dwellings that follow the German 'PassivHaus' principles. The table below shows how the proposed standard for Elsenham compares to typical good and very good energy efficiency standards for dwellings and also current Building Regulations compliant dwellings.

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[1] NHER – National Home Energy Rating energy modelling software accredited for use to verify Building Regulations part L Approved document L1compliance.

BUILDING FABRIC ASSUMPTIONS	Building Regs 2006 Compliant (typical)	Good Energy Efficient (typical)	Very Good Energy Efficient (typical)	Elsenham Dwelling (typical)
Wall U-value (W/m²K)	0.35	0.20	0.15	0.12
Roof U-value (W/m²K)	0.25	0.15	0.15	0.12
Floor U-value (W/m²K)	0.25	0.20	0.15	0.12
Window & door U-value (W/m²K)	2.2	1.6	1.0	0.8
Airtightness (m³/hr/m²)	10	7	3	1
Thermal bridging (y-value)	0.08	0.08	0.08	0.08
Heat Loss Parameter (W/m²K)	1.73	1.46	0.98	0.80
% low energy lighting	30%	75%*	100%*	100%
Ventilation type	Natural	Natural	MVHR AppQ	MVHR AppQ
Window type	Natural	Double low-e	Triple low-e	Triple low-e

* benefit of only 30% low energy lighting taken for energy demand calcs (in line with Part L stipulations)

Table 3 - Building Fabric Assumptions for Energy Assessment

ENERGY DEMAND ASSUMPTIONS	Building Regs 2006 Compliant (typical)	Good Energy Efficient (typical)	Very Good Energy Efficient (typical)	Elsenham Dwelling (typical)
TER (kgCO$_2$/m²/yr)	23.64	23.64	23.64	23.64
DER (kgCO$_2$/m²/yr)	23.64	20.03	16.07	15.02
% Improvement TER-DER	0.0%	15.3%	32.0%	36.5%
Space Heating Demand (kWh/m²/yr)	52.92	41.74	21.47	14.47
Hot Water Heating Demand (kWh/m²/yr)	33.40	33.40	33.40	33.40
Electricity Demand - Part L (kWh/m²/yr)	7.55	7.55	9.02	7.08
Electricity Demand - Non regulated (kWh/m²/yr)	31.09	31.09	31.09	31.09
Total Energy Demand	124.96	113.79	94.98	86.04

Table 4 – Resultant Energy Demand Assumptions for Energy Assessment

There will ultimately be some, relatively small, differences in relation to minimum specification standards for different sized dwellings, and varying development mix, that will need to be taken into account as design development progresses.

5.3 NON-DOMESTIC ENERGY DEMAND ASSUMPTIONS

Due to the nature of this project not much detail is currently available as to the exact nature of the non-domestic elements of the development. Therefore in order to define an estimated energy demand profile for the site, published benchmark figures have been used to determine the likely energy demand of the various non-domestic building types.

The assumed energy demands for both an assumed Building Regulations 2006 compliant building type, and the assumed Elsenham Standard are shown in Table 4 and 5 below. The assumptions made in reaching these can be found in the Appendices to this report.

	Energy Demand – Current Compliance Equivalent (kWh/m²/yr)				
Description	Space Heating	Space Cooling	Hot Water Heating	Electricity - Part L	Electricity - Non regulated
Offices	62.1	42.0	15.5	74.2	39.8
Retail - Food	144.0	823.5	16.0	417.0	223.5
Retail - Non Food	59.0	67.2	6.6	131.2	70.4
100 Bed Hotel	149.8	7.2	58.2	50.5	77.1
B1 Floorspace	62.1	42.0	15.5	74.2	39.8
Primary School	72.3	0.0	18.1	14.3	7.7
Secondary School	69.1	0.0	17.3	16.3	8.7
Library	81.4	0.0	9.0	20.8	11.2
Health	111.4	0.0	27.8	20.8	11.2
B2 Industrial	11.0	0.0	62.6	0.0	0.0
Other B1 employment including R&D and light industry	10.8	0.0	61.2	20.2	10.8

Table 5 - Energy Demand Assumptions for Energy Assessment – Estimate of Current Building Regulations Compliant

	Energy Demand – Elsenham Standard (kWh/m²/yr)				
Description	Space Heating	Space Cooling	Hot Water Heating	Electricity - Part L	Electricity - Non regulated
Offices	40.4	33.6	15.5	74.2	29.8
Retail - Food	93.6	658.8	16.0	417.0	167.7
Retail - Non Food	38.4	53.8	6.6	131.2	52.8
100 Bed	97.3	5.8	58.2	50.5	57.8
B1 Floorspace	40.4	33.6	15.5	74.2	29.8
Primary School	47.0	0.0	18.1	14.3	6.9
Secondary School	44.9	0.0	17.3	16.3	7.9
Library	52.9	0.0	9.0	20.8	10.1
Health	72.4	0.0	27.8	20.8	10.1
B2 Industrial	7.2	0.0	62.6	0.0	0.0
Other B1 employment including R&D and light industry	7.0	0.0	61.2	20.2	9.7

Table 6 - Energy Demand Assumptions for Energy Assessment – Elsenham Proposed Standard

5.4 BASELINE ENERGY DEMAND

Figure 2 below illustrates the baseline and proposed energy demand breakdowns considered in this assessment.

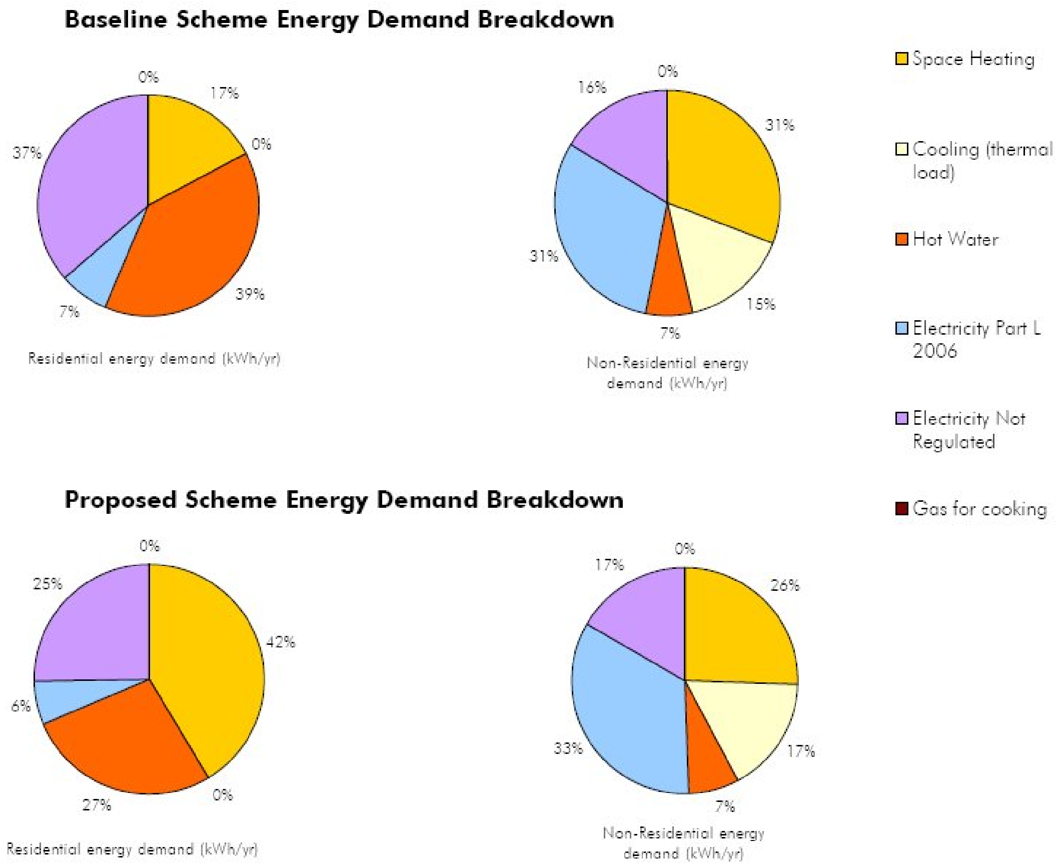

Figure 2 - Energy Demand Breakdown

Figures 3 and 4 below illustrate the estimated approximate annual energy demand profile for the whole development upon completion in 2025, based on the given assumptions. It shows the space heating, hot water and electricity demand for all the dwellings and non-domestic spaces.

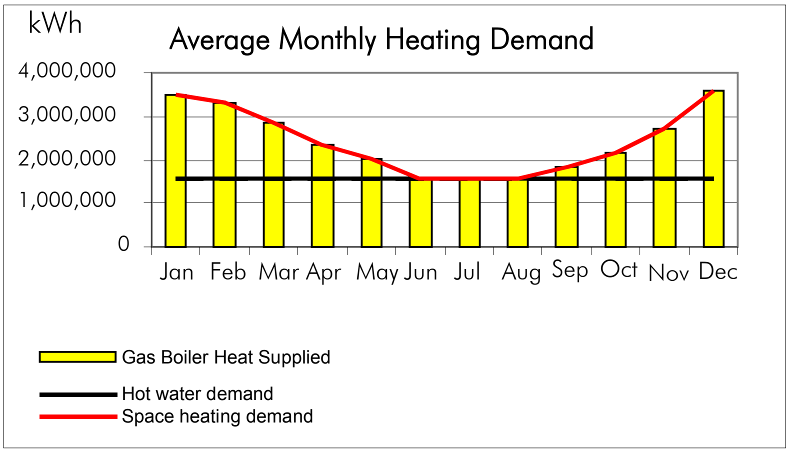

Figure 3 - Annual Heating Demand Profile

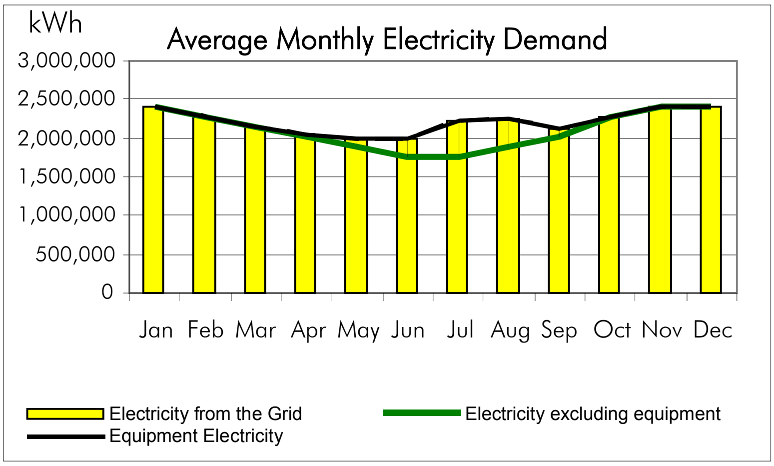

Figure 4 - Annual Electricity Demand Profile

The energy strategy scenarios described below in Section 6 look at ways to address the above energy demand profile, i.e. one where demand reduction benefits have already been taken into account.

5.5 QUANTIFYING SAVING DUE TO ENERGY EFFICIENCY BASELINE CO_2 EMISSIONS

Baseline CO_2 emissions were calculated on the basis gas fired boilers and grid electricity.

Comparison of the TER with the CO_2 emissions after energy saving measures have been applied provides the CO_2 savings achieved from these energy efficiency measures.

In this way it has been estimated that the energy efficiency measures described in the above sections represent approximately a 23% reduction overall in CO_2 emissions.

Further CO_2 savings can be through the use of low and zero carbon energy technologies.

6 ENERGY SCENARIOS

6.1 SCENARIO SUMMARY

Various combinations of heating, cooling and power generation technologies were explored in order to assess the options for meeting (or exceeding) the demands of the new development through lo and zero carbon technology, an ultimately to inform future decision making in relation to the ambition of achieving a net-zero carbon development.

The Scenarios are presented in broad brush terms and make use of currently available and technically robust technologies that do not rely on unsecure or dubious fuel choices (e.g. hydrogen). The choice of technology is dependent on its own technical limitations in providing energy (i.e. optimized size) and the optimized delivery of zero carbon energy.

The Scenarios are as follow:

- Scenario 1: Community Heating (CH) with Biomass Combined Heat and Power (CHP) serving Elsenham + Neighbouring Client, together with 3 x 2.5MW wind turbines (including export) and Aquifer Thermal Energy Storage (ATES) sized for 75% of cooling demand
- Scenario 2: CH & Gas-Fired CHP + Biomass Boilers serving Elsenham + Neighbouring Client, together with 2 x 2.5MW wind turbines export predominantly + ATES providing 75% of cooling demand
- Scenario 3: CH & Biomass CHP serving Elsenham + Neighbouring Client + ATES for 44% of cooling
- Scenario 4: CH & Biomass CHP + ATES for 75% of cooling
- Scenario 5: CH & Biomass CHP + biomass boilers for 4,800 dwellings + ATES for 75% of cooling + 200 Independent Approach CHS6 Houses

It can be seen that all Scenarios have been chosen to include CHP, either gas or biomass fired. The particular engine type and size of overall CHP selected have a very key affect on the heat and electricity proportions that the CHP system can then support and therefore which other technologies are needed to achieve the zero carbon aspiration. In some cases, to increase the proportions of electricity supplied via CHP will result in an over provision of heat. However this will still form useful energy if it can be utilised elsewhere and some scenarios explore this option. For example, several of the scenarios (i.e. Scenario 1 and 2) consider the use of CHP technologies sized with an ability to provide low or zero carbon heat to a 'Neighbouring Client'. The Neighbouring Client could be the adjacent existing communities, and/or a heat-required industrial or agricultural activity. Opportunities for use of waste heat for food growing as part of the development proposals is one idea under consideration.

The site has been assessed in very initial terms and indications are that it is favourable to consideration of large scale wind, thus some scenarios include this as a renewable technology. In all options, grid electricity is supplied to the development to meet peak demands and ensure full availability of electricity during maintenance down-time periods. In some cases export of renewable electricity is required to offset import of fossil fuels,

Aquifer Thermal Energy Storage is a form of communal heating and cooling. A typical system will use borehole pairs (or groups of paired boreholes) to transfer and store heat in the ground on an inter-seasonal basis. When the circumstances are right it can form an extremely cost effective way of producing low carbon heating and cooling, however the applicability of the system depends on the local hydrogeology. More information on ATES is included in the technology background information appendix.

Several of the scenarios make use of biomass, and some are likely to have a significant requirement for biomass.

6.2 SCENARIO 1

This scenario considers the use of a community heating system sized to meet the hot water demands of the development via a Biomass CHP installation. The CHP would also provide a proportion of the electricity required. Gas boilers would provide the majority of the space heating requirement. Approximately 75% of the cooling demand would be met by the ATES system, which would also provide some space heating, and Chillers would meet remaining cooling needs. 3 x 2.5MW wind turbines would provide the residual electricity plus offset the use of fossil fuel.

The Biomass CHP considered in this scenario would use a ORC Turbine as prime mover. In this kind of Plant the solid biomass is straight burned into the furnace of a thermal oil boiler – the power:heat ratio for this technology is typically around 0.2.

The following graph illustrates the break down of delivered annual energy for each use by the chosen technology mix in Scenario 1. Note that the heat available for the Neighbouring client is not shown, however, the additional heat load allows for an increased contribution of electricity from the Bio-CHP to meet the electricity demand of the site.

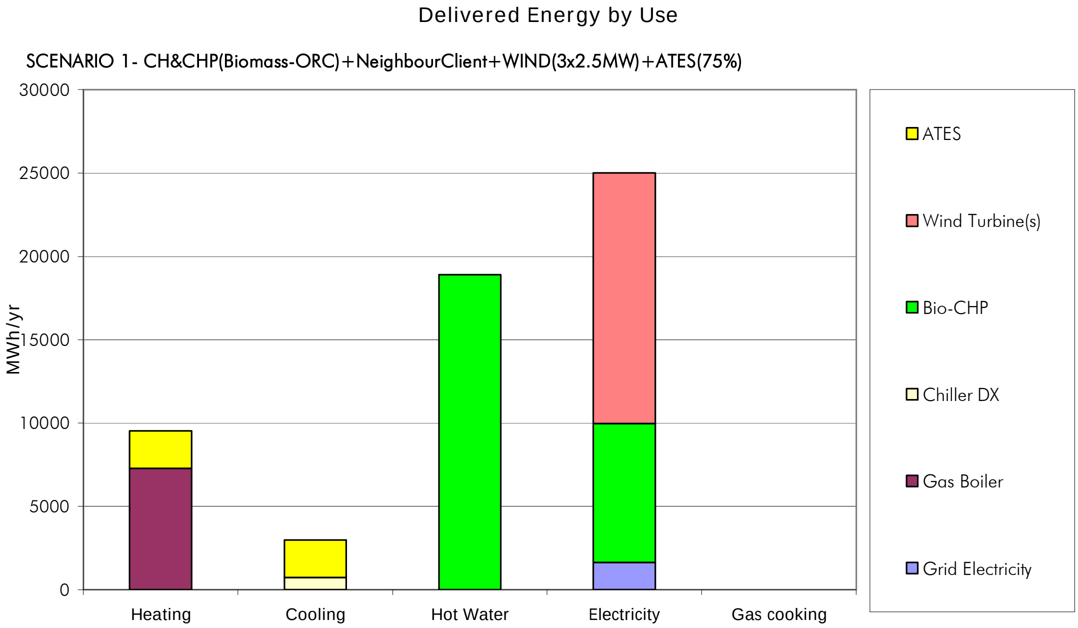

Figure 5 - Scenario 1 Delivered Energy - Steps to Zero Carbon

The following graph illustrates the CO_2 reductions achieved using the above technology mix in order to meet zero carbon. The Bio-CHP and wind turbines contribute the greatest savings.

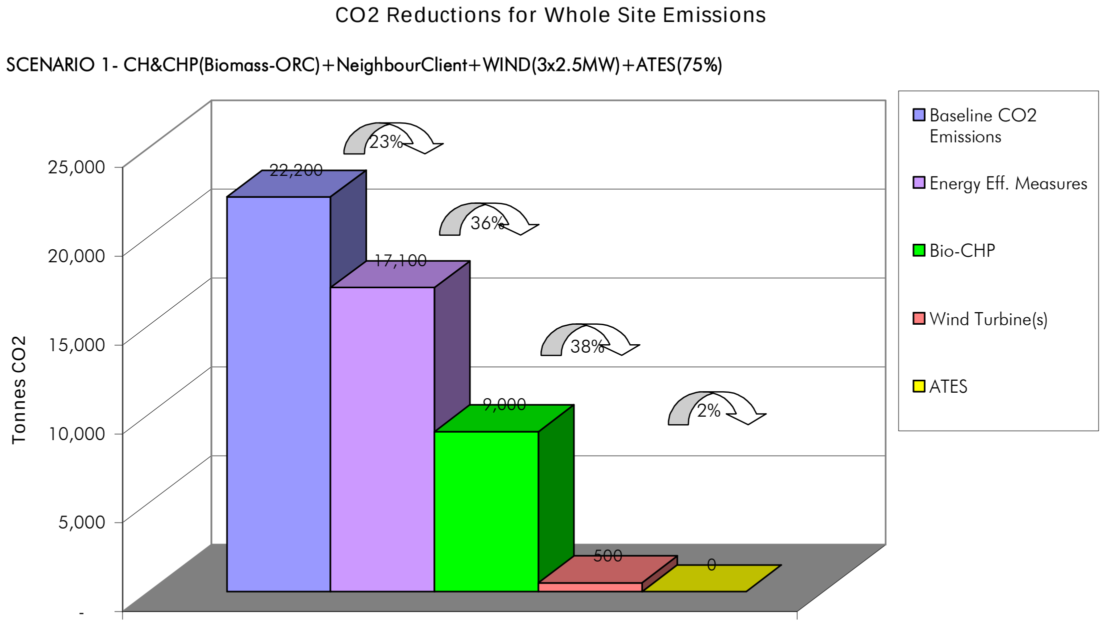

Figure 6 - Scenario 1 CO_2 Reductions - Steps to Zero Carbon

This scenario reflects a case whereby a combination of technologies is used meet zero carbon. It uses Biomass CHP to provide all the hot water for the site and an additional heating demand required by an external client. However the size of CHP does not support all electricity use, hence the need for wind turbines.

The additional heat for a neighbouring client is approximately equivalent to the domestic heat demand for around 1,300 houses if an average heat demand of 17 MWh/yr per property is assumed, which is typical of the existing stock heat demand.

6.3 SCENARIO 2

This scenario considers the use of a community heating system sized to meet the hot water demands of the development plus heat demand from an adjacent community (via a Gas-Fired CHP. The CHP would be able to provide all of the electricity required and export part of the electricity generated to the Grid. A proportion of electricity will also be provided by 2 x 2.5MW wind turbines in order to offset the CO_2 emission of the Gas Fired CHP.

Biomass boilers would provide the majority of the space heating requirement. 75% of the cooling would be supplied by the ATES system, which would also provide space heating to non-domestic buildings, with notional assumption that chillers would meet remaining cooling needs.

The Gas fired CHP considered in this scenario would use as prime mover a Spark ignition engine, – the power:heat ratio for this technology is typically around 0.8.

The following graph illustrates the break down of delivered annual energy for each use by the chosen technology mix in scenario 2. Again, note that the heat available for the Neighbouring client is not shown, but the additional heat demand and the increased power:heat ratio of the gas-CHP allows for an increased contribution of electricity to the electricity demand of the site.

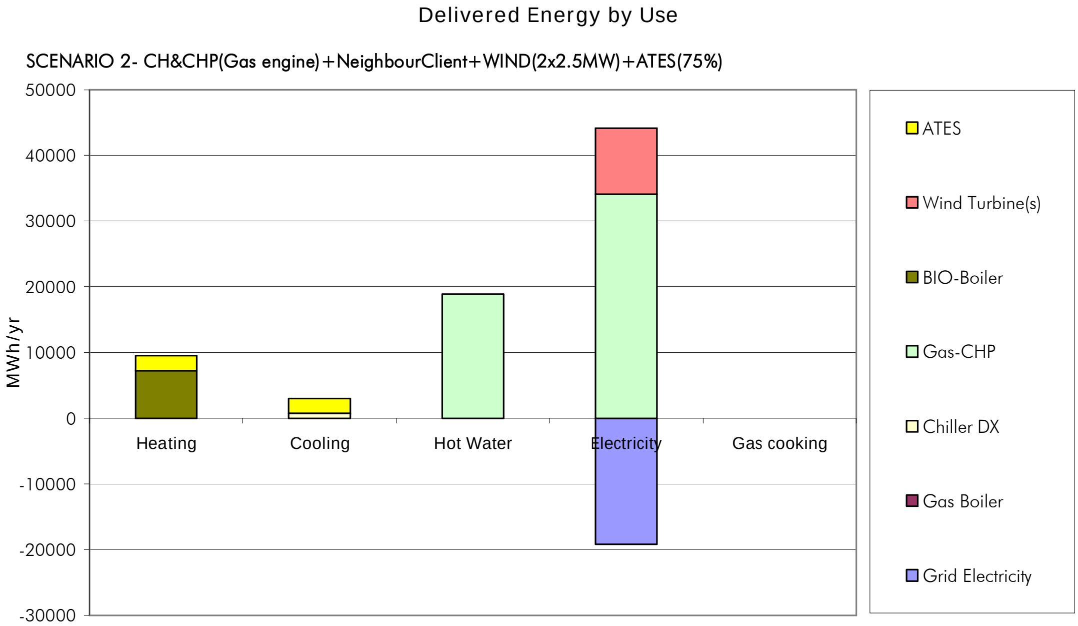

Figure 7 - Scenario 2 Delivered Energy

The following graph illustrates the CO_2 reductions achieved using the above technology mix in order to meet zero carbon. The gas CHP and wind turbines contribute the greatest savings.

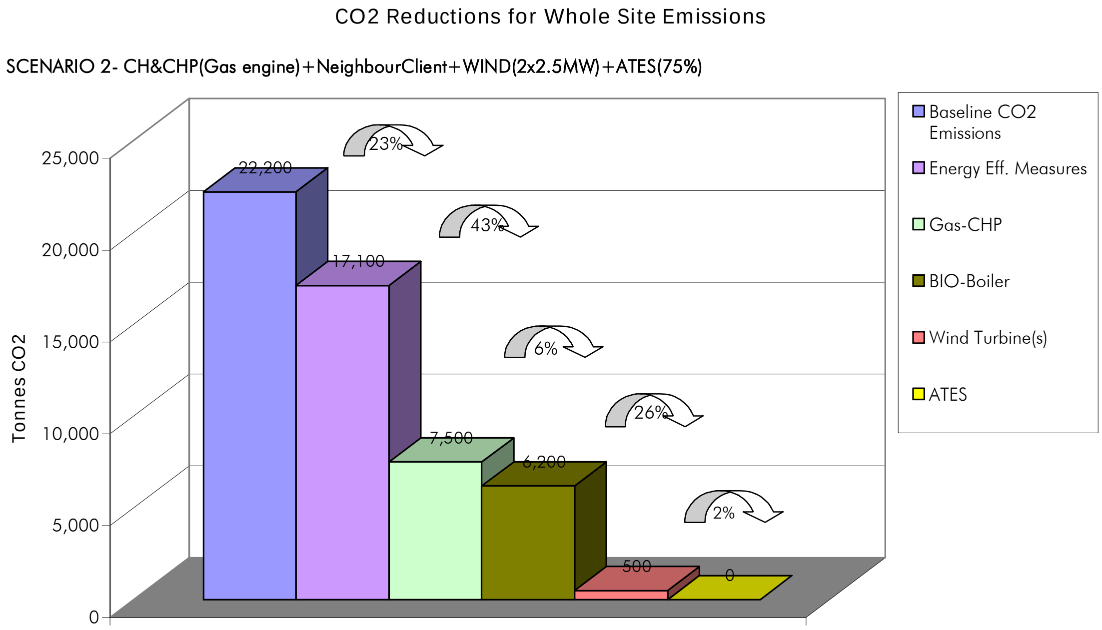

Figure 8 - Scenario 2 CO_2 Reduction - Steps to Zero Carbon

This scenario divides the provision of heat, with biomass boilers providing the space heating and gas fired CHP providing the hot water and an additional heating demand required by an external client. Electricity from the turbines is not required to provide residual energy for the site but is required to export electricity in order to offset the use of fossil fuel.

The additional heat demand is approximately equivalent to the domestic heat demand for around 1,400 houses if an average heat demand of 17 MWh/yr per property is assumed.

6.4 SCENARIO 3

This scenario considers the use of a community heating system sized to meet the hot water demands of the development plus heat demand from an adjacent community (via Biomass CHP. The CHP would be able to provide all of the electricity required. Gas boilers would provide the majority of the space heating requirement. A proportion of cooling would be supplied by the ATES system, which would also provide space heating to non-domestic buildings, with notional assumption that chillers would meet remaining cooling needs.

The Biomass CHP considered in this scenario would gasify the biomass, which would then be burned in a spark ignition engine – the power:heat ratio for this technology is typically around 0.8.

The following graph illustrates the break down of delivered annual energy for each use by the chosen technology mix in scenario 3. This scenario is similar to scenario 2, but uses a bio-CHP rather than gas.

The heat available for the Neighbouring client is less than in scenario 1 and 2, which is a result of the CHP type. However, the additional heat demand and the increased power:heat ratio of the bio-CHP allows for an increased contribution of electricity to the electricity demand and eliminates the need for wind turbines.

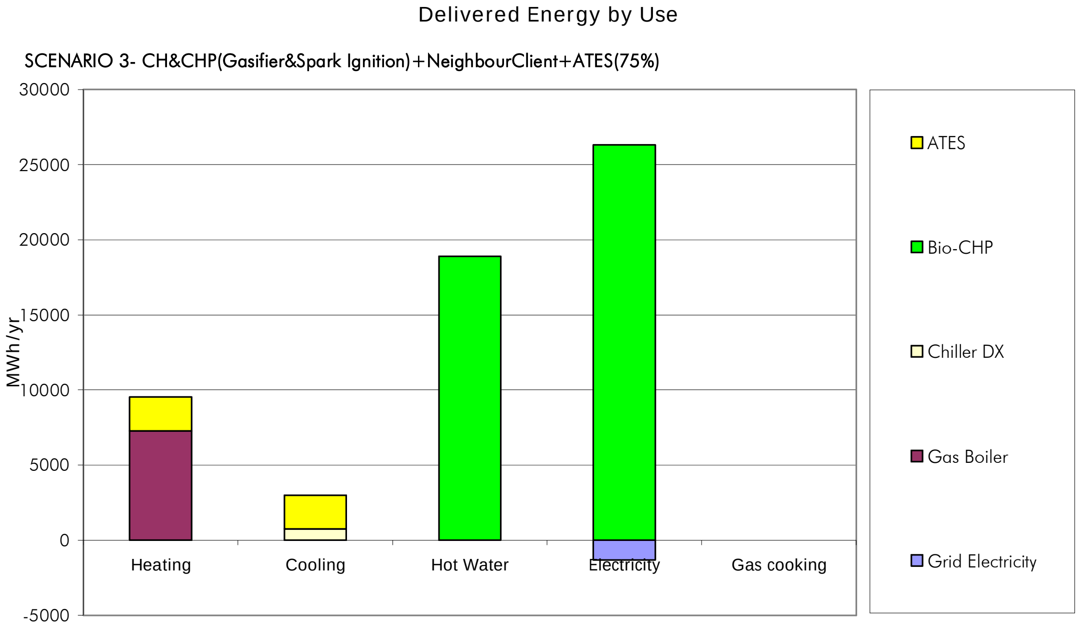

Figure 9 - Scenario 3 Delivered Energy

The following graph illustrates the CO_2 reductions achieved using the above technology mix in order to meet zero carbon. The bio-CHP contributes the greatest savings.

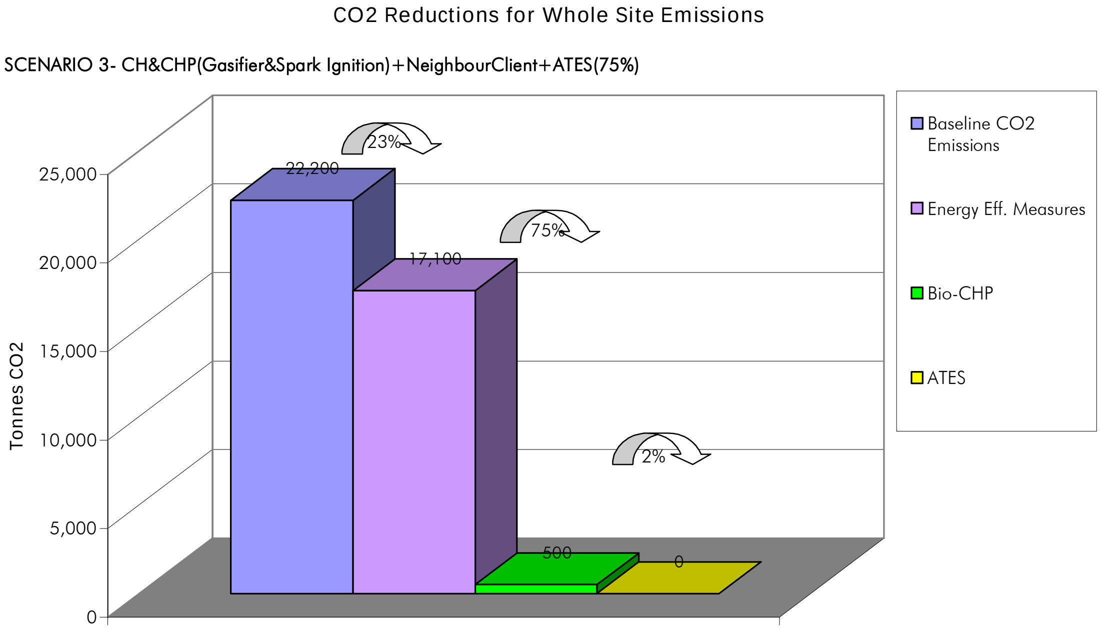

Figure 10 - Scenario 3 CO_2 Reduction - Steps to Zero Carbon

This scenario includes a Biomass CHP technology that provides considerably more electricity, however in being sized this way there is considerable excess heat which good practice dictates would need to be used in some capacity when therefore creates an ability to export this heat to the surrounding villages.

This additional heat would be approximately equivalent to the domestic heat demand for around 800 houses if an average heat demand of 17 MWh/yr per property is assumed.

6.5 SCENARIO 4

This is a similar scenario to number 3, but uses a different selection of CHP engine to alter the proportion of heat and power provided.

A community heating system is sized to meet the only hot water demands of the development via Biomass CHP. However the CHP would be sufficient to provide all of the electricity required due to an increased power:heat ratio. Biomass boilers would provide the majority of the space heating requirement. The remaining Space heating would be provided by Gas boilers. A proportion of cooling would be supplied by the ATES system, which would also provide space heating to non-domestic buildings, with notional assumption that chillers would meet remaining cooling needs.

The Biomass CHP considered in this scenario would gasify the biomass, which would then be burned in a combined cycle turbine – the power:heat ratio for this technology is approximately 1.3.

This scenario uses biomass fired CHP and boilers that only serve the demand of the community, with no potential for the export of heat to the surrounding villages.

The following graph illustrates the break down of delivered annual energy for each use by the chosen technology mix in scenario 4. The proportion of heat and electricity provided by the bio-CHP is vastly increased over Scenario 1 and 3, however there is an associated cost with gasifying.

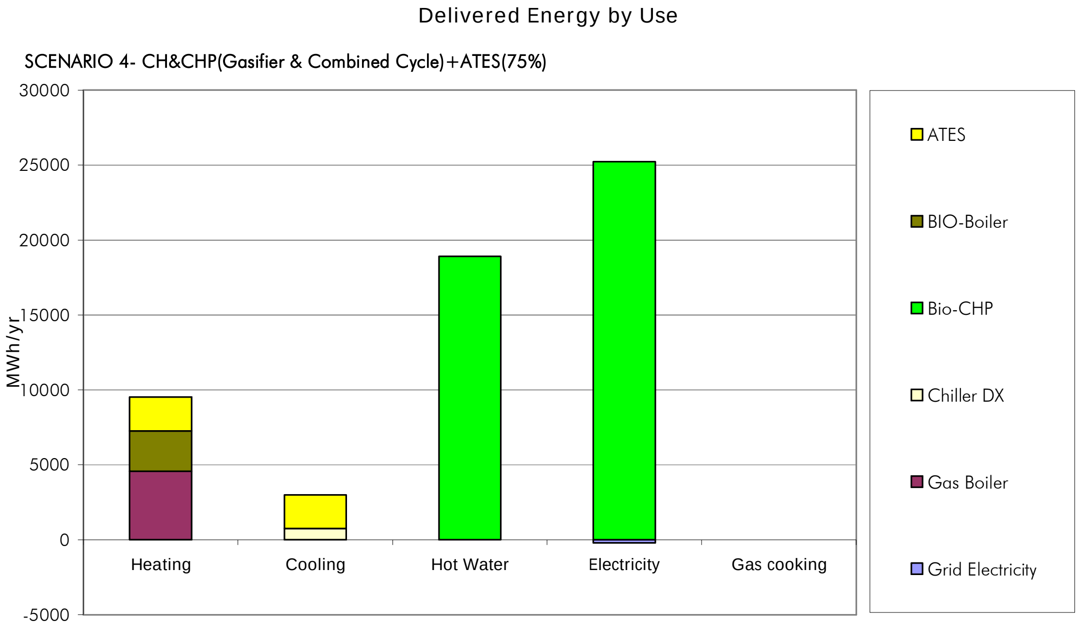

Figure 11 - Scenario 4 Delivered Energy

The following graph illustrates the CO_2 reductions achieved using the above technology mix in order to meet zero carbon. Again, it is the use of a bio-CHP that contributes the greatest savings.

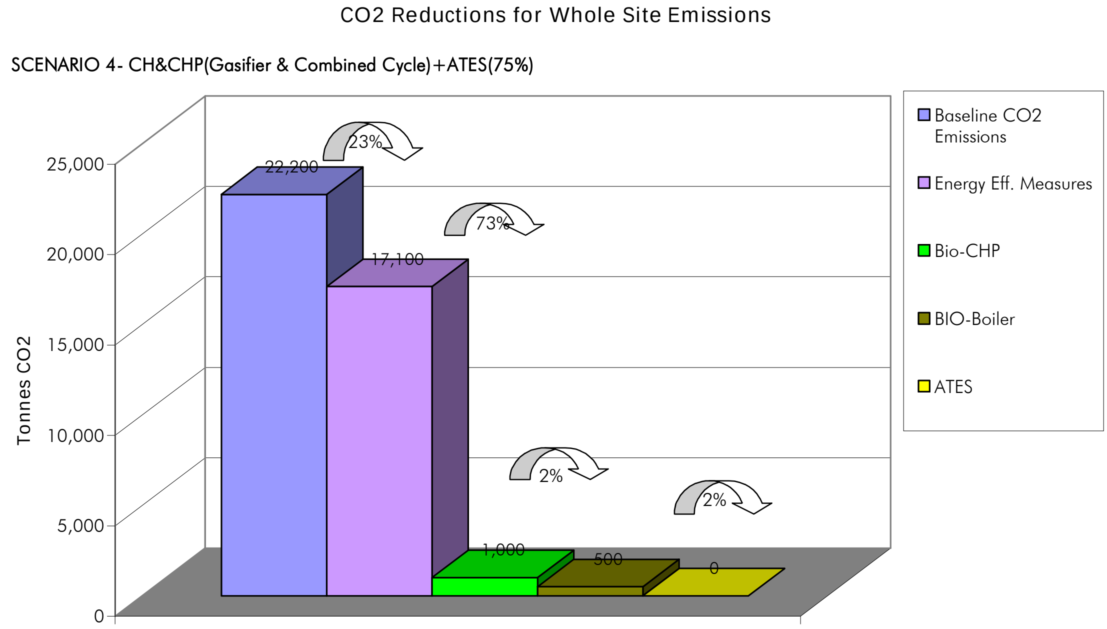

Figure 12 - Scenario 4 CO_2 Reduction - Steps to Zero Carbon

6.6 SCENARIO 5

This scenario considers the same community energy network and technology mix as scenario 3 above, but with the variation that approximately 200 homes (a notional number) meet the net zero carbon requirements through independent and building integrated renewable technologies. This is to reflect a case where development densities in out reach areas lend themselves to a local rather than communal solution rather than by connection to the community energy network

For the community connected buildings, this scenario considers the use of a community heating system, with biomass CHP sized to meet hot water demands. The CHP would be able to provide all of the electricity required due to an increased power:heat ratio. Biomass boilers would provide the majority of the space heating requirement. With remaining Space heating provided by Gas boilers. A proportion of cooling would be supplied by the ATES system, which would also provide space heating to non-domestic buildings, with the notional assumption that chillers would meet remaining cooling needs.

For the 200 homes achieving net zero carbon via independently, around 50% of hot water needs would be met via 4 m^2 solar thermal panels per house, with remaining space heating and hot water needs met via a ground-source heat pump. Electricity needs, including the electricity to serve the grounds source heat pump, would be generated by around 27m^2 photovoltaic (PV) panels per house, (totalling around 5,400 m^2. for the whole 200 homes).

As for scenario 4The Biomass CHP considered in this scenario would gasify the biomass, which would then be burned in a combined cycle turbine – the power:heat ratio for this technology is approximately 1.3.

The following graph illustrates the break down of delivered annual energy for each use by the chosen technology mix in scenario 5. The proportion of heat and electricity provided by the gasified bio-CHP is still high. The technologies applied to the 200 homes contribute only the energy that they require.

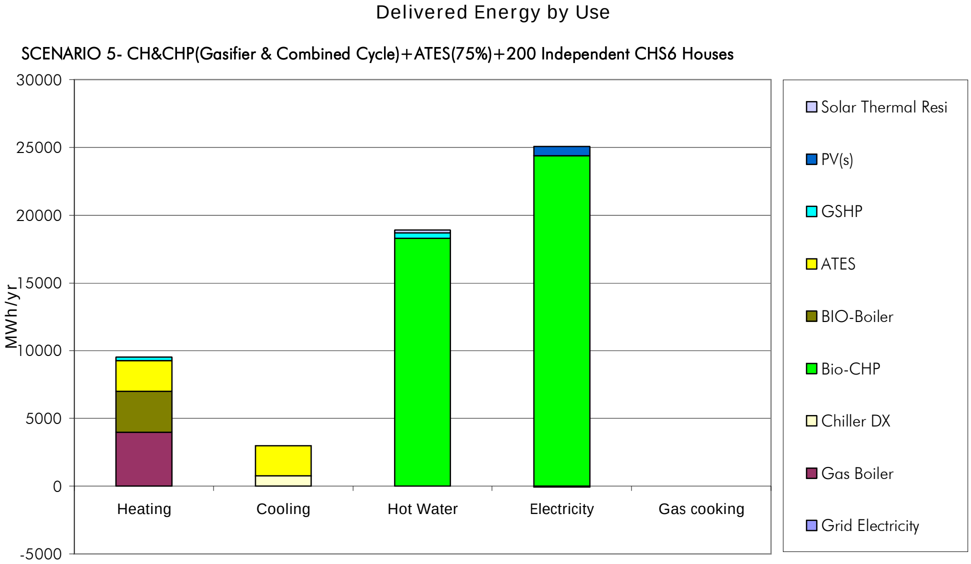

Figure 13 - Scenario 5 Delivered Energy

This scenario considers how a wider range of independent and community energy systems, at different scales, work towards meeting a zero carbon energy system.

The following graph illustrates the CO_2 reductions achieved using the above technology mix in order to meet zero carbon. For which the bio-CHP contributes the greatest savings and the independent dwelling technologies contributing a smaller amount of savings.

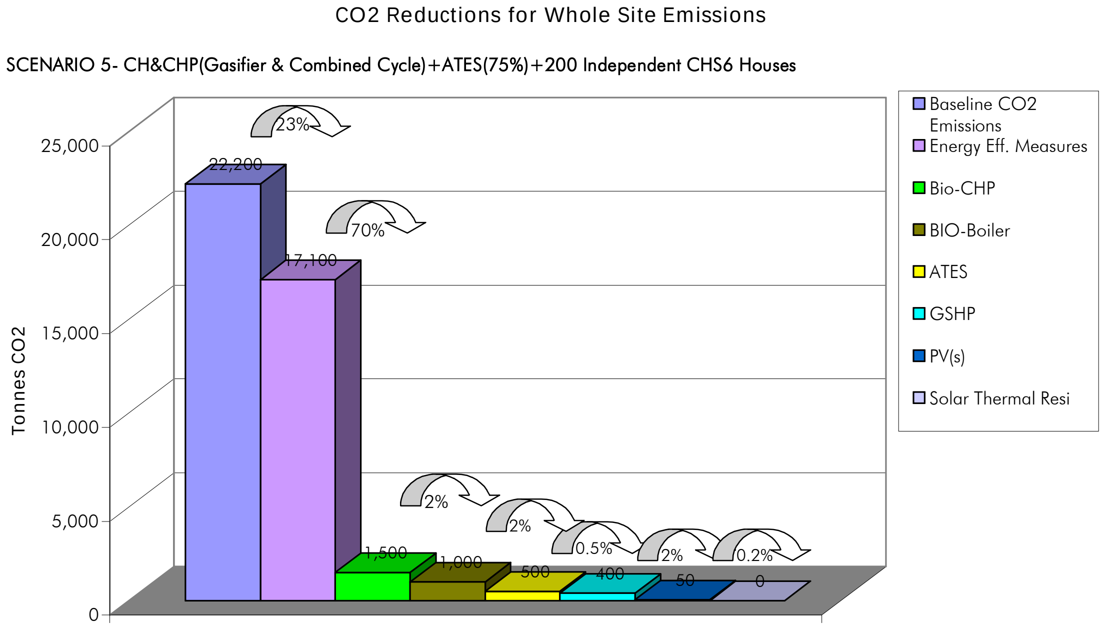

Figure 14 - Scenario 5 CO_2 Reduction - Steps to Zero Carbon

7 CONSIDERATIONS

The above scenarios look at options for achieving a net zero carbon outcome for the Elsenham Eco-town development.

As outlined, the scenarios incorporate technologies whose optimal combination will be dependent on a variety of influencing factors. These will be further considered as part of deriving the final energy strategy for the development.

Specific considerations for technology and strategy choices will be further developed over the coming months and will include, amongst other things; fuel availability and supply chain security, aesthetics and visual impact, cost, maintenance, and logistical feasibility.

It is important to recognise that the classification of biomass can include a broad range of fuel types. Fuel types may include waste products, such as straw, organic fractions of dried output from anaerobic digestion or other refuse derived fuel (RDF), as well as biomass crops and woody biomass. More examples of biomass conversion options are contained within appendix C to this report. Further investigations will be made; particularly into opportunities sustainable biomass fuel sources for the Elsenham development.

Similarly within each technology type there are a range of solutions, for example different wind turbine sizes and quantities to produce the same annual electricity output, or different CHP prime mover technology options, examples of which are provided within appendix B.

Initial findings from a British Geological Study desktop study of the Elsenham area give a positive indication regarding likely feasibility of the aquifers in the area to support an ATES (Aquifer Thermal Energy Storage) system. ATES has been assumed to meet a maximum of 75% of the development cooling demand, allowing for the fact that it will not be appropriate for every building demanding cooling to connect to a community cooling network, due to location or other factors. The carbon saving from ATES is likely to constitute at least 20%-30% carbon emission reduction for any building with a cooling demand. This is not an insignificant contribution, despite being only a small percentage in the overall CO_2 because the cooling demand, on which the ATES is based, represents just around 5% of the total energy demand.

In addition to issues related to the implementation of technology choices, the design of systems in relation to construction phasing will also be further considered. Community networks can be configured to accommodate development, however some of the technologies serving the network require a certain critical mass prior to their implementation and most efficient operation, for both cost and technology availability reasons.

8 NEXT STEPS

The scenarios outlined provide an indicative assessment of the energy demands and the possible technologies that may be used to provide zero-carbon energy to the 5,000 homes and mixed uses within the proposed Elsenham Eco-town.

The next steps are to further refine the above scenarios through further technical feasibility assessments, and to develop a preferred energy strategy that can be used to further inform the masterplan design and phasing considerations.

9 APPENDIX A: NON-DOMESTIC ENERGY DEMAND ASSUMPTIONS

9.1 CURRENT BUILDING REGULATIONS EQUIVALENT

Assumed annual energy demands: OFFICE

Space Heating	Good practice heating & hot water use, air conditioned office = 97kWh/m2 – Split 80:20 heating:hot water (ECG 19), assume 80% efficient boilers to convert delivered energy to energy demand.
Space cooling (thermal)	Good practice cooling, air conditioned office (ECG 19), assumed COP = 3 to convert elec load to thermal load
Hot Water Heating	Good practice heating & hot water use, air conditioned office = 97kWh/m2 – Split 80:20 heating:hot water (ECG 19), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use (fans pumps & controls, lighting, office equipment, catering, other elec, computer room), air conditioned office (ECG 19). Assume 65% total elec demand is Part L related.

Assumed annual energy demands: RETAIL – FOOD

Space Heating	Good practice heating and hot water use = 200kWh/m2 – Split 90:10 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Space cooling (thermal)	Good practice cooling (CIBSE Guide F), assumed COP = 3 to convert elec load to thermal load
Hot Water Heating	Good practice heating and hot water use = 200kWh/m2 – Split 90:10 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L related.

Assumed annual energy demands: RETAIL – NON-FOOD

Space Heating	Good practice heating and hot water use, non-food store = 82kWh/m2 – Split 90:10 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Space cooling (thermal)	Good practice cooling, non-food store (CIBSE Guide F), assumed COP = 3 to convert elec load into thermal load
Hot Water Heating	Good practice heating and hot water use, non-food store = 82kWh/m2 – Split 90:10 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use, non-foodstore (CIBSE guide F). Assume 65% total elec demand is Part L related.

Assumed annual energy demands: HOTEL

Space Heating	Good practice heating and hot water use, holiday hotel=260kWh/m2 – Split 72:28 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Space cooling (thermal)	Good practice cooling, holiday hotel (CIBSE Guide F), assumed COP = 3 to convert elec load into thermal load
Hot Water Heating	Good practice heating and hot water use, holiday hotel=260kWh/m2 – Split 72:28 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use, holiday hotel (CIBSE guide F). Assume 65% total elec demand is Part L related.

Assumed annual energy demands: B1 FLOORSPACE

Space Heating	Good practice heating & hot water use, air conditioned office = 97kWh/m2 – Split 80:20 heating:hot water (ECG 19), assume 80% efficient boilers to convert delivered energy to energy demand.
Space cooling (thermal)	Good practice cooling, air conditioned office (ECG 19), assumed COP = 3 to convert elec load to thermal load

Hot Water Heating	Good practice heating & hot water use, air conditioned office = 97kWh/m2 – Split 80:20 heating:hot water (ECG 19), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use (fans pumps & controls, lighting, office equipment, catering, other elec, computer room), air conditioned office (ECG 19). Assume 65% total elec demand is Part L related.

Assumed annual energy demands: PRIMARY SCHOOL

Space Heating	Good practice heating and hot water use = 113kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Space cooling (thermal)	
Hot Water Heating	Good practice heating and hot water use = 113kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L.

Assumed annual energy demands: SECONDARY SCHOOL

Space Heating	Good practice heating and hot water use = 108kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Space cooling (thermal)	
Hot Water Heating	Good practice heating and hot water use = 108kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L related.

Assumed annual energy demands: LIBRARY

Space Heating	Good practice heating and hot water use = 113kWh/m2 90:10 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Space cooling (thermal)	
Hot Water Heating	Good practice heating and hot water use = 113kWh/m2 90:10 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L related.

Assumed annual energy demands: HEALTH

Space Heating	Good practice heating and hot water use = 174kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Space cooling (thermal)	
Hot Water Heating	Good practice heating and hot water use = 174kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L related.

Assumed annual energy demands: B2 INDUSTRIAL

Space Heating	Good practice heating and hot water use = 92kWh/m2 15:85 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Space cooling (thermal)	
Hot Water Heating	Good practice heating and hot water use = 92kWh/m2 15:85 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L related.

Assumed annual energy demands: OTHER B1 EMPLOYMENT INCLUDING R&D AND LIGHT INDUSTRY

Space Heating	Good practice heating and hot water use = 90kWh/m2 15:85 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Space cooling (thermal)	
Hot Water Heating	Good practice heating and hot water use = 90kWh/m2 15:85 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L related.

ECG 19 = Energy Consumption Guide 19 (2000), Energy Use in Offices, EEBPP, DETR
CIBSE Guide F = Energy Efficiency in Buildings, January 2004, CIBSE

9.2 PROPOSED ELSENHAM STANDARD

Assumed annual energy demands: OFFICE

Space Heating	Good practice heating & hot water use, air conditioned office = 97kWh/m2 – Split 80:20 heating:hot water (ECG 19), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures
Space cooling (thermal)	Good practice cooling, air conditioned office (ECG 19), assumed COP = 3 to convert elec load to thermal load. Plus assume 20% reduction in demand due to energy efficiency measures
Hot Water Heating	Good practice heating & hot water use, air conditioned office = 97kWh/m2 – Split 80:20 heating:hot water (ECG 19), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use (fans pumps & controls, lighting, office equipment, catering, other elec, computer room), air conditioned office (ECG 19). Assume 65% total elec demand is Part L related. Plus assume 25% reduction in demand due to energy efficiency measures

Assumed annual energy demands: RETAIL – FOOD

Space Heating	Good practice heating and hot water use = 200kWh/m2 – Split 90:10 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures
Space cooling (thermal)	Good practice cooling (CIBSE Guide F), assumed COP = 3 to convert elec load to thermal load. Plus assume 20% reduction in demand due to energy efficiency measures
Hot Water Heating	Good practice heating and hot water use = 200kWh/m2 – Split 90:10 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures.
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L related. Plus assume 25% reduction in demand due to energy efficiency measures

Assumed annual energy demands: RETAIL – NON-FOOD

Space Heating	Good practice heating and hot water use = 82kWh/m2 – Split 90:10 heating:hot water, non-food store (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures
Space cooling (thermal)	Good practice cooling, non-food store (CIBSE Guide F), assumed COP = 3 to convert elec load to thermal load. Plus assume 20% reduction in

	demand due to energy efficiency measures
Hot Water Heating	Good practice heating and hot water use = 82kWh/m2 – Split 90:10 heating:hot water, non-food store (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures.
Electricity	Good practice electricity use, non-food store (CIBSE guide F). Assume 65% total elec demand is Part L related. Plus assume 25% reduction in demand due to energy efficiency measures

Assumed annual energy demands: HOTEL

Space Heating	Good practice heating and hot water use, holiday hotel=260kWh/m2 – Split 72:28 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures
Space cooling (thermal)	Good practice cooling, holiday hotel (CIBSE Guide F), assumed COP = 3 to convert elec load into thermal load. Plus assume 20% reduction in demand due to energy efficiency measures
Hot Water Heating	Good practice heating and hot water use, holiday hotel=260kWh/m2 – Split 72:28 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures.
Electricity	Good practice electricity use, holiday hotel (CIBSE guide F). Assume 65% total elec demand is Part L related. Plus assume 25% reduction in demand due to energy efficiency measures

Assumed annual energy demands: B1 FLOORSPACE

Space Heating	Good practice heating & hot water use, air conditioned office = 97kWh/m2 – Split 80:20 heating:hot water (ECG 19), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures
Space cooling (thermal)	Good practice cooling, air conditioned office (ECG 19), assumed COP = 3 to convert elec load to thermal load. Plus assume 20% reduction in demand due to energy efficiency measures
Hot Water Heating	Good practice heating & hot water use, air conditioned office = 97kWh/m2 – Split 80:20 heating:hot water (ECG 19), assume 80% efficient boilers to convert delivered energy to energy demand
Electricity	Good practice electricity use (fans pumps & controls, lighting, office equipment, catering, other elec, computer room), air conditioned office (ECG 19). Assume 65% total elec demand is Part L related. Plus assume 25% reduction in demand due to energy efficiency measures

Assumed annual energy demands: PRIMARY SCHOOL

Space Heating	Good practice heating and hot water use = 113kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures
Space cooling (thermal)	
Hot Water Heating	Good practice heating and hot water use = 113kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume a 35% reduction in demand due to energy efficiency measures
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L. Plus assume a 10% reduction in demand due to energy efficiency measures

Assumed annual energy demands: SECONDARY SCHOOL

Space Heating	Good practice heating and hot water use = 108kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures
Space cooling (thermal)	

Hot Water Heating	Good practice heating and hot water use = 108kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume a 35% reduction in demand due to energy efficiency measures
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L. Plus assume a 10% reduction in demand due to energy efficiency measures

Assumed annual energy demands: LIBRARY

Space Heating	Good practice heating and hot water use = 113kWh/m2 90:10 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures
Space cooling (thermal)	
Hot Water Heating	Good practice heating and hot water use = 113kWh/m2 90:10 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume a 35% reduction in demand due to energy efficiency measures
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L. Plus assume a 10% reduction in demand due to energy efficiency measures

Assumed annual energy demands: HEALTH

Space Heating	Good practice heating and hot water use = 174kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures
Space cooling (thermal)	
Hot Water Heating	Good practice heating and hot water use = 174kWh/m2 80:20 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume a 35% reduction in demand due to energy efficiency measures
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L. Plus assume a 10% reduction in demand due to energy efficiency measures

Assumed annual energy demands: B2 INDUSTRIAL

Space Heating	Good practice heating and hot water use = 92kWh/m2 15:85 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures
Space cooling (thermal)	
Hot Water Heating	Good practice heating and hot water use = 92kWh/m2 15:85 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume a 35% reduction in demand due to energy efficiency measures
Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L. Plus assume a 10% reduction in demand due to energy efficiency measures

Assumed annual energy demands: OTHER B1 EMPLOYMENT INCLUDING R&D AND LIGHT INDUSTRY

Space Heating	Good practice heating and hot water use = 90kWh/m2 15:85 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume 35% reduction in demand due to energy efficiency measures
Space cooling (thermal)	
Hot Water Heating	Good practice heating and hot water use = 90kWh/m2 15:85 heating:hot water (CIBSE Guide F), assume 80% efficient boilers to convert delivered energy to energy demand. Plus assume a 35% reduction in demand due to energy efficiency measures

Electricity	Good practice electricity use (CIBSE guide F). Assume 65% total elec demand is Part L. Plus assume a 10% reduction in demand due to energy efficiency measures

ECG 19 = Energy Consumption Guide 19 (2000), Energy Use in Offices, EEBPP, DETR
CIBSE Guide F = Energy Efficiency in Buildings, January 2004, CIBSE

10 APPENDIX B: CHP TECHNOLOGY OPTIONS TABLE

CHP system			Advantages	Disadvantages	Available sizes (Mwe)	Power efficiency (HHV	Heat efficiency (HHV)	Typical power to heat ratio	Part-load	Fuels	Uses for thermal output
	Cycle	Prime mover									
1.congiguration	Brayton cycle	Gas turbine	High reliability. Low emissions. High grade heat available. No cooling required.	Require high pressure gas or in house gas compressor. Poor efficiency at low loading. Output falls as ambient temperature rises.	1-500	27%	45%	0.6	Poor	natural gas, biogas, propane, oil	LP-HP steam
		Microturbine	Small number of moving parts. Compact size and light weight. Low emissions. No cooling required.	High costs. Relatively low mechanical efficiency. Limited to lower temperature cogeneration applications.	0.03-0.35	29%	43%	0.67	Ok	natural gas, biogas, propane, oil, biofuel	High temperature hot water
	Reciprocating engine	Spark ignition (SI)	High power efficiency with part-load operational flexibility. Fast start-up. Relatively low investment cost. Can be used in island mode and have good load following capability. Can be overhauled on site with normal operators. Operate on low-pressure gas.	High maintenance costs. Limited to lower temperature cogeneration applications. Relatively high air emissions. Must be cooled even if recovered heat is not used. High levels of low frequency noise.	0.05-5	34.8%	43.5%	0.8	Ok	natural gas, biogas, propane, landfill gas	Medium Temperature hot water
		Diesel/compression ignition (CI)			High speed (1,200 RPM) ≤4MW Low speed (60-275 RPM) ≤65MW	35.2%	High temperature: 18.1% Low temperature: 18.1%	0.97	Good	diesel, residual oil, biofuel	Lower temperature hot water, LP steam
2.congiguration	Rankine cycle	Back-pressure Steam turbine	High overall efficiency. Any type of fuel may be used. Ability to meet more than one site heat grade requirement. Long working life and high reliability. Power to heat ratio can be varied.	Slow start up. Low power to heat ratio.	3- 800	8.2%	76%	0.1	Ok	All	LP steam
		Extraction-condensing Steam turbine				10.2%	73.3%	0.14			Hot water, HP steam
		ORC Turbine			0.25-2.5	15%	75%	0.2			Hot water
3.congiguration	Electrochemical cycle	Fuel Cells: (PAFC), (MCFC)	Low emissions and low noise. High efficiency over load range. Modular design.	High costs. Low durability and power density. Fuels requiring processing unless pure hydrogen is used.	0.01-2	40%	40%	1	Good	hydrogen, natural gas, propane, methanol	Hot water, LP steam
4.congiguration	Combined Cycle	Combination of gas turbine and steam turbine	Higher electrical efficiency and if supplementary firing is also employed, provide the most flexible CHP systems currently available. Other advantages as gas turbines.	As gas turbines. Higher capital cost due to the complexity of the system.	3.5 -600	42%	31.5%	1.33	Ok	natural gas, biogas, propane, oil	LP steam

11 APPENDIX C: BIOMASS CONVERSION OPTIONS TABLE

Energy Conversion Technology	Conversion Technology Commercialization Status	Integrated CHP Technology (Prime Mover)	Prime Mover Commercialization Status
Anaerobic Digestion			
Anaerobic digester (from animal feeding operations or wastewater treatment facilities)	Commercial technology	Internal combustion engine	Commercial technology
		Microturbine	Commercial technology
		Gas turbine	Commercial technology
		Fuel cell	Commercial introduction
		Stirling engine	Emerging
Direct Combustion—Boilers			
Fixed bed boilers (stoker)	Commercial technology – Stoker boilers have long been a standard technology for biomass as well as coal, and are offered by a number of manufacturers.	Steam turbine	Commercial technology
Fluidized bed boilers	Commercial technology – Until recently fluidized bed boiler use has been more widespread in Europe than the United States. Fluidized bed boilers are a newer technology, but are commercially available through a number of manufacturers, many of whom are European-based.		
Cofiring	Commercial technology – Cofiring biomass with coal has been successful in a wide range of boiler types including cyclone, stoker, pulverized coal, and bubbling and circulating fluidized bed boilers.		
Modular* direct combustion technology	Commercial technology – Small boiler systems commercially available for space heating. A small number of demonstration projects in CHP configuration.	Small steam turbine	Commercial technology
		Organic Rankine cycle	Commercial technology
		“Entropic” cycle	Research and development (R&D) status
		Hot air turbine	R&D status
Gasification			
Fixed bed gasifiers	Emerging technology – The actual number of biomass gasification systems in operation worldwide is unknown, but is estimated to be below 25	Gas turbines – simple cycle	Prime movers have been commercially proven with natural gas and some medium heating value biogas
Fluidized bed gasifiers	A review of gasifier manufacturers in Europe, USA, and Canada identified 50 manufacturers offering commercial gasification plants from which 75 percent of the designs were fixed bed; 20 percent of the designs were fluidized bed systems.	Gas turbines – combined cycle	Operation on low heating value biogas and the effects of impurities on prime mover reliability and longevity need to be demonstrated
		Large internal combustion (IC) engines	
Modular* gasification technology	Emerging technology – A small number of demonstration projects supported with research, design, and development funding	IC engine	Commercial technology – But operation on very low heating value biogas needs to be demonstrated
		Microturbine	
		Fuel cell	Commercial introduction
		Stirling engine	Emerging technology
Modular* hybrid gasification/combustion	Emerging technology – Limited commercial demonstration	Small steam turbine	Commercial technology – But integrated system emerging
*Small, packaged, pre-engineered systems (smaller than 5 MW).			

Schedule of Revisions

Issue	Date	Remarks	Prepared by	Checked by
A	17/08/08	Draft for comment	Ian Hamilton Diego Calandrino	Chani Leahong
B	20/08/08	Format corrections	Ian Hamilton Diego Calandrino	Chani Leahong
C	17/02/09	For Publication	Ian Hamilton	Clare Wildfire