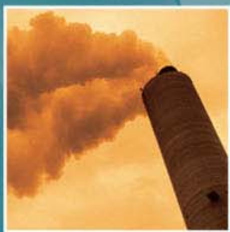
Gloucestershire County Council

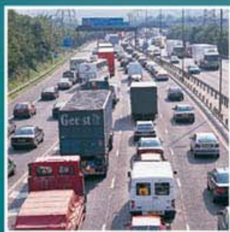
Renewable Energy Study

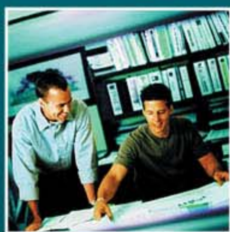
Final Report

14 June 2010



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Document Revisions

No.	Details	Date
CW027iR	Draft report for comment	14/05/2010
CW029iR	Final Draft Report	28/05/2010
CW031iR	Final Report	14/06/2010

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15 June 2010

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Certificate No. FS 13881

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Contents

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1. Introduction

1.1 Purpose of this Report

This report has been produced for the purpose of providing an evidence base to help develop local planning policy for renewable energy infrastructure provision on potential strategic development sites in Gloucestershire to help contribute to a reduction in carbon dioxide emissions in line with national climate change targets.

In order to provide evidence for renewable energy infrastructure provision this study first examines typical types of development that might come forward in Gloucestershire over the next 15 years, such as small infill housing developments, city centre office and retail development and extension of an employment park on a greenfield site. Given that there are a wide range of future development sites consisting of different building types and geographic locations, it is not possible to assess every potential development site in Gloucestershire. Moreover, many sites will have broadly similar results so performing this process for many sites is unnecessary. The approach adopted in this study is therefore to define a number of distinct theoretical site 'typologies' which include a mix of buildings which is assumed to represent a particular type of site such as a greenfield urban extension or a retail led city centre development. This study takes as a baseline assumption that all forthcoming sites in Gloucestershire will have to examine ways of providing 10% of energy needs from on site renewables and low carbon technology. The study then builds on this by looking at which technologies and systems may be able to provide significantly more than 10% of the energy needs and whether it is possible to provide 100% of energy needs from on site technology.

In order to achieve this, the likely carbon dioxide emissions (from both heat and electrical energy requirements) associated with each of the site typologies has been estimated, and the CO_2savings that could be made over and above the baseline through installing different renewable energy and low carbon technologies examined. The additional cost to build a development using the technologies was also calculated along with the build cost per tonne of CO_2 saved and the cost of energy over a 20 year baseline examined. The potential savings in CO_2 emissions can then be compared with the cost of the technology options for the different site types.

The results of the study can be used by Local Planning Authorities in Gloucestershire to set out carbon reduction targets for particular types of site can be met by developers through installing renewable energy and low carbon technology. As the study shows, the potential costs associated with the different technology options will also allow developers to ascertain whether this is likely to be viable or not when taking into consideration other requirements such as affordable housing and the provision of community infrastructure.

As well as generic site typologies the study also considers a number of specific sites within Gloucestershire that have been identified as having the potential to come forward for development in the next 15 years. The same calculations in terms of carbon reduction targets, technology mixes and likely costs were made for each of the sites together with an additional assessment of wind and hydroelectric potential.

A number of technical, financial and developmental assumptions related to the delivery of renewable and low carbon energy systems were made in the preparation of this report. These are included in Appendix A.

The remainder of this report is set out as follows:

- Section 1 Policy background, methodology and assumptions;
- Section 2 Methodology;
- Section 3 Results;
- Section 4 Discussion of results and how these apply to generic and specific sites;
- Section 5 Key points and next steps.

1.2 Planning Policy Background

This study has been commissioned by Gloucestershire County Council (GCC) in direct response to Planning Policy Statement: Planning and Climate Change (the PPS1 Supplement[1]) which requires local planning authorities to adopt policies for delivering reductions in CO_2 emissions supported by a robust local evidence base. This includes a requirement for planning authorities to consider opportunities where local circumstances allow further progress to be made in achieving the Key Planning Objectives set out in the PPS1 Supplement. These objectives are set out in Box 1. In considering these objectives local planning authorities should ensure their Core Strategy should be informed by, and in turn inform, local strategies on climate change.

[1] A revised PPS Supplement was published for consultation in March 2010.

Box 1 PPS1 Climate Change Supplement Key Planning Objectives

To deliver sustainable development, and in doing so a full and appropriate response on climate change, regional planning bodies and all planning authorities should prepare, and manage the delivery of, spatial strategies that:

- make a full contribution to delivering the Government's Climate Change Programme and energy policies, and in doing so contribute to global sustainability;
- in providing for the homes, jobs, services and infrastructure needed by communities, and in renewing and shaping the places where they live and work, secure the highest viable resource and energy efficiency and reduction in emissions;
- deliver patterns of urban growth and sustainable rural developments that help secure the fullest possible use of sustainable transport for moving freight, public transport, cycling and walking; and, which overall, reduce the need to travel, especially by car;
- secure new development and shape places that minimise vulnerability, and provide resilience, to climate change; and in ways that are consistent with social cohesion and inclusion;
- conserve and enhance biodiversity, recognising that the distribution of habitats and species will be affected by climate change;
- reflect the development needs and interests of communities and enable them to contribute effectively to tackling climate change; and
- respond to the concerns of business and encourage competitiveness and technological innovation in mitigating and adapting to climate change.

Fundamentally the PPS1 Supplement requires local planning authorities to adopt planning policies which promote renewable energy schemes and require more energy efficient developments supplied with energy from decentralised and renewable or low carbon sources.

The Local Planning Authorities (LPAs) in Gloucestershire are at varying stages of progress with their Core Strategies. This study is part of the evidence base which will be used to set local targets for renewable and low carbon energy development in Gloucestershire and is part of a wider study regarding renewable energy provision across Gloucestershire in the period to 2026. This report focuses on an initial investigation of renewable energy options for particular site types and a number of key sites in the county. The outputs of this report will be used by LPAs to inform the process of site assessment and associated policy development for their Core Strategies.

1.3 Technologies Considered in this Report

Entec have analysed a number of different technologies that can be installed in a range of site types to help reduce CO_2 emissions and to give an indication of their likely viability. The technologies ranged in scale from individual building integrated micro-renewables to large community-scale heat and power generation and included:

- Solar thermal panels (for heat);
- Solar photovoltaic panels (for electricity);
- Ground source heat pumps (providing heat and cooling);
- Biomass (heat only and Combined Heat and Power [CHP]);
- Natural gas (CHP);
- Energy from waste (including incineration and anaerobic digestion);
- Wind power (for key sites only); and
- Hydroelectric power (for key sites only).

Wind and hydroelectric power were not considered for the generic site type assessments as the amount of energy they can produce is reliant on the wind or water resource present on a site.

A brief description of each of these technologies and the baseline electrical and heating technologies is included in Table 1.1.

Table 1.1 Technologies Considered in this Study

Technology	Description
Gas Boilers (baseline)	Individual gas boilers in each dwelling and commercial building, typical of current practice and the baseline assumption for this study
National Grid (baseline)	All electricity sourced from the grid
Solar Thermal Panels	Collector positioned on the roof concentrates energy from the sun onto tubes through which water (or other fluid) which is circulated. Contributes to hot water supply.
Gas CHP	Natural gas is combusted in an internal combustion engine which turns a generator to produce electricity, with residual heat collected and used for space heating and hot water
Biomass Heating	Biomass combusted in a specialised boiler to provide space heating and hot water
Biomass CHP	Biomass combusted, with the heat used to turn a generator via a number of possible technologies to produce electricity, with residual heat collected and used for space heating and hot water

Technology	Description
Ground Source Heat Pumps (GSHP) - Heating Only	Coils installed underground through which fluid is circulated, transferred heat from the ground to provide a proportion of space heating
GSHP - Heating and Cooling	As above, but with the system operated in reverse to provide cooling in summer months
Solar Photovoltaic (PV) Panels	Photoreceptive panels that convert energy from sunlight into electricity, reducing the net electrical demand of a building
Waste	Waste incineration plants (or alternative thermal treatment technology) generate large quantities of surplus heat which is typically wasted to the atmosphere. This residual heat can be exported to nearby developments to provide space heating and hot water
Wind (Key sites assessment only)	Large-scale wind turbines (2.5MW). The contribution from small scale wind is considered to be negligible.
Hydro (Key sites assessment only)	This desk-based assessment has been completed using aerial photography and OS data of the area. The requirements for a good site are that it is close to a watercourse with a significant head.

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2. Methodology

The following methodology has been used to quantitatively assess the CO_2 emissions reductions and economic performance of a range of sustainable energy technologies for a number of generic site typologies which represent the types of new development that may come forward in Gloucestershire in the next 15 years. This is achieved through using a spreadsheet model which takes a number of assumptions relating to energy demand, technologies and economics that can be varied as appropriate to a particular site typology. The model was also used to assess the CO_2 emissions reductions and economic performance of a range of sustainable energy technologies for a number of identified key sites in addition to an assessment of site specific technologies (hydro and wind) to take place.

An overview of the methodology is set out in the following sections of the report and a full list of assumptions that have been made for this report can be found in Appendix A.

2.1 Step 1 - Energy Demand Assessment

For each site typology (or key site) a number of assumptions are made regarding the development mix (number of residential dwellings, floor area of commercial space) are combined with industry standard energy benchmark data to determine the total demand for heat, electricity and cooling. Estimates of peak loads for the purpose of plant sizing are also made at this stage.

2.2 Step 2 –Technologies Assessment

The energy supply technologies that can be appraised in the model were summarised earlier in this report in Table 1.1, along with a brief description of each technology. The energy technologies can be split into two main types; decentralised and communal. Decentralised systems are those in which each individual building has its own heating system (and potentially electricity generation system). Communal systems are those where heat, and possibly electricity, is generated at a central ‘energy centre’ at the development, with heat distributed to individual buildings via a network of pipes carrying hot water and electricity distributed through a private network (though this may not always be the case as it may be simply exported to the grid). The estimation of the amount of useful energy a particular system can provide is based on technical knowledge and industry experience.

Note that although the model is designed to consider the contribution of renewable energy to developments in a realistic manner, it does not consider site specific constraints such as available space, shading and adverse ground conditions which will impact on the feasibility. Hence a degree of care must be taken when interpreting the results.

Since the generic typologies are not location specific, it is not possible to consider the impact of technologies such as wind and hydro where the characteristics of the site have a huge impact on the feasibility and potential contribution to energy supply. However for the key sites, knowledge of the geographic location and approximate site boundaries enabled an estimate of the contribution from hydro and wind to be made. In addition, the additional detail of the type of site allows assumptions regarding infrastructure to be refined.

All technologies are assessed in a similar manner within the model except PV, wind and hydro which are considered somewhat differently. The infrastructure requirements (district heating or gas pipework primarily) are also estimated by the model. An overview of how each technology has been considered is given in the following sections.

Decentralised Systems

The following scenarios shown in Table 2.1 have been modelled, with the contribution to the development's energy supply detailed in the table below. In all cases cooling is assumed to be supplied via air-cooled chillers (powered by electricity), apart from the scenario in which GSHP supplies both heating and cooling.

Table 2.1 Energy Provided by Technology (Decentralised Systems)

Primary Technology	Contribution	Secondary Technology	Contribution
Individual Gas Boilers (Baseline)	100% of space heating	n/a	n/a
GSHP (Heating Only)	50% of space heating	Gas Boilers	50% of space heating, 100% of hot water
GSHP (Heating and Cooling)	50% of space heating, 100% of cooling	Gas boilers	50% of space heating, 100% of hot water
Solar Thermal	50% of hot water in housing and commercial buildings, 20% in flats – this accounts for total useful annual output and efficiency	Gas boilers	100% of space heating, 50% of hot water (80% in flats)

Communal Systems

The following scenarios shown in Table 2.2 have been modelled, with the contribution to the development's energy supply detailed in the table below. For waste it has been assumed that a site is located near to a thermal waste treatment facility, capable of supplying the entire heat demand of the site.

Table 2.2 Energy Provided by Technology (Communal Systems)

Primary Technology	Contribution	Secondary Technology	Contribution
Gas CHP	50% of space heating, 100% of hot water	Gas Boilers	50% of space heating
Biomass Heating	90% of space heating, 90% of hot water	Gas Boilers	10% of space heating, 10% of hot water
Biomass CHP	50% of space heating, 100% of hot water	Biomass Boilers	40% of space heating (gas boilers make up the remaining 10%)
Waste	100% of space heating, 100% of hot water	n/a	n/a

Solar PV

The roof area of all buildings in the assessed development is estimated based on the floor area and assumed number of stories (see benchmark tables). It has been assumed that 25% of the roof area of each building is suitable for PV panels, based on the proportion of the roof that is south facing and allowing for obstructions such as flues, skylights etc.

The energy output for a PV system is assumed to be 0.14 kWp/m^2 and 700 kWh/kWp/year which equates to 1m^2 PV array generating 98 kWh/year. These figures are based on information provided by manufacturer Segen and supported by typical generic figures from the Energy Savings Trust.

Wind

Wind has not been considered in the assessment of generic typologies as the output is highly site specific. Wind has been considered in the appraisal of key sites.

Wind generation estimates are based on a combination of Entec's own yield calculations and the Carbon Trust wind yield estimator[2] developed by Entec and the Met Office.

This desk-based exercise has been completed using aerial photography and OS mapping for only the sites identified below. This is in no way intended to preclude development within other sites nor indicate that those areas identified will include a wind turbine of some size. While the locations identified are seen as places where development of wind is most likely, there are further decisions to be made to finalise the layout of housing, etc, which will have an effect on the potential location.

[2] http://www.carbontrust.co.uk/emerging-technologies/current-focus-areas/offshore-wind/_layouts/ctassets/aspx/windpowerestimator

For many large-scale wind developments the most onerous restriction is that of turbine noise adversely affecting properties. For the purposes of this assessment a buffer distance of 500m has been assumed. This is based on noise modelling of a candidate turbine Nordex N90 2.5MW machine and the recommended night-time limit of 43dB(A) apparent at surrounding noise sensitive properties.

Small-scale wind turbines are much closer to the ground (~10-15m) and therefore are significantly affected by turbulence from nearby obstructions (buildings/trees etc). There is recommended siting guidance which states that small-scale turbines should be separated from nearby obstructions by at least 10x the height of the obstruction (~100m for an average 3 story building) to limit the adverse effects turbulent air can have on turbine performance. While this is not a ‘hard’ limit and turbine placement could stray into these areas it is recommended the guidance is followed as the effect of turbulent air can lead to a reduced performance or damage to the turbine.

The assessment has been completed using the following buffers and separation distances for large-scale wind development:

- Noise (500m);
- Road and Railway lines (125m);
- Overhead power lines (125m).

No account has been made for visual or cumulative impact.

Given the low wind speed and the ‘exclusion area’ which is required to be free from obstacles, the contribution from small scale wind is considered to be negligible at this stage.

Hydro

The potential for hydro generation schemes was reviewed at the seven key sites. The energy available in a body of water depends on the water’s flow rate and the height that the water falls (head). As a general rule, a head of at least 5m is required.

The actual output of the scheme can vary significantly depending primarily on how efficiently the equipment converts the power in the water into electrical power (efficiencies of over 90% are possible for very large-scale systems but for small scale systems more likely in Gloucestershire 50% is a more typical estimate).

Run of river schemes require the partial or complete diversion of a watercourse to a turbine, and tend to require a significantly greater head (~20m) unless the river is large.

Infrastructure

In the vast majority of cases the most significant capital cost element of a communal heating system is the pipework required to transport hot water to individual buildings. Hence the higher the building density, the lower the length of pipe required and the lower the costs. This increases the viability of this type of scheme.

For the generic typology assessment the pipe length required per dwelling/unit is assumed to be 5m for flats and 30m for commercial units across all site types. The pipe length required for houses is estimated to be 20m. This is based on Entec's own estimate and represents a relatively high density development (>50 dwellings per hectare), and hence assumes the development has been carefully designed to minimise pipe length.

For the assessment of key sites, a slightly improved estimate can be made given that the location of the development is known. However, the boundaries of the site and proposed layout are unknown at this stage so no attempt has been made to estimate the housing density. The following assumptions have been made:

- 15m for brownfield sites – broadly representative of terraced and semi-detached housing at build densities greater than 60 dwellings per hectare;
- 25m for greenfield sites – broadly representative of detached and semi-detached housing at greater than 40 dwellings per hectare;
- 5m for flats in all cases.

The model allows for any figure to be used so where detailed development is available a more accurate figure can be determined.

2.3 Step 4 - Results

The model can be used to estimate the maximum contribution from on-site renewables that is *technically* achievable at a particular type of site, as well as the maximum contribution likely to actually be viable (by factoring in costs and revenues). Given the number of assumptions and lack of specific detail of the sites, the model is not intended to provide a detailed and accurate assessment of viability, rather it can be used to give a broad idea of what levels of carbon emissions reduction can be achieved, and at approximately what cost. It gives a clear indication as to which technologies are likely to be best suited to a particular type of site.

The model allows the comparison of a large number of parameters, four of the most important of which are listed below and are the primary indicators used in the analysis. **In all cases the impact is considered relative to the baseline scenario**, which assumes all heat is provided by individual gas boilers and electricity is sourced from the national grid as is the case for the vast majority of buildings in the UK at present:

- **Carbon dioxide emissions reductions** – approximate percentage reduction in CO_2 emissions by installing the renewable energy system;

- **Increase in capital / build costs** – gives an indication of the level of additional costs incurred by the developer (or third party) as a result of the renewable energy system;
- **Cost per tonne of carbon dioxide saved**– calculated over a 20 year lifetime, does not include revenues from support mechanisms for renewable energy;
- **Long-term cost of energy** – the estimated combined cost of heat, electricity and cooling to residents of the development, including support mechanisms for renewables.

The outputs of the model can then be used to estimate whether a particular technology, or combination of technologies, is likely to be viable at a particular typology or actual site.

2.4 Step 5 - Analysis/Discussion

The outputs of the model have been analysed and a summary of the implications for each typology and key site is presented in the report. Though a range of technology combinations are possible, the report focuses on the most viable scenarios.

For example a combination of solar thermal and solar PV is generally feasible providing there is adequate roof space, but a combination of solar thermal and GSHP is not considered in detail since the two technologies are not normally used in conjunction with each other as a very complex heating system is required.

2.5 Model Assumptions and Limitations

There are, necessarily, a large number of assumptions built into the model. These can all be varied, but for the typology assessment we have used a common set of technical and economic assumptions. Up-to-date published data is used as far as possible, though it is not possible to use such data in all cases as they do not always exist. Where this is the case our own estimates have been made based on our experience and engineering judgement.

A full breakdown of the assumptions in the model is presented in Appendix A.

3. Results

3.1 Typologies Assessment

The composition of the nine site typologies considered in this study are shown in Table 3.1.

Table 3.1 Typology Assumptions

Typology	Label	Assumed Composition of Sites	Additional Notes
City Centre Development – Retail Led	A	20,000 – 25,000m^2 City Centre Retail 5,000 – 6,000m^2 Office 1,000 – 2,000m^2 Bars/Cafes/Restaurants	
City Centre Development – Office/Municipal Administration Led	B	5,000 – 6,000m^2 City Centre Retail 20,000 – 25,000m^2 Office 1,000 – 2,000m^2 Bars/Cafes/Restaurant	
City Centre Development – Culture/Leisure Led	C	5,000 – 6,000m^2 City Centre Retail 5,000 – 10,000m^2 Office 1,000 – 2,000m^2 Bars/Cafés/Restaurants 8,000m^2 Leisure Facilities – Cinema/Theatre 5,000 – 6,000m^2 Hotel/Conferencing Facilities	
City/Town Centre Housing – Brownfield Regeneration Led	D	600 dwellings	Split as 450 houses and 150 apartments
Suburban – Residential Led	E	150 dwellings	Split as 110 houses and 40 apartments
Greenfield Urban Extension	F	1,500 dwellings ~7,000m^2 Office ~7,000 m^2 Industry ~5,000m^2 Distribution	Split as 1,100 houses and 400 apartments Up to approximately 700 jobs-worth of floorspace for non-B use classes (retail/hospitality)
Expanded Employment Park	G	11,000m^2 Office 5,000m^2 Industry 2,000m^2 Storage/Distribution	Assumes total of 10ha
Market Town Greenfield Housing Site on Fringe	H	150 dwellings	Split as 110 houses and 40 apartments
Infill Housing	I	Less than 10 dwellings 10-50 dwellings	Considered as one typology with 30 dwellings (negligible difference in results)

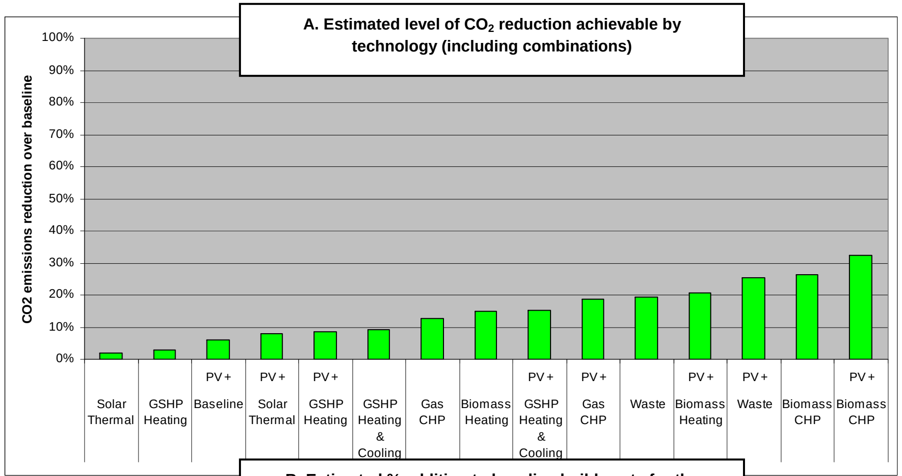
The typology assessment provides an overview of the likely suitable technology options for generic site types. This can help form principles on which actual sites can be developed, perhaps through policy or guidance. The full results are available in a spreadsheet accompanying this report and a summary of the key findings is presented in a series of graphs in the following section of the report.

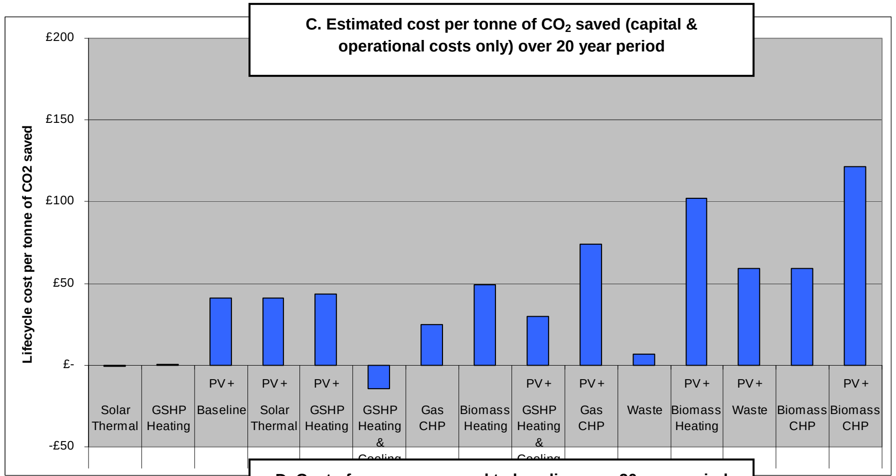
Four graphs have been produced for each site typology ranked in order of their potential carbon reductions. The four graphs show:

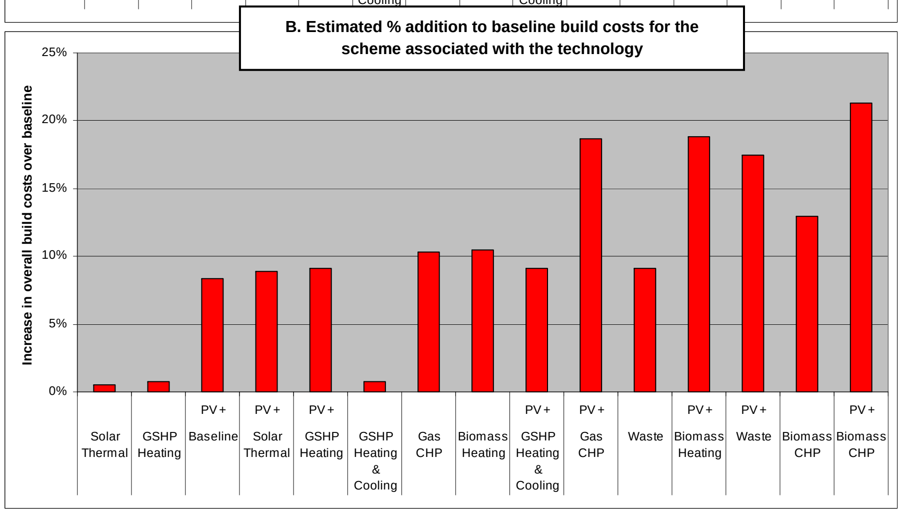
- A. The estimated level of CO_2 reduction achievable within the site type utilising a number of different technologies and combinations of technologies;
- B. The estimated increase (in percentage terms) to baseline build costs for the scheme associated with the technology or technology combination;
- C. The estimated cost (capital & operational costs only) per tonne of CO_2 saved over a 20 year period by the technology or technology combination;
- D. The cost of energy using the technology or technology combination compared to the baseline energy cost baseline over a 20 year period.

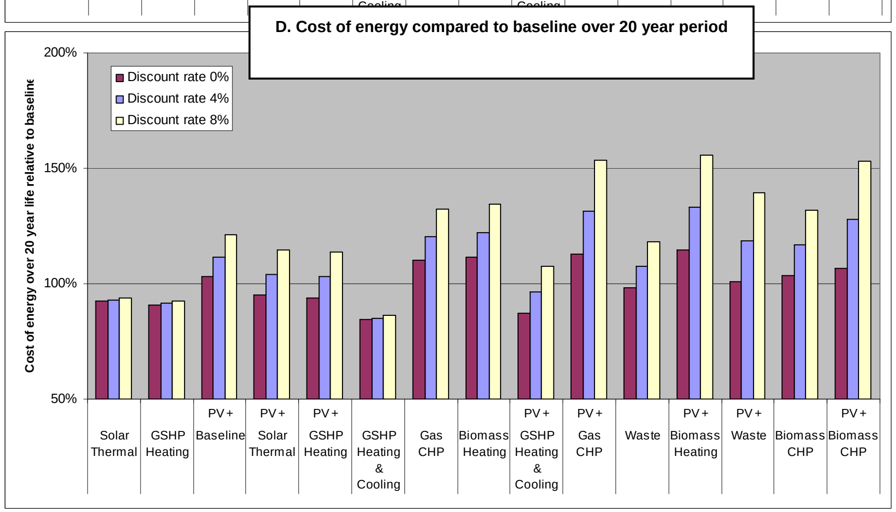
It should be noted that when interpreting the graphs (and accompanying spreadsheet) that they do not take into account the technical feasibility of the proposed technology in significant detail. Some options that appear viable purely based on the output of the model may not actually be feasible on all sites. Potential constraints (such as limited space in a built up area) are considered in Section 4 of this report but detailed consideration of constraints is only possible at the project level.

Site A – City Centre Development, Residential Led

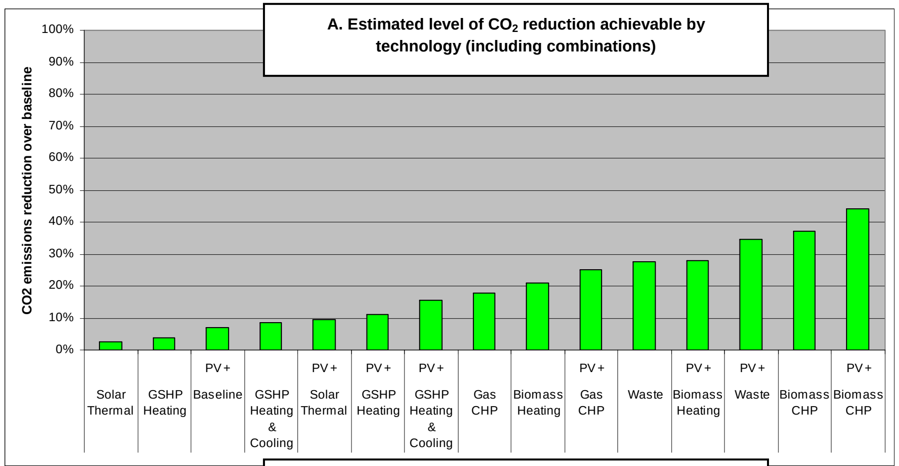


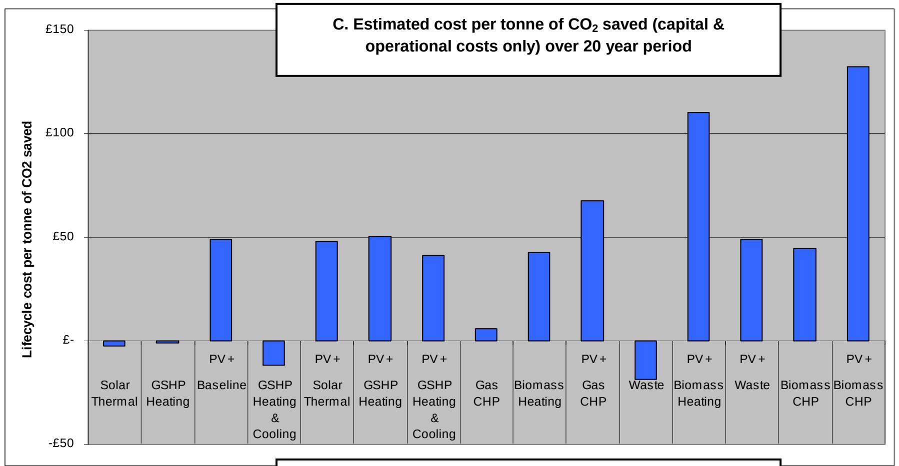


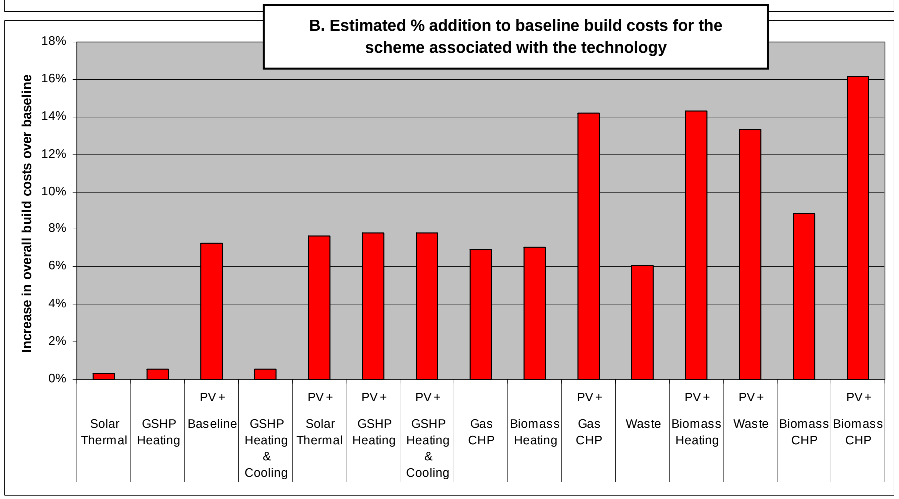


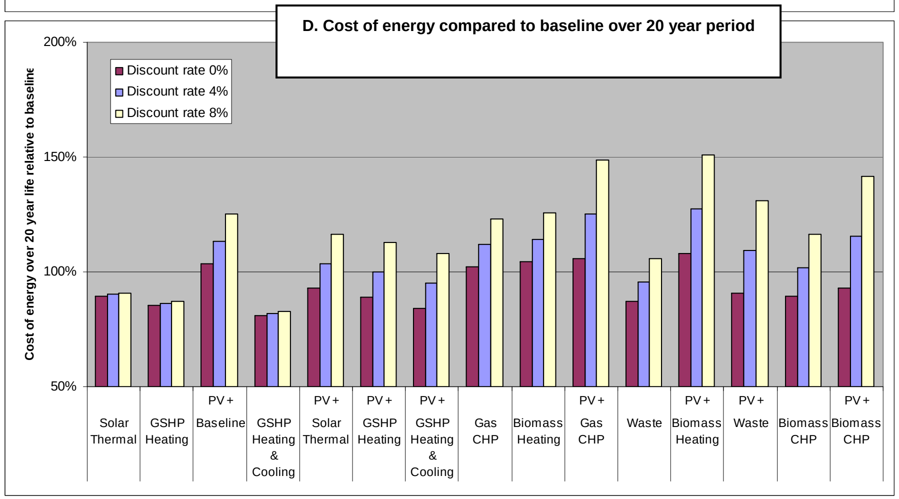


Site B – City Centre Development, Office Led

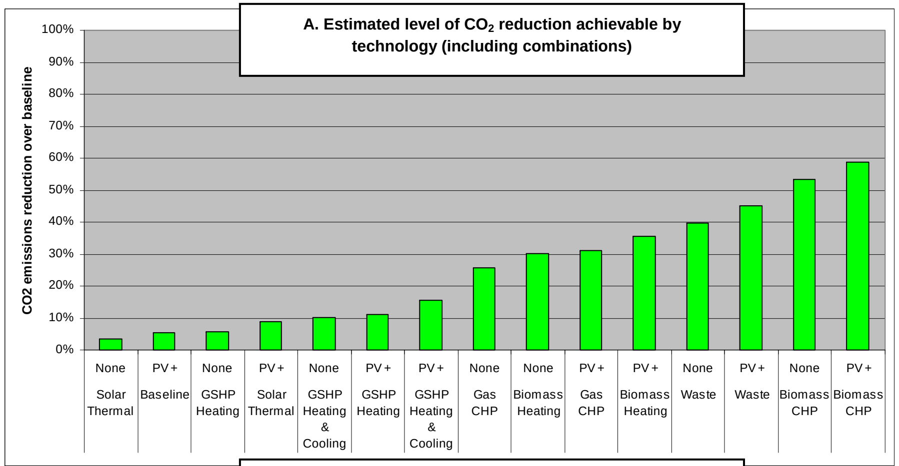


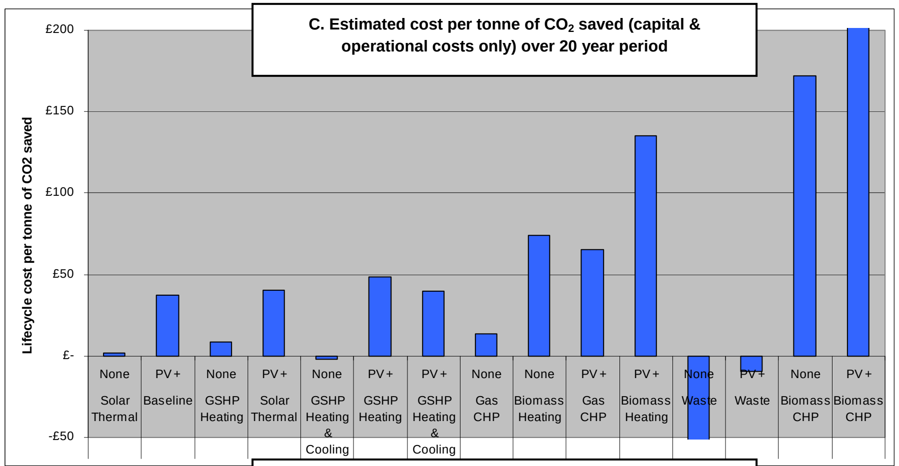


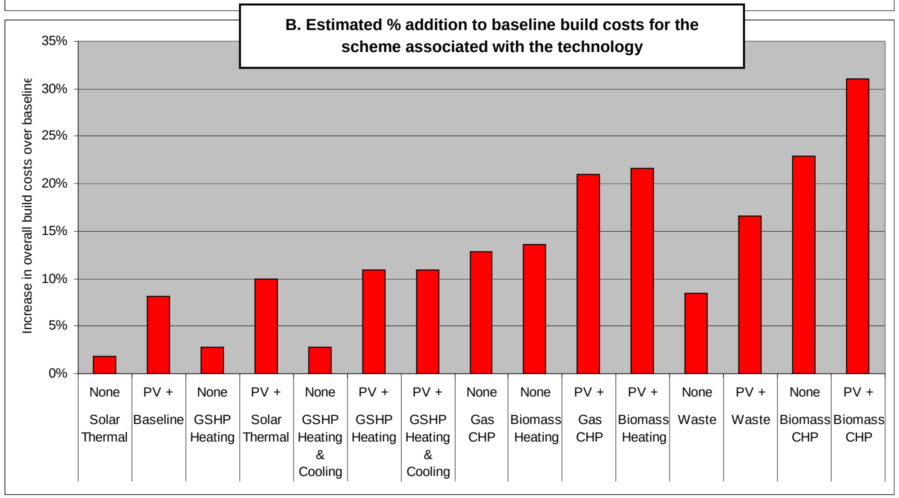


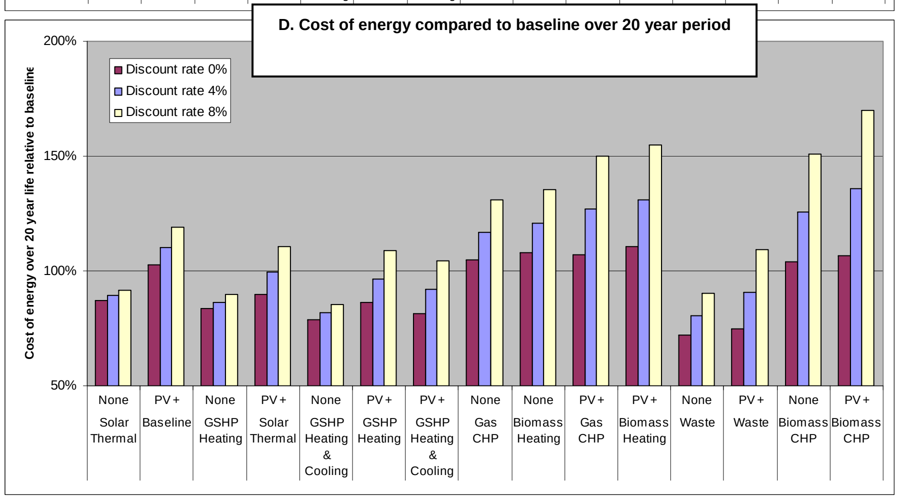


Site C – City Centre Development, Leisure Led









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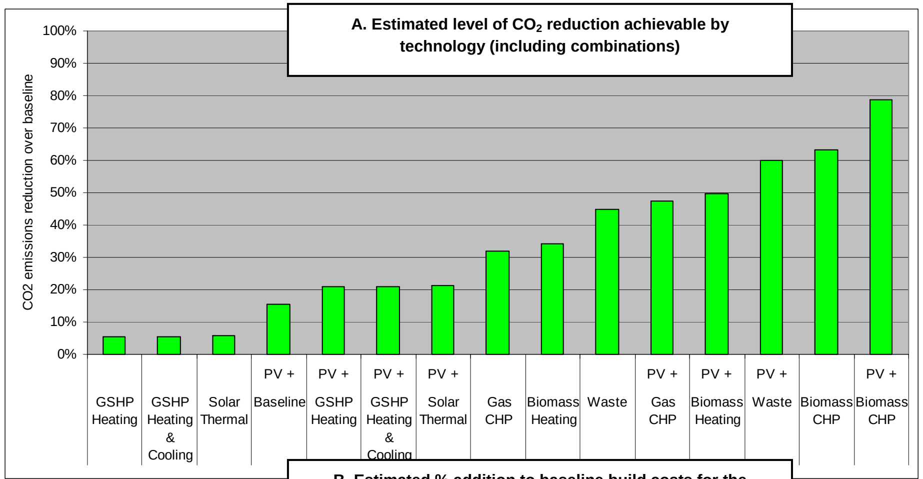
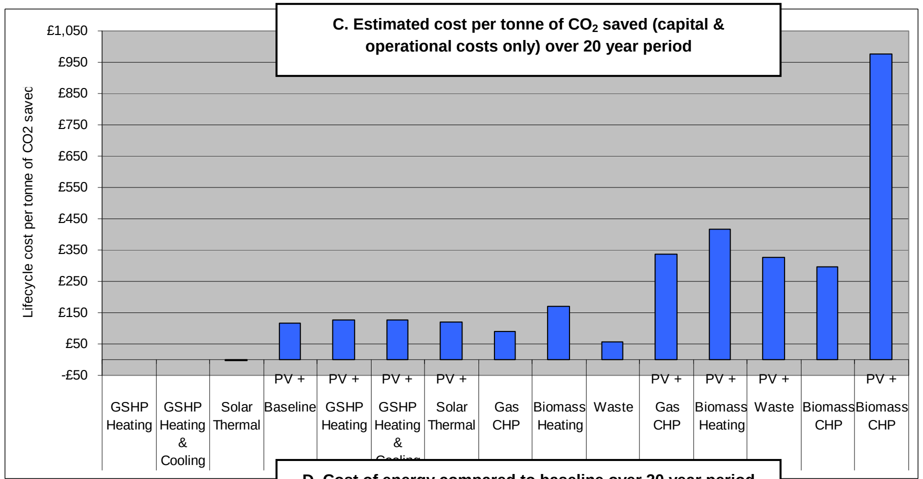
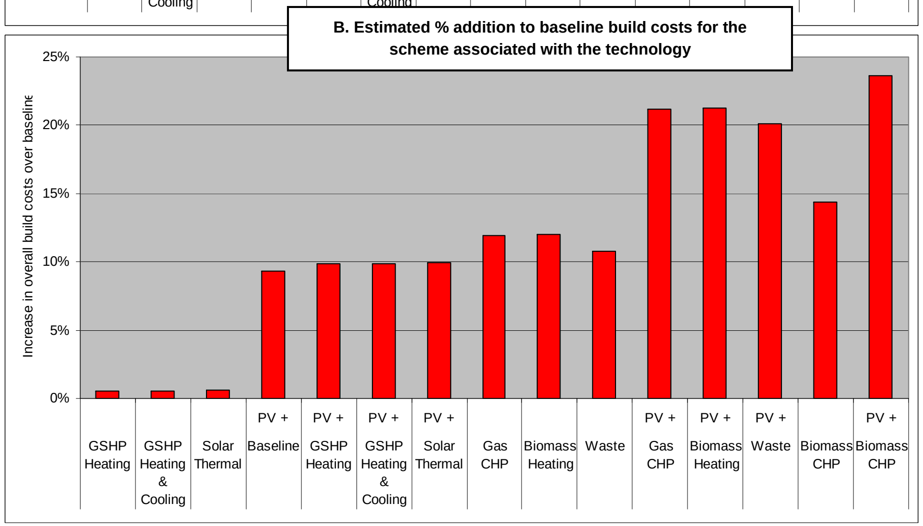
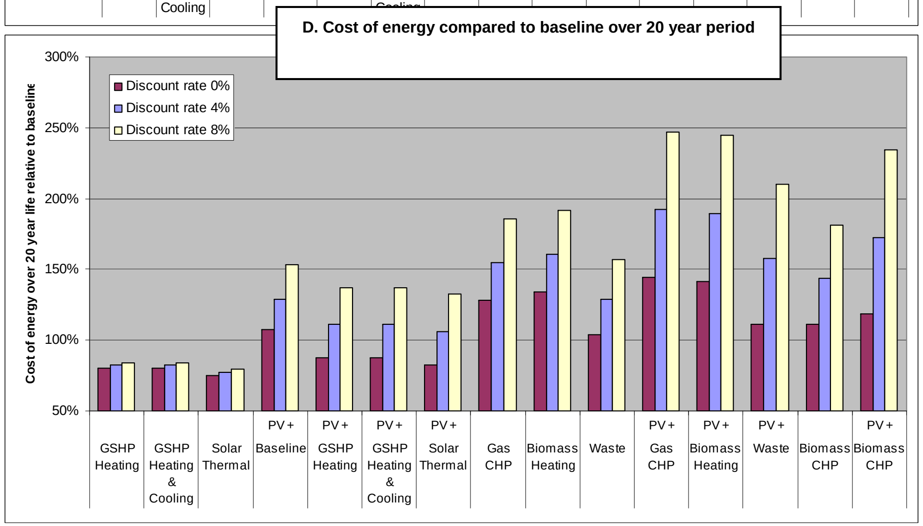
Site D – City/Town Centre Brownfield Regeneration, Residential Led









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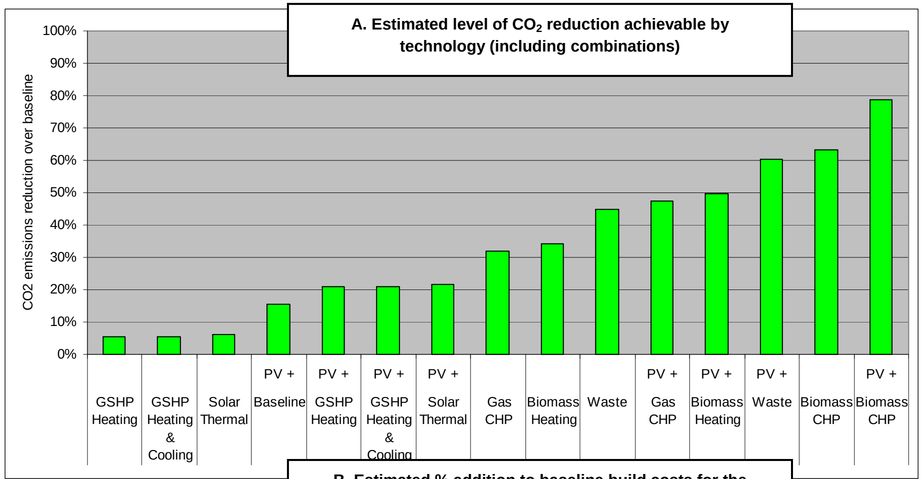
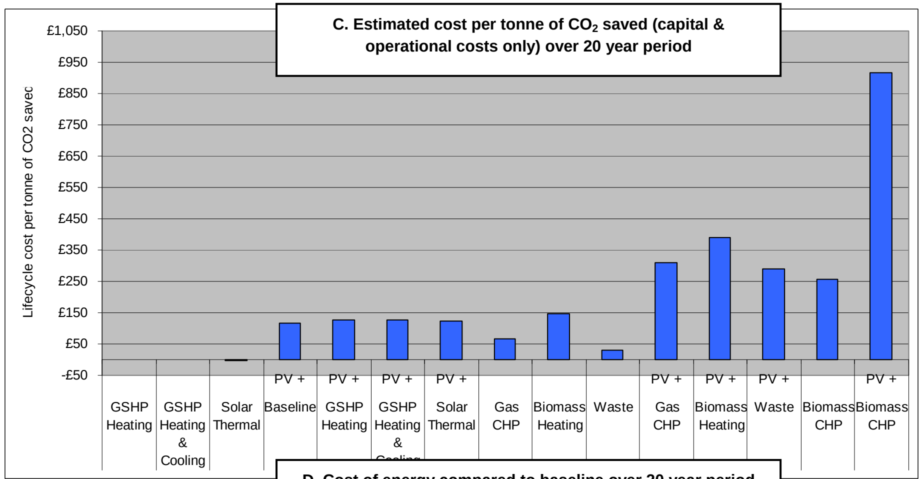
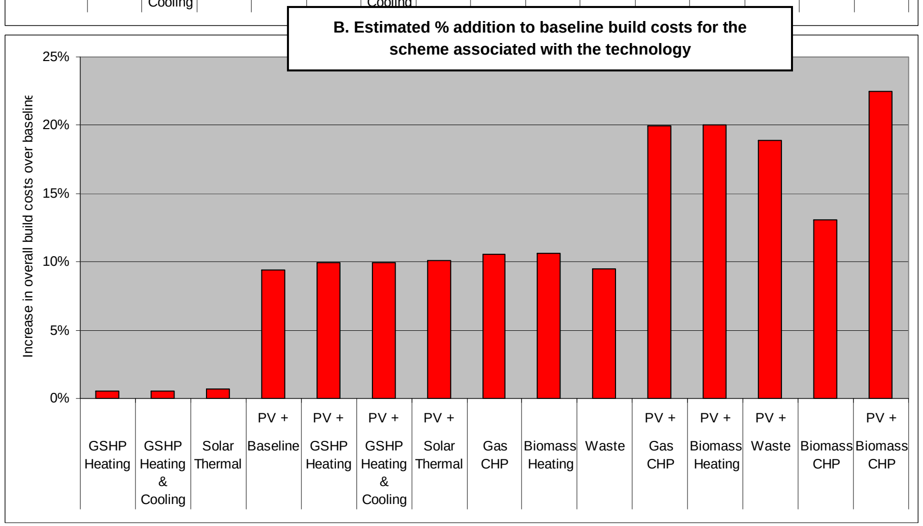
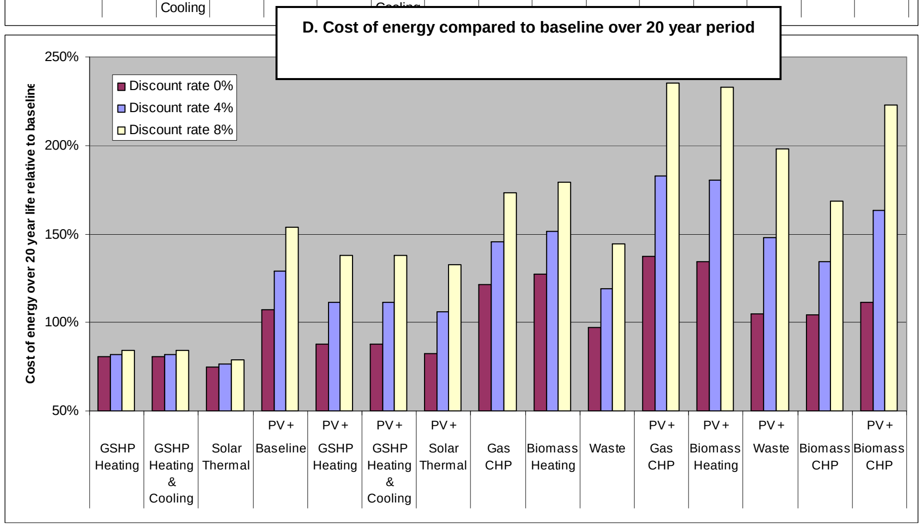
Site E – Suburban, Residential Led









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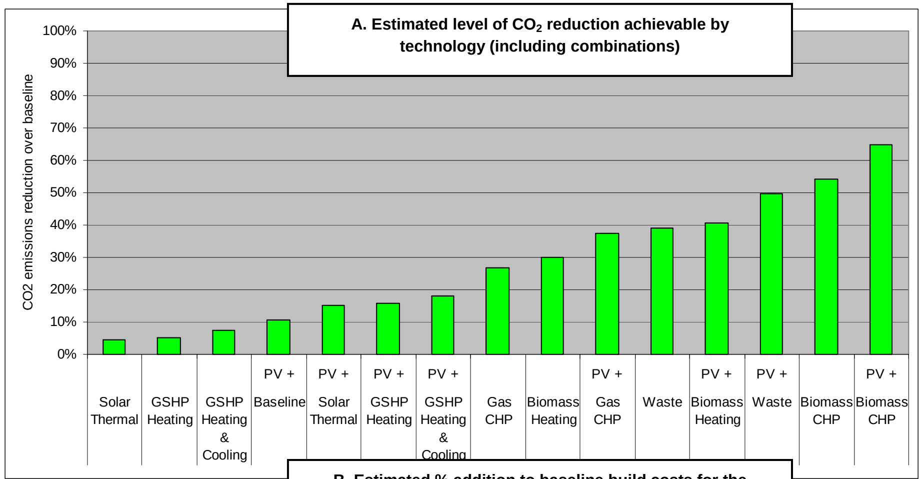
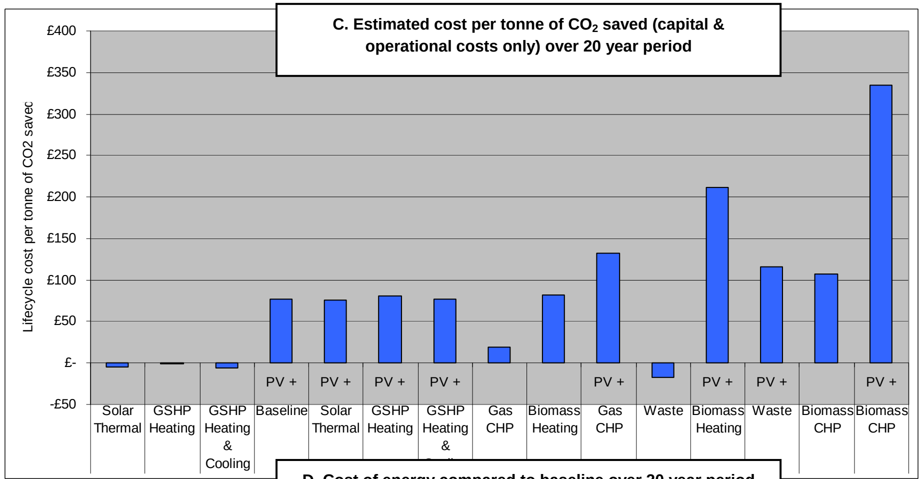
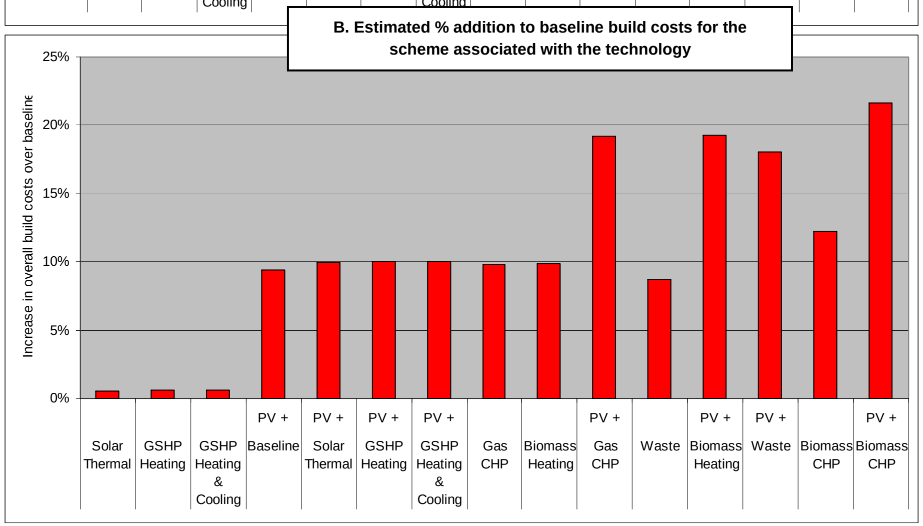
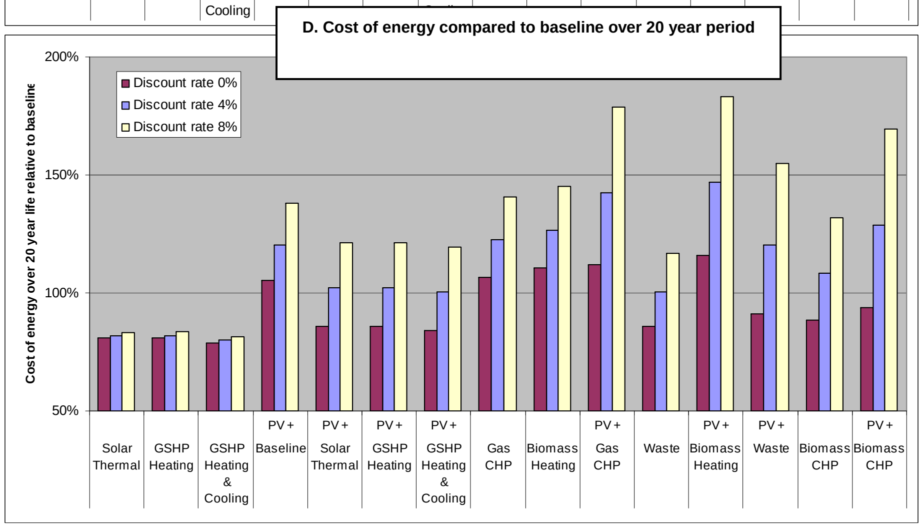
Site F – Greenfield Urban Extension









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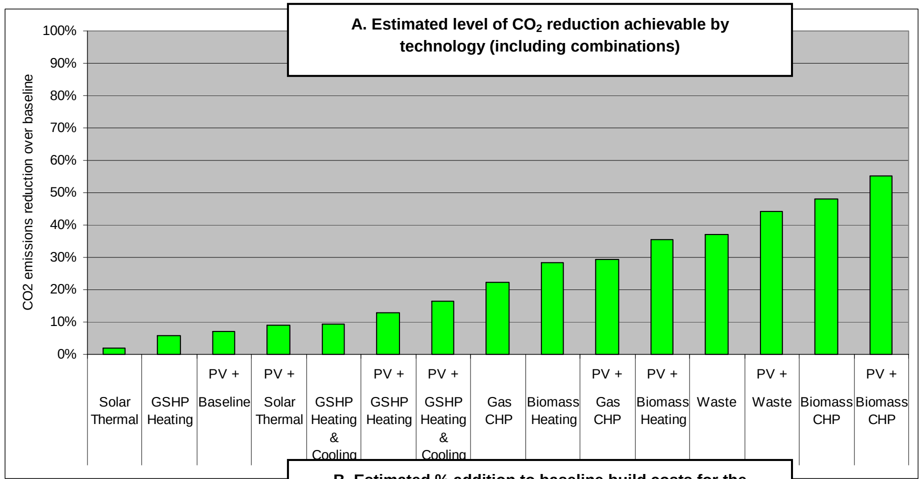
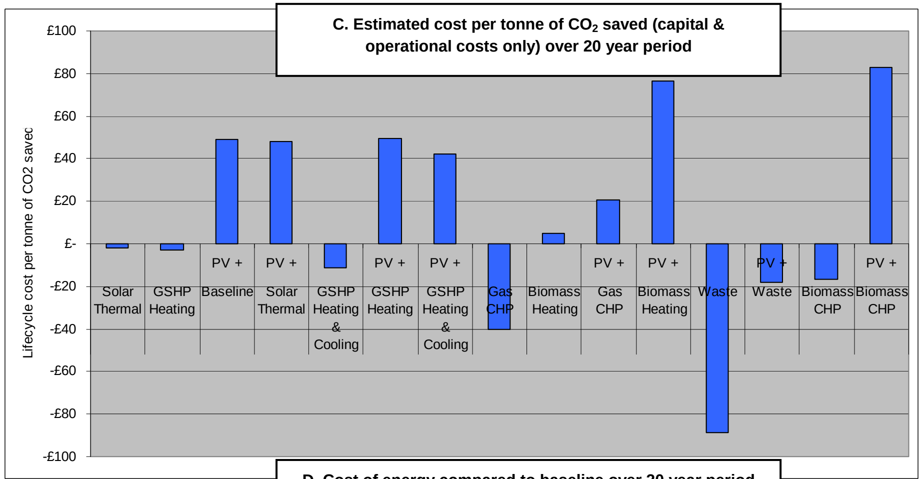
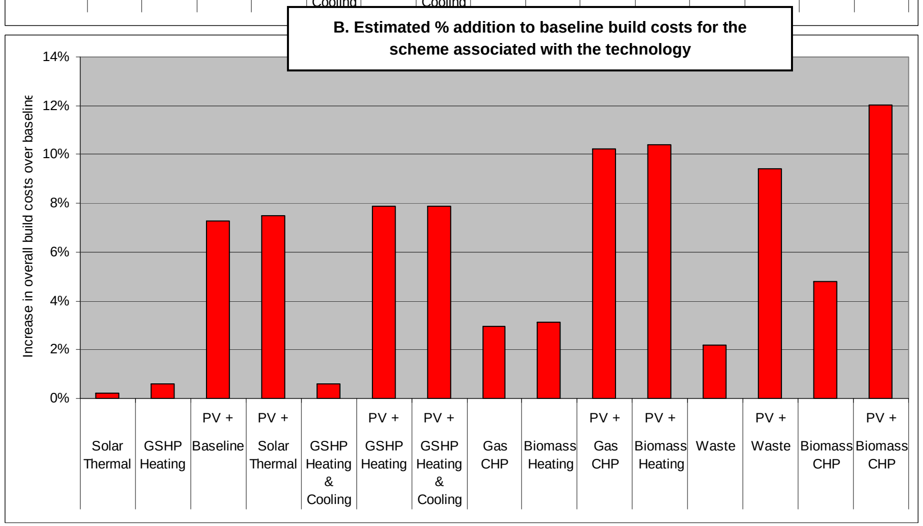
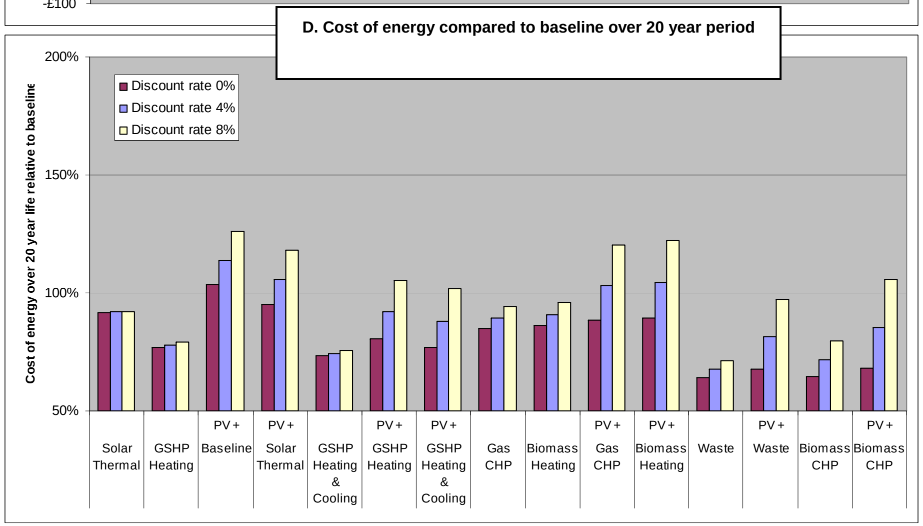
Site G – Expanded Employment Park

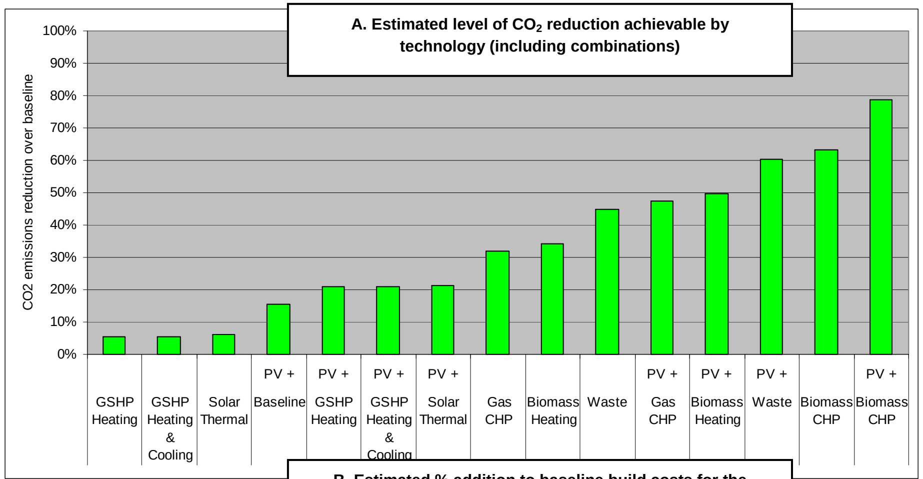


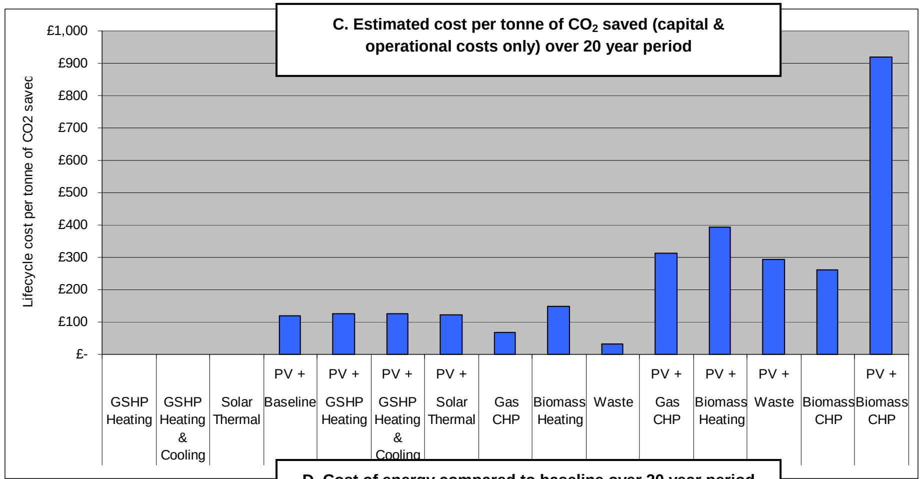


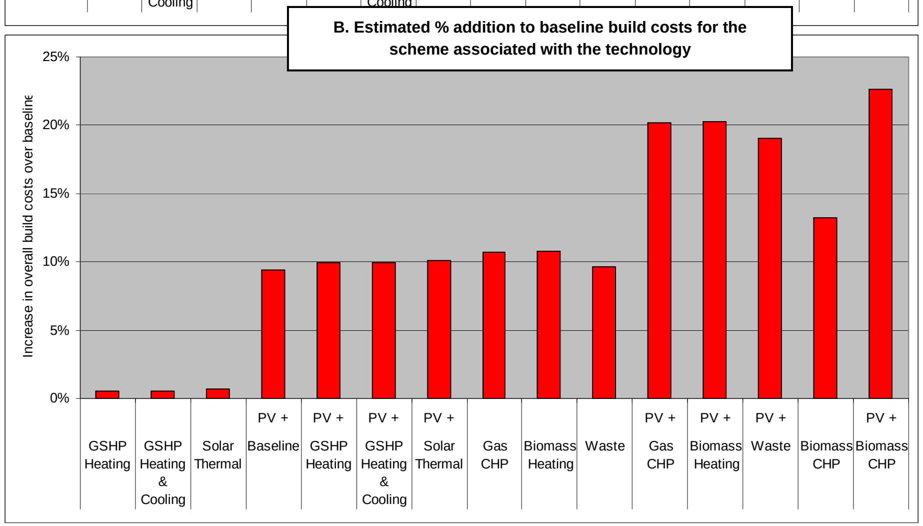


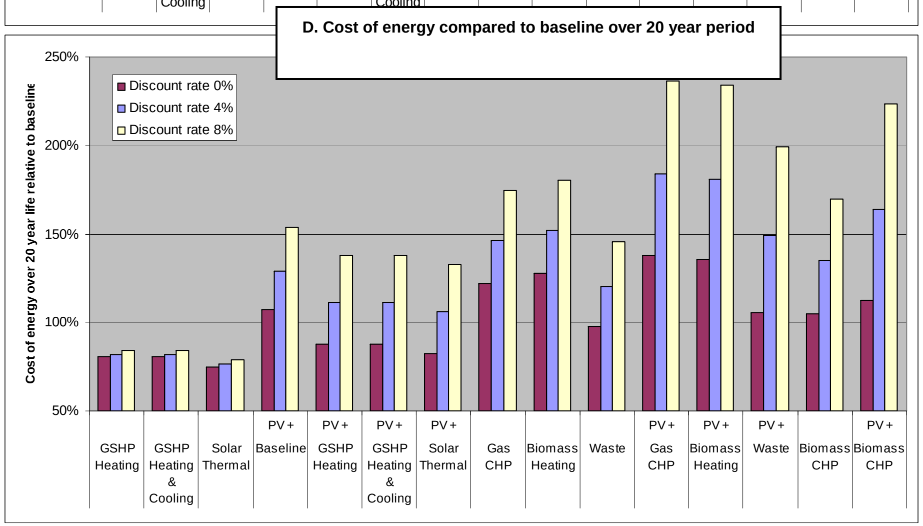


Site H – Market Town Greenfield Residential Site on Fringe









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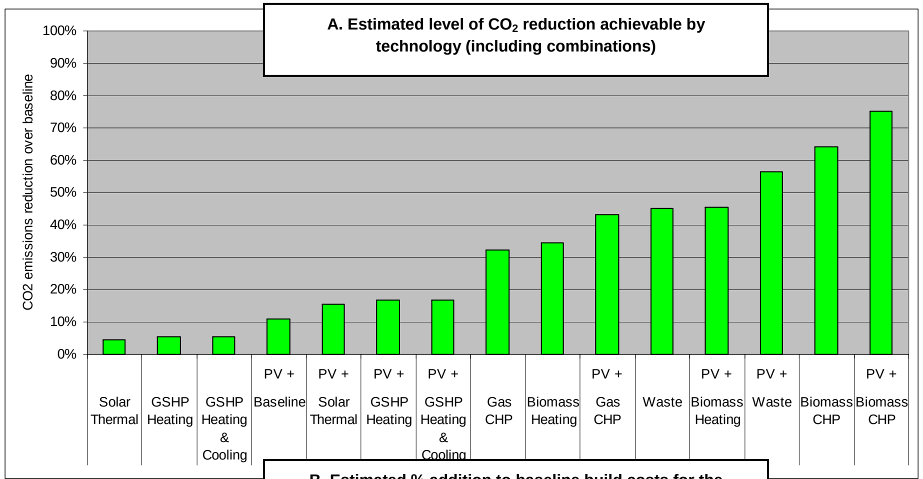
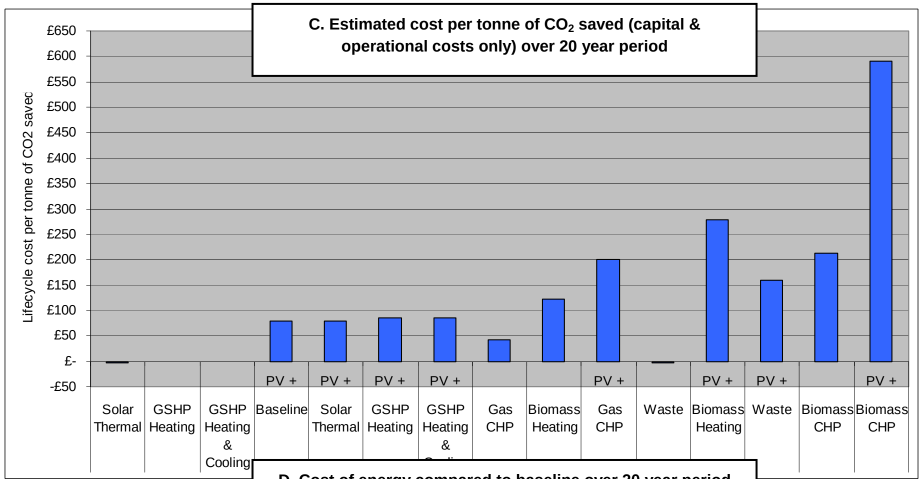
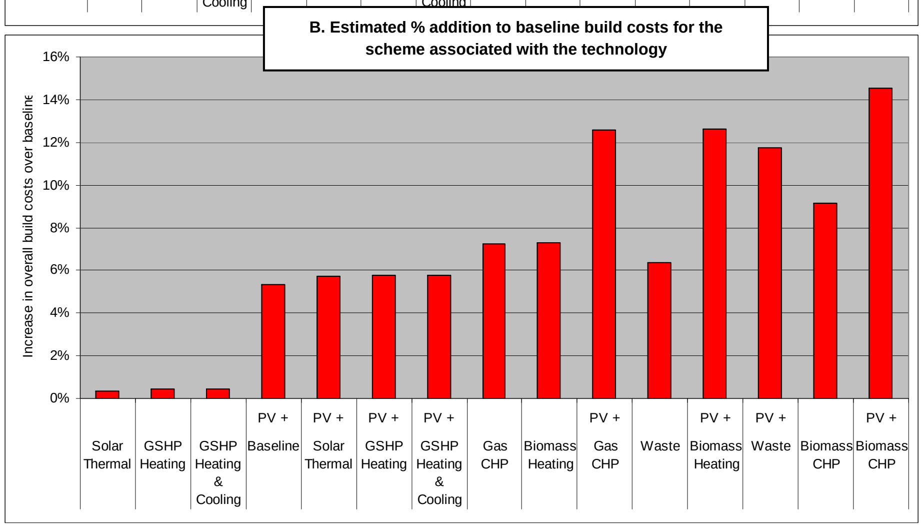
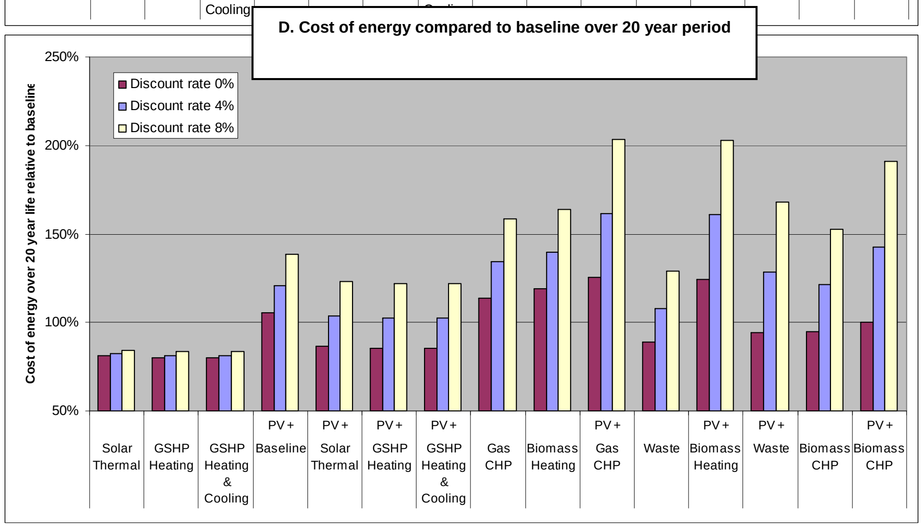








3.2 Key Sites Assessment

The typology assessment in Section 3.1 explains the likely viable mix of appropriate low carbon technologies for generic site types. In this section we apply the same principles to some actual *key* sites that have potential to come forward for development in the next 15 years. This helps show the process in action and illustrates how the results can be used. The results of the appraisal of key sites are presented in this section.

The seven key sites assessed by Entec were provided by GCC from the Strategic Infrastructure Development Partnership (SIDP) Phase 2 report, though limited detail regarding the proposals was available. The approximate number of dwellings and commercial floorspace was available for the majority of sites. The SIDP does not contain exact details regarding the site and it was necessary for Entec to estimate site boundaries and total site area. The key sites considered in the assessment are detailed in Table 3.2, along with the housing and employment allocation provided for each site in the SIDP report.

Table 3.2 Key Sites Development Assumptions

Site Name	Approximate Area (ha)	Development Composition
Midwinter (CH2)	10	119 houses 42 maisonettes/ flats
Leckhampton Urban Extension (CH9)	40	962 houses 338 maisonettes/ flats
Gloucester Business Park	170	Unknown number of business units
Tuffley – Whaddon Urban Extension (CH9)	220	1095 houses 405 maisonettes/ flats
North West Cheltenham Urban Extension (CH1)	250	3700 houses 1300 maisonettes/ flats
Land at Cranhams (CT7)	100	1540 houses 660 maisonettes/ flats
North Cam (ST5)	120	1442 houses 558 maisonettes/ flats

Following the methodology identified in the previous section the following general points with regard on site hydro and wind at the key sites should be noted:

- Wind: At this stage that all the key sites assessed experience a very low wind speed (less than 6m/s at 45m height) and therefore are unlikely to be economically viable regardless of proposed turbine size or site location;

- Hydro: For many of the key sites no watercourses have been identified within 2km. None of the watercourses identified in proximity to the key sites has a suitable head to consider progressing.

The results of the wind assessment is summarised in Table 3.3. For the wind assessment the impact of the low wind speed on the financial viability has been disregarded. None of the wind sites are thought likely to be commercially attractive to developers; however the opportunities for placing turbines and the potential energy yield has been estimated in any case although it is not possible to be certain of the viability at this stage and level of assessment. If the layout and size of a development is known a full desk-based site screening exercise could be carried out to enable a more accurate assessment of viability.

Table 3.3 Key Site Development Information

Site Name	Wind Assessment Outcome
Midwinter (CH2)	Not considered suitable for large-scale wind due to limited demand and lack of space in the town centre location – No further assessment completed.
Leckhampton Urban Extension (CH9)	Not considered suitable for large-scale wind due lack of space in high potential building density area and proximity to existing residential properties – No further assessment completed.
Gloucester Business Park	Very low estimated wind speed: According to Carbon Trust Model 4.9m/s @45m, 5.5m/s @80m. A single large-scale turbine could be suitable as there are a large number of apparent residential properties surrounding the site. Given the site use as a business park this could potentially be reduced as (depending on the type of business/working hours/unit ownership etc) offices can often be subjected to lower separation distances. If placed in the proposed location approximately 44 ha could be lost due to noise (this could vary depending on background noise levels and business occupant types). Potential Yield: 4.2GWh per year with a comparatively low capacity factor of 19%.
Tuffley – Whaddon Urban Extension (CH9)	Very low estimated wind speed: According to Carbon Trust Model 4.5m/s @45m, 5.0m/s @80m. There is one existing property in the centre of the site, which has not been included as part of this assessment as the use could not be confirmed. If this is a residential property located in the identified position then to minimise noise nuisance risk an area of approximately 51 ha could be lost – it should be noted this land could still be used for parks/gardens, but not for residential properties. Potential Yield: 3.4GWh per year with an untypically low capacity factor of 15%
North West Cheltenham Urban Extension (CH1)	Wind speed: Carbon Trust Model 4.4m/s @45m, 5.0m/s @80m. If located in the identified position an area of 72 ha could be lost due to noise and proximity to residential properties – it should be noted this land could still be used for parks/gardens, but not for residential properties. Potential Yield: 5.3GWh per year (two turbines) with a capacity factor of 12%. Space to include additional turbines is available within the site, however they have not been included at this stage as the exclusion zone from these additional turbines would reduce the remaining available land for dwellings.
Land at Cranhams (CT7)	Very low estimated wind speed: According to Carbon Trust Model 5.8m/s @45m, 6.5m/s @80m. No potential location for a large-scale turbine has been identified. Should the buffer distance from Chesterton Farm be reduced to 400m it may be possible to install a single large-scale turbine on the site.

Site Name	Wind Assessment Outcome
North Cam (ST5)	Very low estimated wind speed: According to Carbon Trust Model 5.1m/s @45m, 5.7m/s @80m. This site is made up of 3 separate areas, a small area to the west of the A4135, an area larger due north and the largest (and most likely candidate for a large-scale wind development) to the east of the A4135. A breakdown of the housing types across these areas has not been provided. If located in the identified position an area of 43 ha may be lost due to noise and proximity to residential properties – it should be noted this land could still be used for parks/gardens, but not for residential properties. Potential Yield: 4.6GWh per year with a comparatively low capacity factor of 21%.

The following conclusions can be drawn from the above analysis:

- There is no potential for hydro power at any of the sites; and
- Based on the constraints considered there is potential to install wind turbines at four of the seven sites. However none are expected to be viable due to low wind speeds. The low wind speed issue is true for much of Gloucestershire which will limit the contribution from this technology in the county;

As there is little potential for wind and no potential for hydro at any of the key sites investigated for this report the results for each of the sites will therefore be very similar to the results associated with the site typology assessment that best describes the site, for example the Gloucester Business Park key site has very similar results to those for Typology G in Table 3.1.

Despite the low likelihood of a deliverable wind project on the sites, the potential yield (in terms of energy produced over the course of a year) has been estimated and this scenario included in the model to see the impact of this technology. The outputs of the modelling are shown later in this section of the report.

Given the limited detail available in relation to the key sites the model assumptions have been largely unchanged, apart from the refinement of average pipe lengths for housing. Hence the degree of accuracy of the results is of the same order as the typologies assessment. For sites where greater detail is known the following assumptions could be altered to give more accurate results:

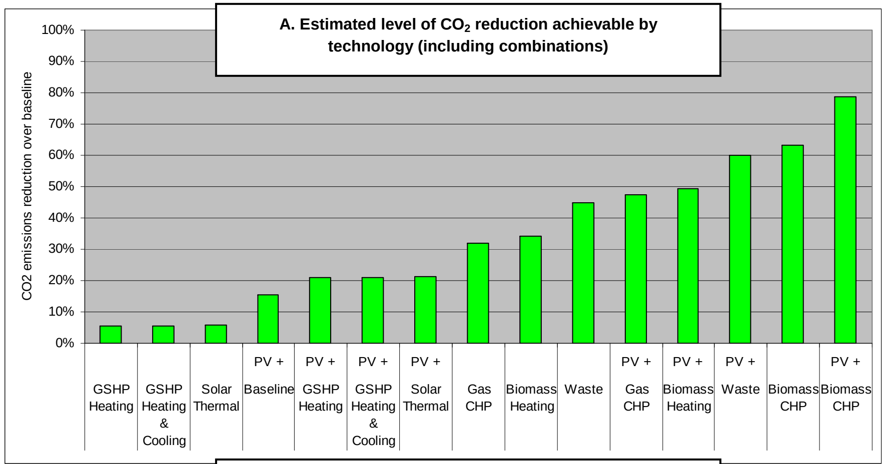
- Where site boundaries known – available space known and building density can be estimated, leading to improved estimates of potential for GSHP, solar and pipe lengths;
- Where site layout known– pipe lengths can be determined much more accurately;
- Where detail of commercial units known – assumptions regarding pipe lengths and roof space for solar can be refined, technical feasibility of communal systems and GSHP can be determined;
- Where location of existing or planned thermal waste treatment plants known – can enable the contribution from waste to be considered in more detail.

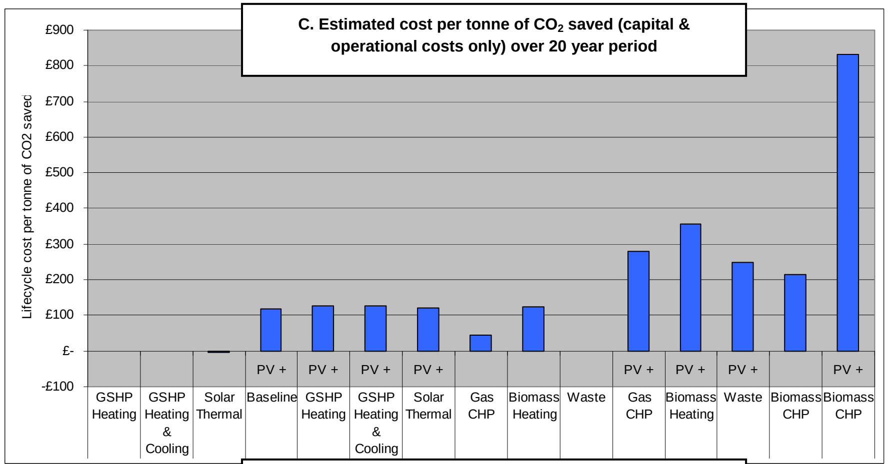
The full results of the assessment of the key sites are included in a spreadsheet which accompanies this report and summarised in graphical form in the following pages. As with the typology assessments four graphs have been prepared for each key site:

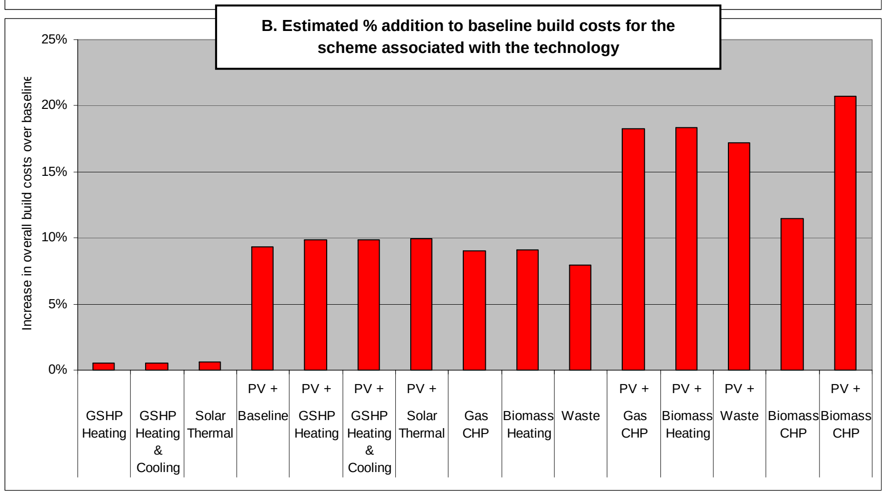
- A. The estimated level of CO_2 reduction achievable within the site type utilising a number of different technologies and combinations of technologies;
- B. The estimated increase (in percentage terms) to baseline build costs for the scheme associated with the technology or technology combination;
- C. The estimated cost (capital & operational costs only) per tonne of CO_2 saved over a 20 year period by the technology or technology combination
- D. The cost of energy using the technology or technology combination compared to the baseline energy cost baseline over a 20 year period.

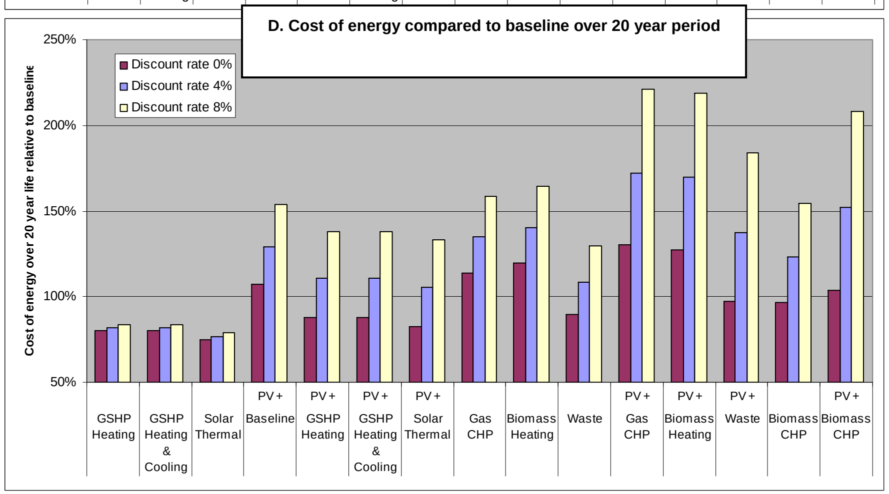
A discussion of the results is included in Section 4.2 of this report.

Midwinter (CH2)

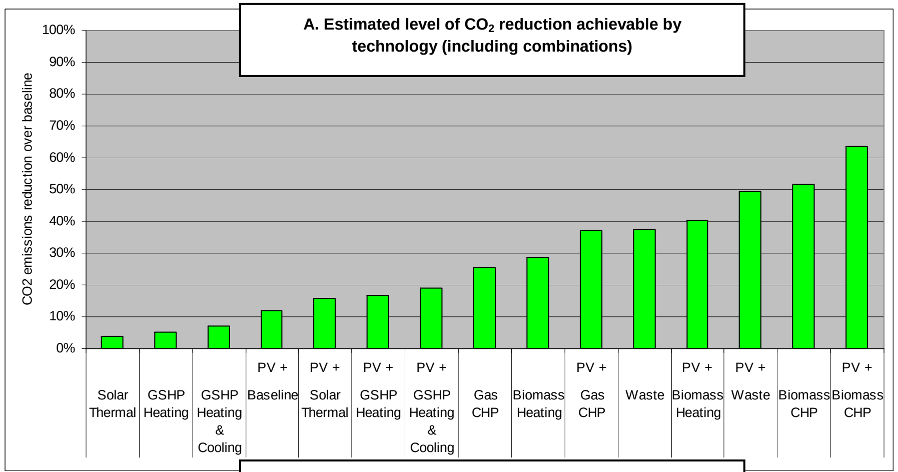


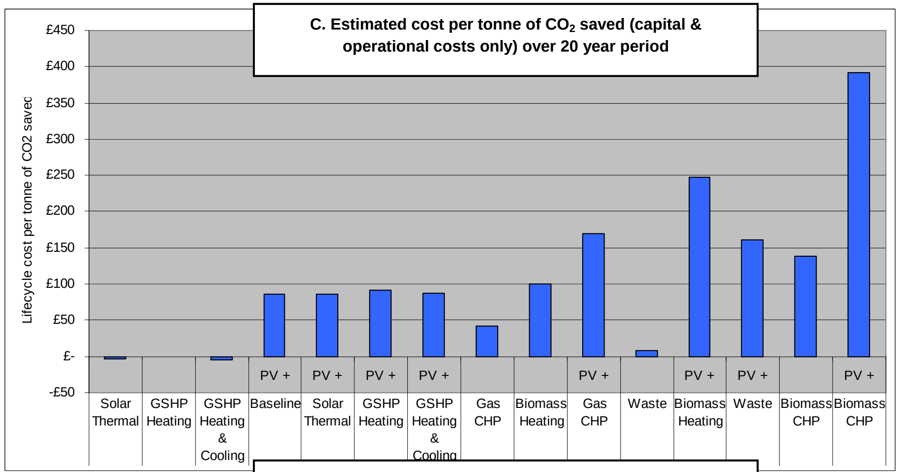


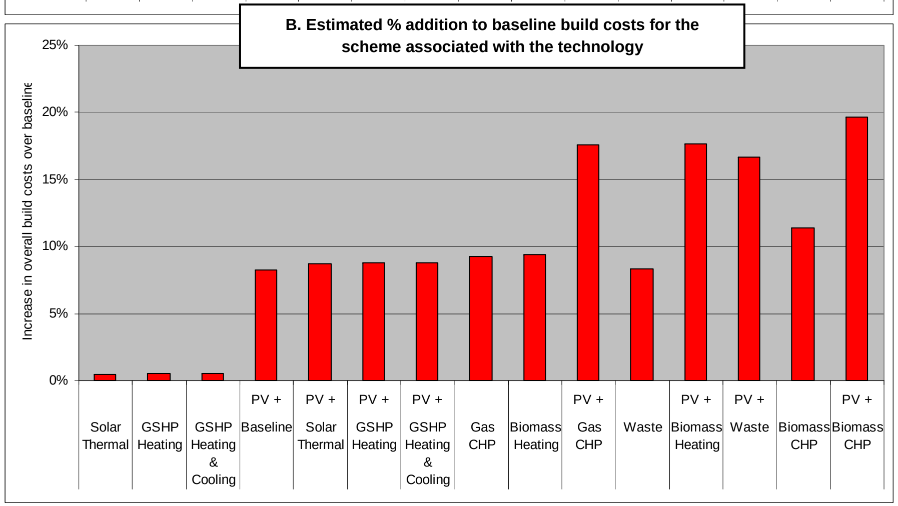


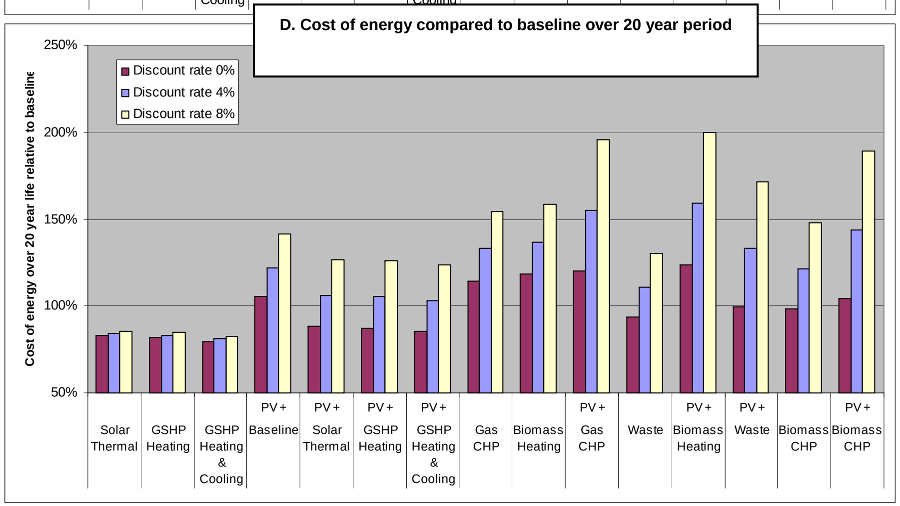


Leckhampton Urban Extension (CH9)

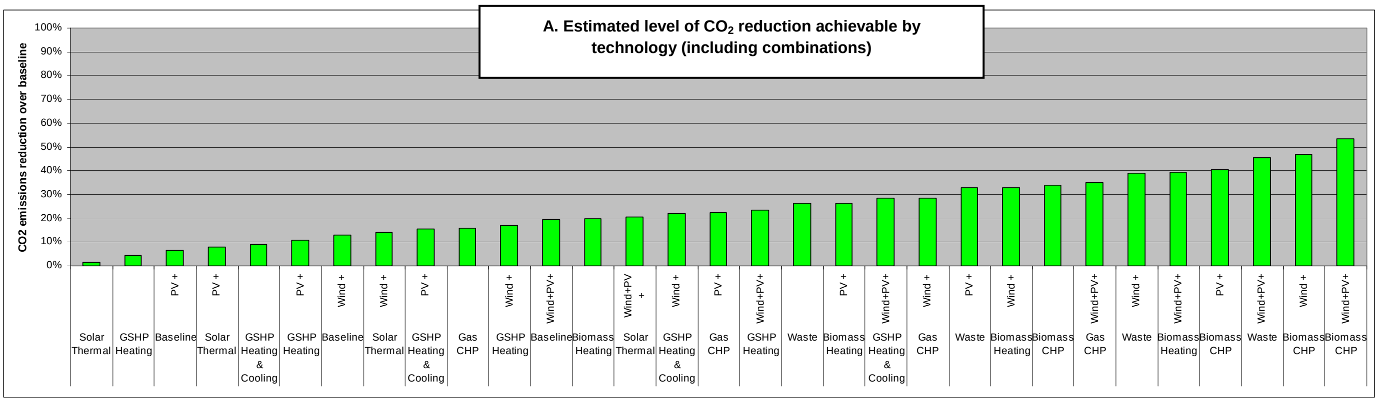


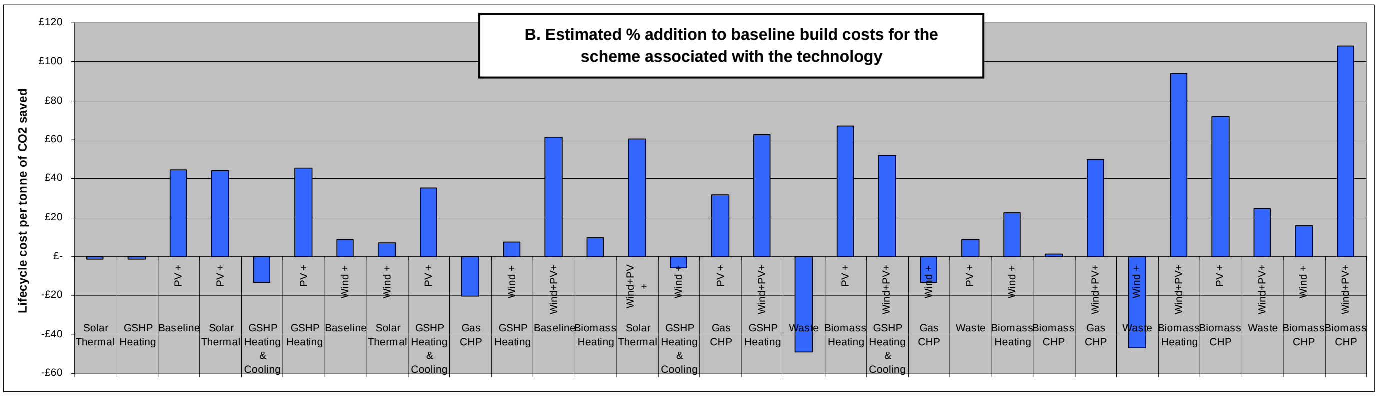


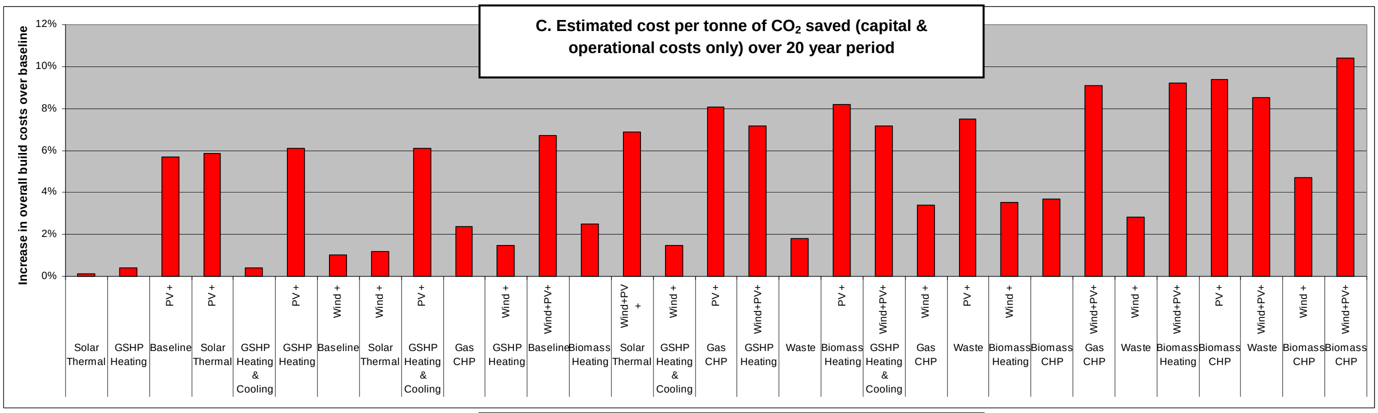


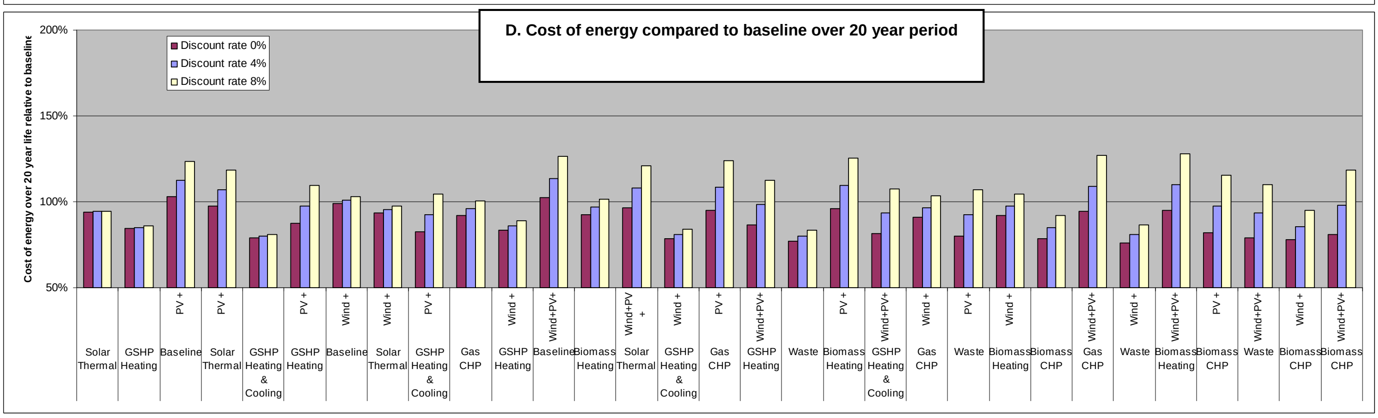


Gloucester Business Park









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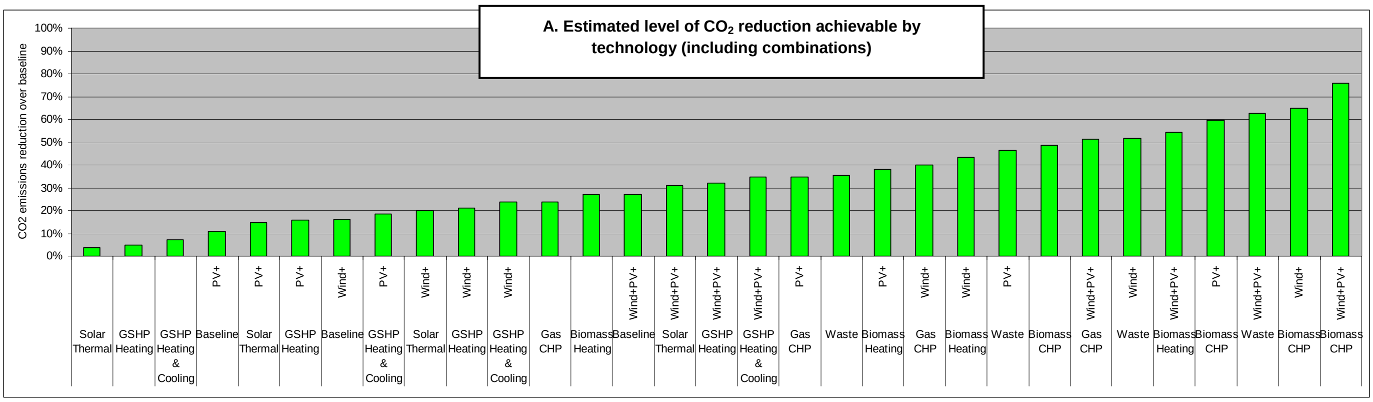
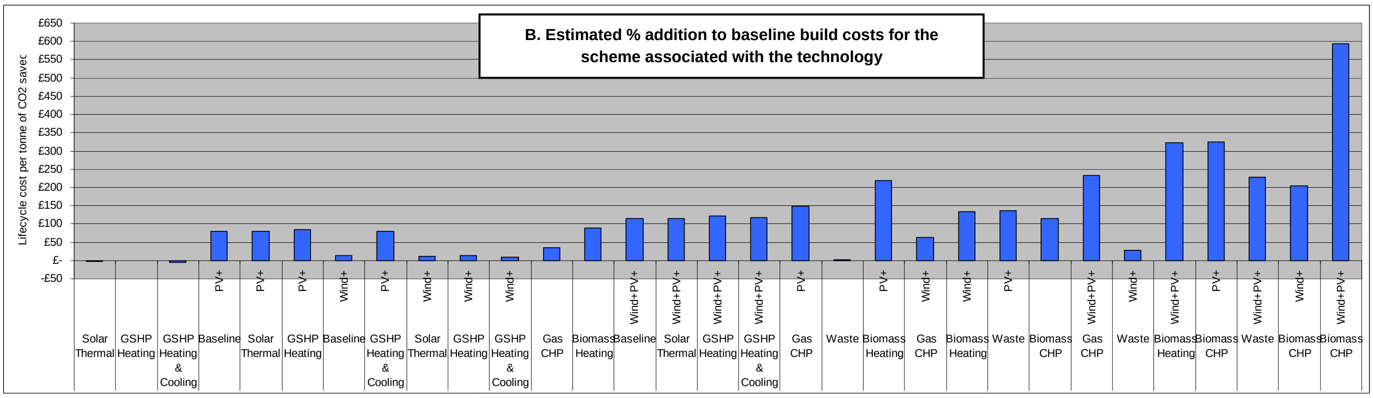
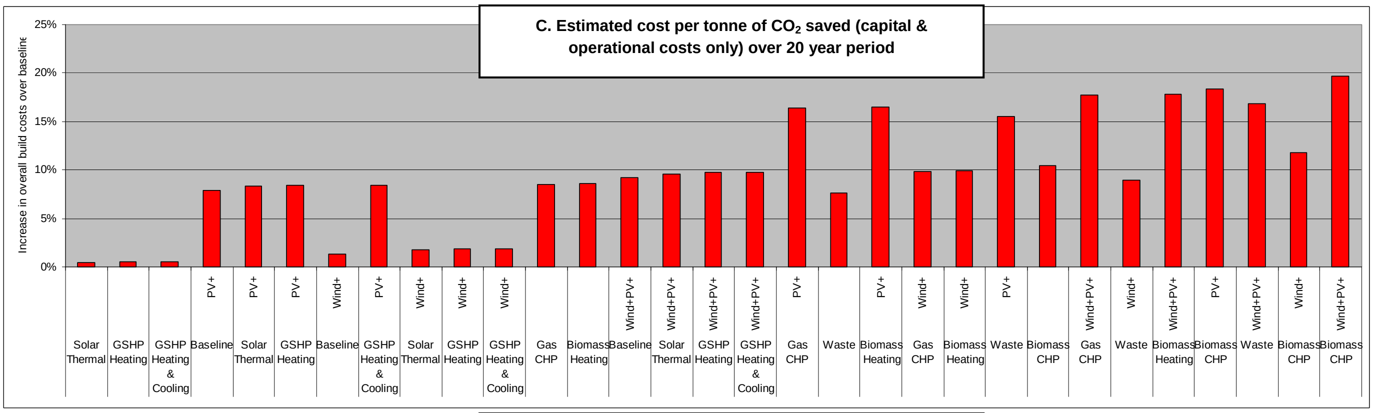
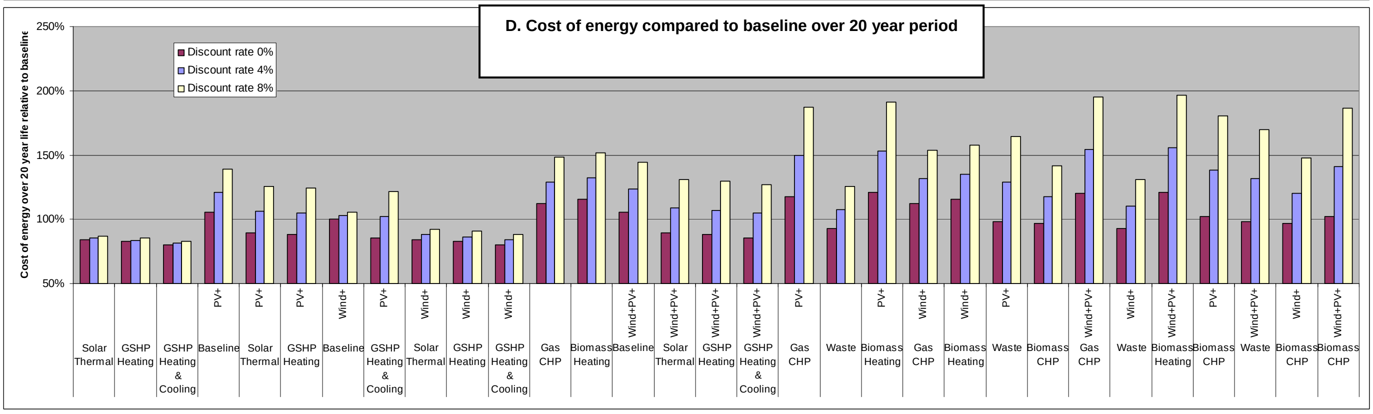
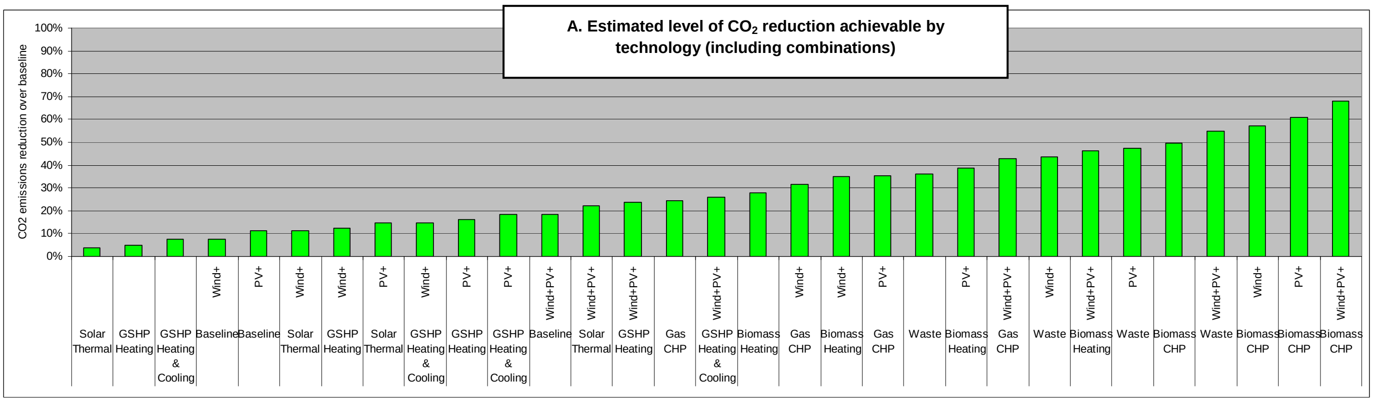


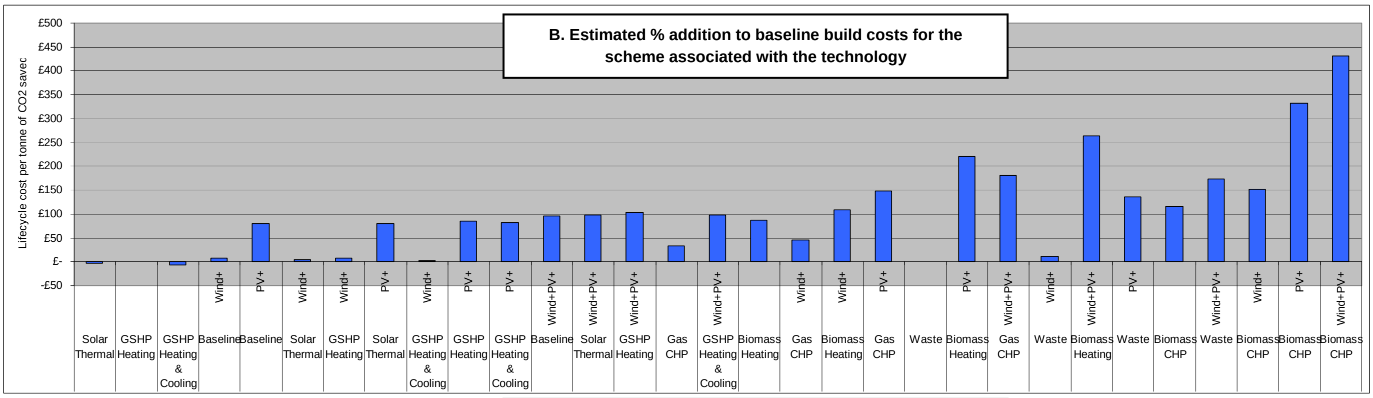


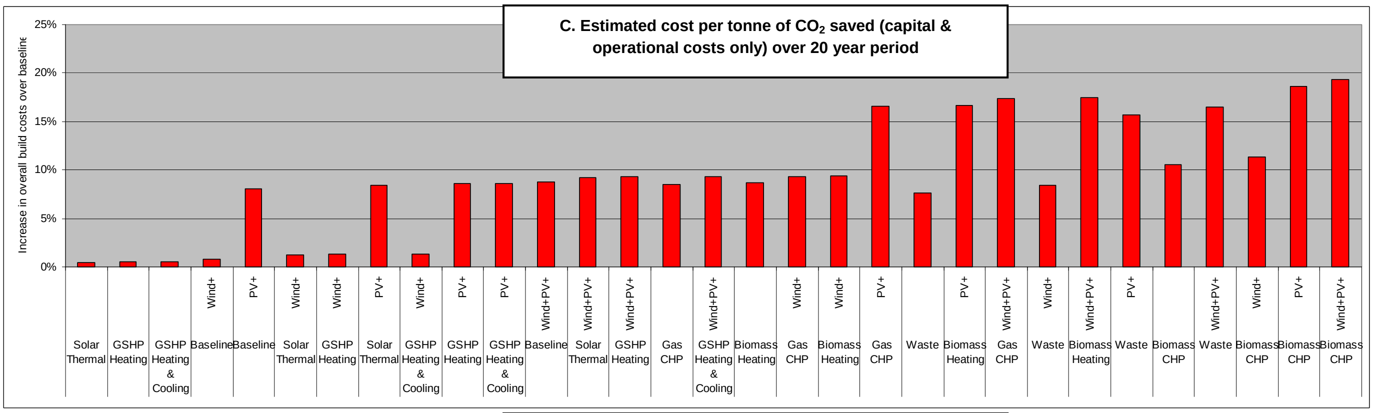


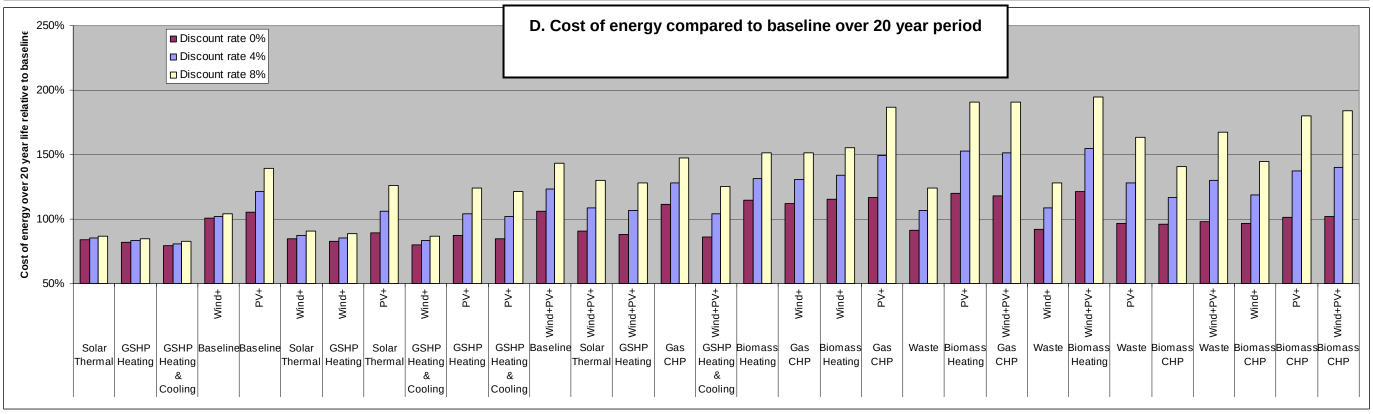


North West Cheltenham Urban Extension (CH1)

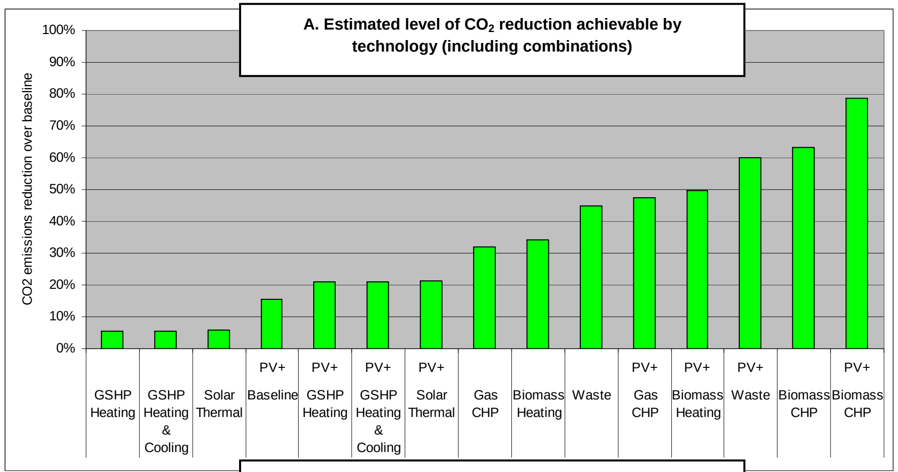


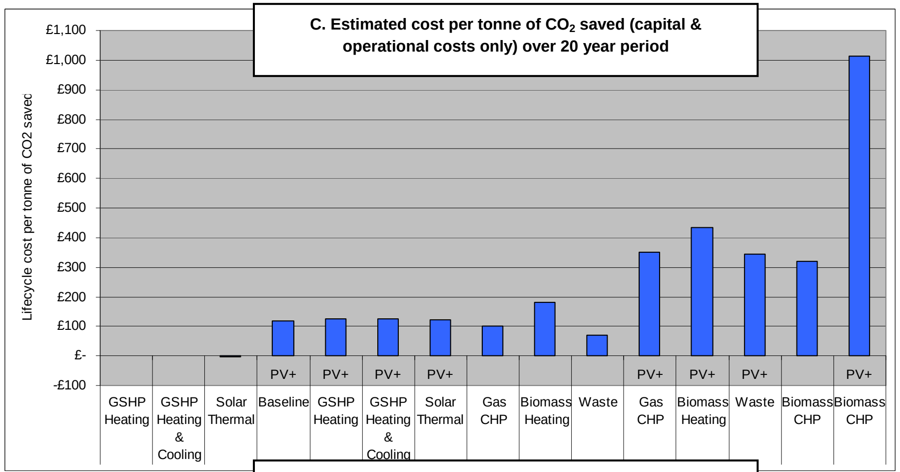


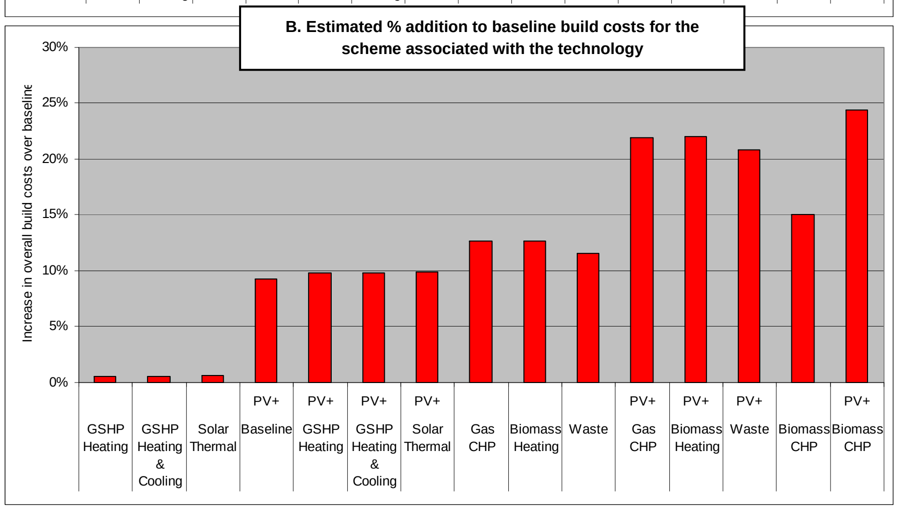


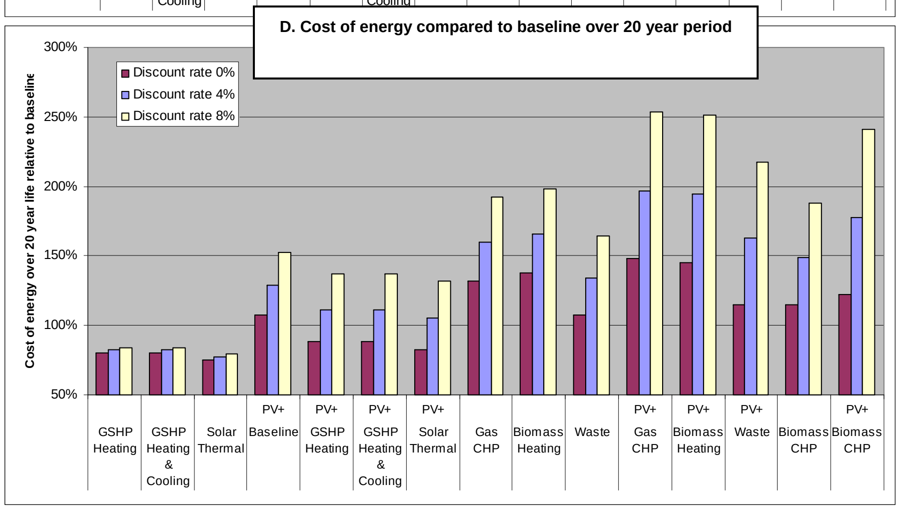


Land at Cranhams (CT7)

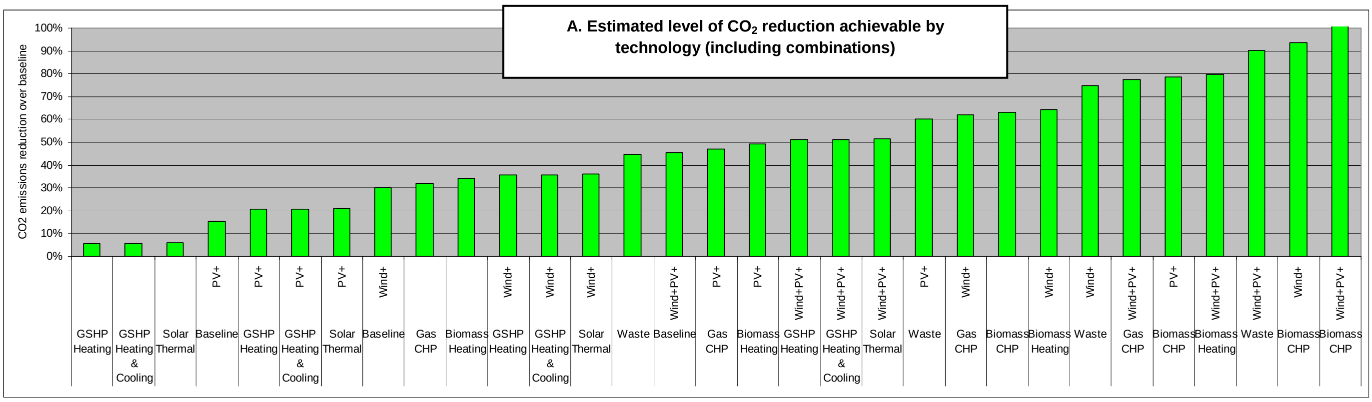


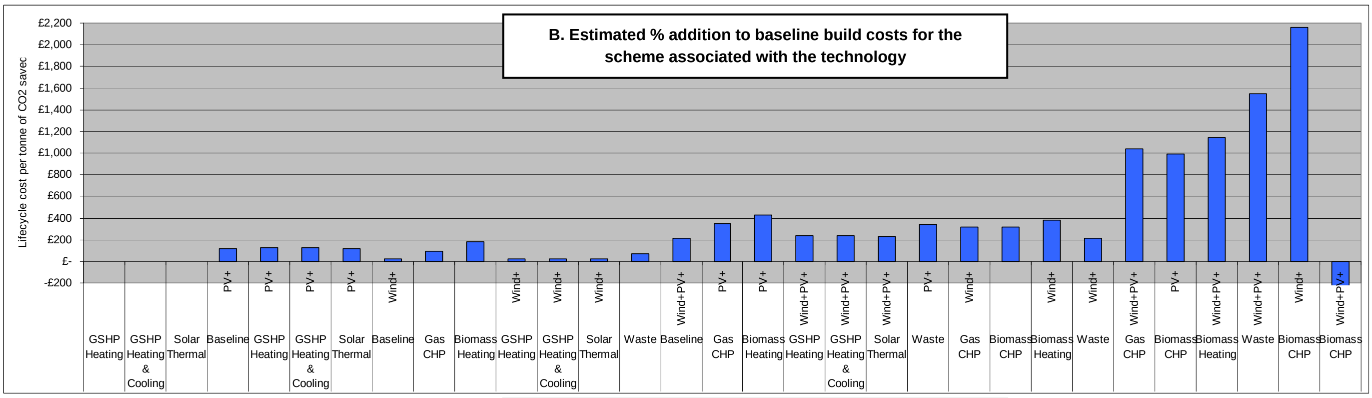


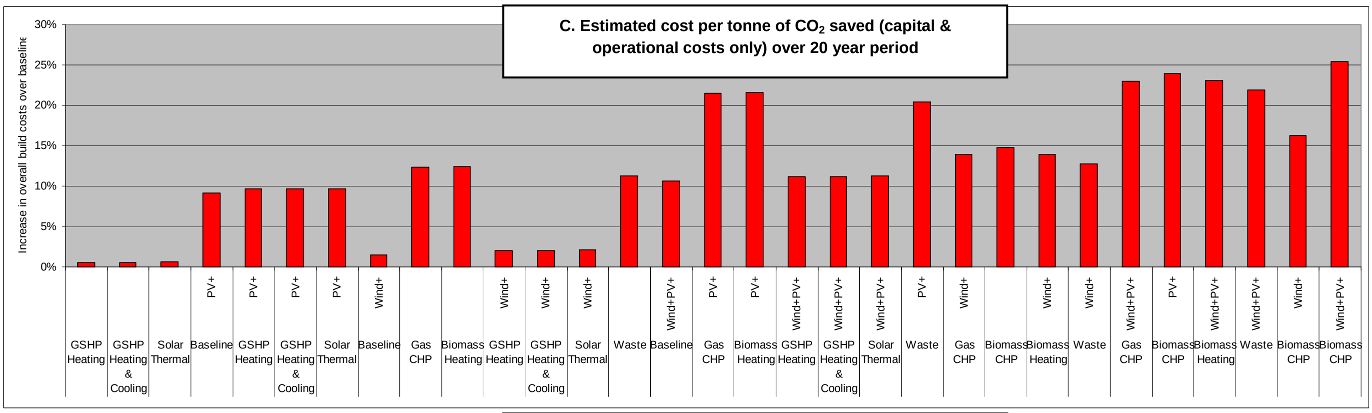


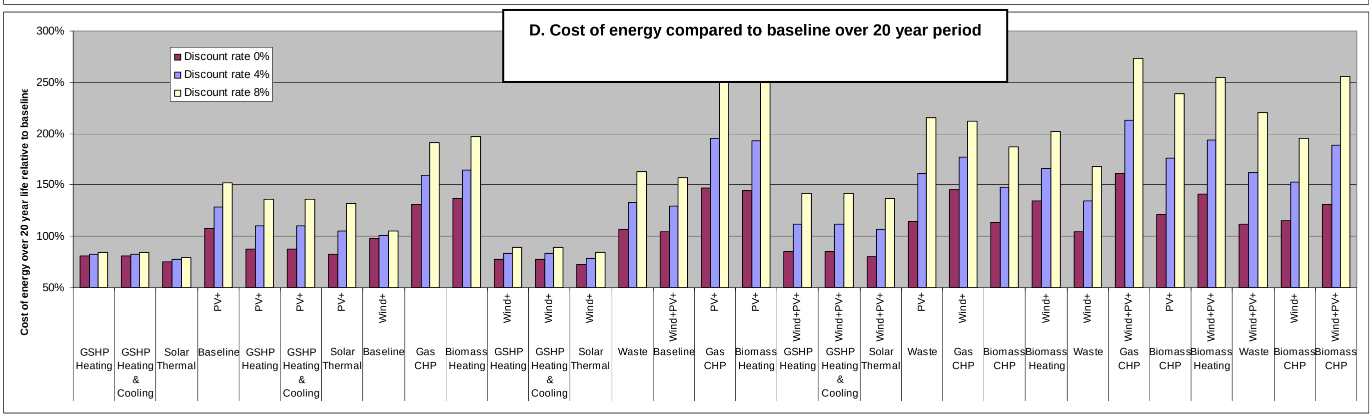


North Cam (ST5)









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4. Discussion of Results

Table 4.1 summarises the findings of the options appraisal for each of the nine typologies. The feasibility and viability of achieving various levels of CO_2 emissions reductions is considered in this table. The analysis covers the following issues:

- **Viability of achieving 10% CO_2 emissions reductions** – the potential to achieve a 10% reduction, the technologies that can achieve this and associated costs and viability for each typology is discussed.
- **Viability of going significantly beyond 10% reduction in CO_2 emissions** – the potential for exceeding this minimum target is considered. Greater than 10% emissions reductions will be required to meet higher levels of the Code for Sustainable Homes.
- **Feasibility of achieving zero carbon** – the potential for a zero carbon development is considered (i.e. 100% reduction in emissions over the baseline).
- **General Conclusions** – a summary of *potentially* appropriate (i.e. generally feasible and viable) CO_2 emissions reductions targets for each typology, and the technologies that may best achieve this.

The analysis of the results for the site typologies is presented in Table 4.1 and for the key sites in Table 4.2.

Table 4.1 Summary of Options Appraisal by Typology

Typology	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
A. City Centre Development – Retail Led	**Technologies** Options to achieve circa 10% include: i. GSHP (only where providing both heat ***and*** cooling) ii. Combination of GSHP (heat only) and solar PV iii. Combination of solar PV and solar thermal 10% reduction is likely to be the *limit* of what is achievable using these technologies at this type of site **Costs** The options with PV represent additional build costs of between 5% and 10%. GSHPs are much less expensive (less than 1%), but technical feasibility uncertain at this type of site. Cost of energy over a 20 year period likely to be similar to or less than the baseline. **Conclusions** 10% achievable via micro renewables at some but not all sites. Physical constraints on some sites in relation to roof space for solar options and ground conditions and space for GSHP systems	**Technologies** Communal systems required to go significantly beyond 10% reduction. Gas CHP or biomass could achieve emissions reductions of 10-15% Could achieve a maximum of a 30% reduction via combination of biomass CHP and solar PV. **Costs** Biomass CHP and solar PV have a predicted additional build cost of circa 20% Gas CHP and biomass have additional build costs between 5% and 10% so similar to micro-renewable options (except GSHP which is much cheaper where feasible) Energy costs associated with these communal systems estimated to be around 20% above the baseline; biomass options dependent on support mechanisms otherwise energy costs higher Costs of communal gas CHP and biomass heating systems similar to micro-renewables options **Conclusions** Communal system suitable for most sites, but only modest carbon reductions.	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP and solar PV to deliver a 30% reduction, there would be a need to offset emissions by a further 70% (pending government's final adopted definition of zero carbon)	The high electrical and cooling demand and urban setting of this site means reducing CO_2 emissions is challenging 10% reduction using micro-renewables may be achievable at some sites via the use of solar PV and solar thermal, with GSHPs also having potential if significant cooling can be provided Given the high density city centre location there may be practical constraints to micro-renewables in many cases (roof space for solar options and space and ground conditions for ground source heat pumps) which could significantly reduce the potential for reducing emissions via these technologies Achieving more than 10% reduction in emissions will require communal systems (biomass or gas CHP), but only a 15% reduction can be expected. A combination of biomass CHP and solar PV achieves the biggest savings. Maximum savings are limited to around 30% due to high electrical demand of this typology. Communal systems are likely to be a better option than micro renewables as they give higher emissions reductions for similar cost, and are more generally viable. Energy costs are similar or slightly greater than the baseline for all options considered Zero carbon will not be achievable on this type of site without allowable solutions. Potential for wind can be considered nil given the urban location.

Typology	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
B. City Centre Development – Office/Municipal Administration Led	**Technologies** Options to achieve circa 10% include: i. GSHP (only where providing both heat and cooling) ii. Combination of GSHP (heat only) and solar PV iii. Combination of solar PV and solar thermal **Costs** The options with PV represent additional build costs of between 5% and 10%, likely to be slightly lower than typology a. GSHP much less expensive (less than 1%), but technical feasibility uncertain at this type of site. Cost of energy over a 20 year period likely to be similar to or less than the baseline, could be a saving in the long term depending on level of support incentives **Conclusions** 10% achievable via micro renewables at some but not all sites. Physical constraints on some sites in relation to roof space for solar options and ground conditions and space for GSHP systems	**Technologies** Communal system required to go significantly beyond 10% reduction Gas CHP or biomass could achieve emissions reductions of 20-25% Could achieve a maximum of a 40% reduction via combination of biomass CHP and solar PV, at an additional build cost of circa 15-20% **Costs** Gas CHP or biomass have additional build costs of 5-10% so similar to micro-renewable options (except GSHP which is much cheaper where feasible) Biomass CHP and solar PV has a much higher additional build cost of circa 15-20% Energy costs associated with these communal systems estimated to range from similar to the baseline to 20% higher; biomass options dependent on support mechanisms otherwise energy costs higher Costs of communal gas CHP and biomass heating systems not necessarily more expensive than micro-renewables **Conclusions** Communal system suitable for most sites, with greater carbon reductions possible than for Typology A	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP and solar PV to deliver a 40% reduction, there would be a need to offset emissions by a further 60% (pending government's final adopted definition of zero carbon)	The high electrical and cooling demand and urban setting of this site means reducing CO_2 emissions is challenging, but higher reductions are possible than Typology A. 10% reduction using micro-renewables may be achievable at some sites via the use of solar PV and solar thermal, with GSHPs also having potential if significant cooling can be provided Given high density city centre location there may be practical constraints to micro-renewables in many cases (roof space for solar options and space and ground conditions for ground source heat pumps) which could significantly reduce the potential for reducing emissions via these technologies Achieving more than 10% reduction in emissions will require communal systems (biomass or gas CHP), and a 20-25% reduction can be expected. A combination of biomass CHP and solar PV achieves the biggest savings. Maximum savings are limited to around 40% due to high electrical demand of this typology. Costs of communal gas CHP and biomass heating systems comparable to the micro-renewable options Energy costs are similar or slightly greater than the baseline for all options considered Zero carbon will not be achievable on this type of site without allowable solutions. Potential for wind can be considered nil given the urban location.

Typology	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
C. City Centre Development – Culture/Leisure Led	**Technologies** Options to achieve circa 10% include: i. GSHP (only where providing both heat and cooling) ii. Combination of GSHP (heat only) and solar PV iii. Combination of solar PV and solar thermal **Costs** The PV options represent additional build costs of between 5% and 10%, likely to be slightly lower than Typology A. GSHP less expensive (approximately 2-3%), but technical feasibility uncertain at this type of site Cost of energy over a 20 year period likely to be similar to or less than the baseline, could be a saving in the long term depending on level of support **Conclusions** 10% achievable via micro renewables at some but not all sites. Physical constraints on some sites in relation to roof space for solar options and ground conditions and space for GSHP systems	**Technologies** Communal system required to go significantly beyond 10% reduction Gas CHP or biomass could achieve emissions reductions of around 30% Could achieve a maximum of a 60% reduction via combination of biomass CHP and solar PV **Costs** Gas CHP or biomass has additional build costs 20% so similar to micro-renewable options (except GSHP which is much cheaper where feasible) Biomass CHP and solar PV has a much higher additional build cost of circa 30% Energy costs associated with these communal systems estimated to range from similar to the baseline to 20% higher; biomass options dependent on support mechanisms otherwise energy costs higher **Conclusions** Communal system suitable for most sites, with greater carbon reductions possible than for Typology A and B. Facilities such as a large leisure centre or exhibition centre may be well suited to CHP in particular.	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP and solar PV to deliver a 60% reduction, there would be a need to offset emissions by a further 40% (pending government's final adopted definition of zero carbon)	This site type has higher heating and lower electrical demand than Typologies A and B which means reducing CO_2 emissions is more easily achievable, but no less costly 10% reduction using micro-renewables may be achievable at some sites via the use of solar PV and solar thermal, with GSHPs also having potential if significant cooling can be provided Given high density city centre location there may be practical constraints to micro-renewables in many cases (roof space for solar options and space and ground conditions for ground source heat pumps) which could significantly reduce the potential for reducing emissions via these technologies Achieving more than 10% reduction in emissions will require communal systems (biomass or gas CHP), and up to 30% reduction should generally be achievable. A combination of biomass CHP and solar PV achieves the biggest savings of close to 60%. Costs of communal gas CHP and biomass heating systems not slightly more expensive than micro-renewables, but give significantly greater carbon savings Energy costs are between 20% lower to 20% higher than the baseline for all options considered Zero carbon will not be achievable on this type of site without allowable solutions. Potential for wind can be considered nil given the urban location

Typology	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
D. City/Town Centre Housing – Brownfield Regeneration Led	**Technologies** Options to achieve circa 10% include: i. Solar PV alone (could achieve up to 15% in some cases) ii. Combination of solar PV and solar thermal (likely to be cheaper option) **Costs** Solar PV and solar thermal present additional build costs of 5-10%, with energy costs slightly above the baseline. PV forms the majority of the additional build costs. **Conclusions** Roof space and orientation for solar options will determine the actual emissions reductions possible, with 15% being a realistic upper limit. Achieving 10% in this way should be achievable at most sites, unless there are a particularly large proportion of flats limiting available roof space.	**Technologies** The use of PV in conjunction with GSHP or solar thermal could in some cases achieve emissions reductions of around 20%, though this is a likely upper limit. Communal systems are required to go much beyond 20% Gas CHP or biomass could achieve a 30-35% reduction in emissions Could achieve a maximum of 80% reduction in emissions via combination of biomass CHP and solar PV **Costs** Gas CHP or biomass heating has additional build costs of around 10% Biomass CHP and solar PV has much higher additional build costs of 20-25% which may constrain viability in some cases (though public sector funding may assist here). Biomass CHP without PV has an additional build cost of around 15%. All communal systems would present additional long term energy costs of circa 50% above the baseline. However costs (and hence viability) are very sensitive to the building density and layout, so where properly designed additional costs may be significantly lower **Conclusions** Emissions reductions above 20% possible in most cases, with a range of technologies feasible. The building design, especially level of insulation, will have a major impact (super-insulated properties combined with micro renewables may give reductions well in excess of 20%)	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP and solar PV to deliver an 80% reduction, there would be a need to offset emissions by a further 20% (pending government's final adopted definition of zero carbon)	10% reduction relies on combination of solar thermal and solar PV which may not be viable in all cases given dependency on roof space Communal system (gas CHP and biomass) could achieve three times the carbon savings at a similar additional build cost to solar PV and thermal. However energy costs may be more than 50% above the baseline so there may be viability concerns. The costs are highly dependent on building layout, so a carefully designed development may help to significantly reduce long-term costs The specification of very high levels of efficiency is an additional option to help reduce carbon emissions relative to the baseline Regardless of costs, higher than 10% reduction is likely to be required to achieve timetable for zero carbon homes from 2016, including interim targets for 2010 and 2013 so communal systems may be a necessity Zero carbon not currently achievable on site. Potential for wind can be considered nil given the urban location.

Typology	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
E. Suburban – Residential Led	**Technologies** Options to achieve circa 10% include: i. Solar PV alone (could achieve up to 15% in some cases) ii. Combination of solar PV and solar thermal (likely to be cheaper option) **Costs** Solar PV and solar thermal present additional build costs of 5-10%. PV forms the majority of the additional costs. Energy costs are predicted to be 10-30% above the baseline. **Conclusions** Roof space and orientation for solar options will determine the actual emissions reductions possible, with 15% being a realistic upper limit. Achieving 10% in this way should be achievable at most sites, unless there are a particularly large proportion of flats limiting available roof space.	**Technologies** The use of PV in conjunction with GSHP or solar thermal could in some cases achieve emissions reductions of around 20%, though this is a likely upper limit. Communal systems are required to go much beyond 20% Gas CHP or biomass could achieve a 30-35% reduction in emissions. Could achieve a maximum of 80% reduction via combination of biomass CHP and solar PV. **Costs** Gas CHP or biomass has additional build costs of around 10% Biomass CHP and solar PV has much higher additional build costs of 20-25%, which may constrain viability in some cases. Biomass CHP without PV has an additional build cost of around 15%. All communal systems would present additional long term energy costs of circa 50% above the baseline. However costs (and hence viability) are very sensitive to the building density and layout, so where properly designed additional costs may be significantly lower **Conclusions** Emissions reductions above 20% possible in most cases, with a range of technologies feasible. The building design, especially level of insulation, will have a major impact (super-insulated properties combined with micro renewables may give reductions well in excess of 20%)	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP and solar PV to deliver an 80% reduction, there would be a need to offset emissions by a further 20% (pending government's final adopted definition of zero carbon)	Very similar to Typology D. 10% reduction relies on combination of solar thermal and solar PV which may not be viable in all cases given dependency on roof space Communal system (gas CHP and biomass) could achieve three times the carbon savings at a similar additional build cost to solar PV and thermal. However energy costs may be more than 50% above the baseline so there may be viability concerns. The costs are highly dependent on building layout, so a carefully designed development may help to significantly reduce long-term costs Regardless of costs, higher than 10% reduction is likely to be required to achieve timetable for zero carbon homes from 2016, including interim targets for 2010 and 2013 so communal systems may be a necessity May be some potential for wind at this type of site, but only small scale or micro scale turbines likely to be feasible with a small contribution to carbon emissions reductions expected at best (<10%). Zero carbon not currently achievable on site.

Typology	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving ‘Zero Carbon’ Development On-site	General Conclusions
F. Greenfield Urban Extension	**Technologies** Options to achieve circa 10% include: i. Solar PV ii. Solar PV and solar thermal iii. Solar PV and GSHP (heat only) **Costs** Additional build costs are predicted to be around 10% for PV alone and around 5% for the combined systems. PV forms the majority of the additional costs. Energy costs are predicted to be similar to or slightly above the baseline (up to approximately 20% higher) **Conclusions** Roof space and orientation for solar options will determine the actual emissions reductions possible, with 15% being a realistic upper limit. Likely to be fewer physical constraints (primarily in terms of available space) than for similar brownfield sites, but overall development emissions reductions lower than residential only sites due to commercial elements with high electrical load	**Technologies** Communal systems required to go significantly beyond 10% Gas CHP or biomass could achieve circa 20-30% reduction in emissions Could achieve a maximum of 60-70% reduction in emissions via combination of biomass CHP and solar PV **Costs** Gas CHP or biomass have additional build costs of around 10% Biomass CHP and solar PV has much higher additional build costs of 20-25%, which may constrain viability in some cases. Biomass CHP without PV has an additional build cost of around 15%. All communal systems have predicted long term energy costs of 10-30% above the baseline. However costs (and hence viability) are very sensitive to the building density and layout, so where properly designed additional costs may be significantly lower **Conclusions** Emissions reductions above 20% possible with micro renewables if combined with very high levels of insulation. Without this, a communal system will be required which should be technically feasible in almost all cases, but viability will be dependent on the details of the design and building layout.	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP and solar PV to deliver a 65% reduction, there would be a need to offset emissions by a further 35% (pending government’s final adopted definition of zero carbon)	10% reduction relies on combination of solar thermal and solar PV, which should be viable in most cases. Communal system (gas CHP and biomass) could achieve three times the carbon savings at a similar additional build cost to solar PV and thermal. Energy costs may be slightly higher than the baseline but may be viable. The costs are highly dependent on building layout, so a carefully designed development may help to significantly reduce long-term costs Regardless of costs, higher than 10% reduction is likely to be required to achieve timetable for zero carbon homes from 2016, including interim targets for 2010 and 2013 so communal systems may be a necessity Zero carbon not currently achievable on site without allowable solutions. May be some potential for wind at this type of site, but in most cases only small scale or micro scale turbines likely to be feasible, with a small contribution to carbon emissions reductions expected at best (<10%). Some sites may offer opportunities for large scale wind and hence greater emissions reductions, but this will not generally be the case.

Typology	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
G. Expanded Employment Park	**Technologies** Options to achieve circa 10% include: i. Solar PV in combination with either solar thermal *or* GSHP (heating only) ii. GSHP providing heating *and* cooling The options above may not be technically feasible in some cases – will be dependent on the character and mix of the employment units proposed. **Costs** In the case where it is technically feasible to achieve 10% emissions reductions, additional build costs are estimated to around 10% above the baseline for PV options but only around 1% of the GSHP option. Energy costs are predicted to be similar to the baseline for the PV options, but around 25% *below* the baseline for the GSHP (heat and cooling option) **Conclusions** Though GSHP is identified as the cheapest option, this technology is inherently unsuitable for many building types likely to be contained in this typology (e.g. warehouses), and depends on available space and ground conditions; hence in many cases ground source heat pumps may contribute far less than 10%. Solar PV should be generally feasible, but solar thermal will not in all cases as many buildings will have electric hot water systems due to the low demand.	**Technologies** Options to go significantly beyond 10% are limited. Though communal systems could theoretically achieve savings of up to 50-60% they may not be technically feasible given the building types (especially warehouses and small manufacturing units which are typically poorly technically suited to district heating), the demand profile (very low heat demand outside of working hours) and high electrical to heat ratio. Where a development also contains residential dwellings or a site with a relatively high and steady heat load (such as a hospital or leisure centre) the potential for a communal system may be greater There may also be potential for going beyond 10% via wind turbines, though it is not possible to consider this in a generic manner **Costs** Where technically feasible, communal systems have additional build costs of only around 2-4% and energy costs slightly below the baseline, so could be an attractive option. **Conclusions** Maximum carbon savings may often be limited to approximately 30% at this type of site, with the appropriate technology highly dependent on the mix of buildings on the site.	Would need to consider how significant emissions savings can be achieved in the first instance Wind may in some cases allow this target to be met.	10% reduction is potentially achievable via use of ground source heat pumps or combination of solar PV and solar thermal, but not in all cases Though GSHP is the cheapest option in terms of additional build costs *and* cost of energy in relation to the baseline, achieving 10% emissions reductions in this way is unlikely in practice in many cases The viability of achieving a significant reduction in emissions beyond 10% will depend on the nature of the development. Communal heating systems using biomass or gas CHP may be viable on some sites (e.g. high proportion of offices or near anchor loads like hospitals), but not on others (high proportion of warehouses or small units). Wind may be an option worth investigating, particularly given that this type of site will typically be located away from housing and has a high electricity demand.

Typology	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
H. Market Town Greenfield Housing Site on Fringe	**Technologies** Options to achieve circa 10% include: i. Solar PV alone ii. Solar PV with solar thermal or GSHP (both likely to be cheaper options than solar PV alone) **Costs** Solar PV and solar thermal could present additional build costs of 5-10%, with energy costs slightly above the baseline. . PV forms the majority of the additional costs. **Conclusions** Roof space and orientation for solar options will determine the actual emissions reductions possible, with 15% being a realistic upper limit. Achieving 10% in this way should be achievable at most sites, unless there are a particularly large proportion of flats limiting available roof space.	**Technologies** Communal systems required to go significantly beyond 10% Gas CHP or biomass could achieve circa 30% emissions reductions Could achieve a maximum of 70-80% reduction in emissions via combination of biomass CHP & solar PV The feasibility of a communal system will be dependent on the scale and the layout of the development. **Costs** Gas CHP or biomass could achieve circa 30% reduction with additional build costs of around 10% Could achieve a 70-80% reduction in emissions via combination of biomass CHP & solar PV, though high additional build costs of 20-25% could constrain viability All communal systems have predicted long term energy costs of 30-50% above the baseline, so there could be viability issues. This reflects the high infrastructure costs in a relatively low build density site. **Conclusions** A communal system is required to go beyond 10% except in the case where houses are super-insulated where higher reductions may be possible with micro renewables alone. A communal system may not be viable in all cases.	Would need allowable offsite carbon emissions reductions to achieve zero carbon. Assuming a development suitable for biomass heating to deliver a 80% reduction, there would be a need to offset emissions by a further 20% (pending government's final adopted definition of zero carbon).	10% reduction in emission could be achievable using solar PV supplemented by solar thermal or GSHP. This should be generally achievable at this type of site. Cost of communal systems similar to micro renewable options but with significantly greater carbon reductions. However long-term energy costs are higher, reflecting the long payback of infrastructure given the relatively low density of this site. Viability of a communal system will be dependent on the build densities. Regardless of costs, higher than 10% reduction is likely to be required to achieve timetable for zero carbon homes from 2016, including interim targets for 2010 and 2013 so communal systems may be a necessity. Wind may make a small contribution at some sites (generally <10%).

Typology	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
I. Infill Housing	**Technologies** Options to achieve circa 10% include: i. Solar PV alone ii. Solar PV in combination with either solar thermal *or* GSHP **Costs** If solar PV-based options are technically feasible then additional build costs estimated at 10% higher then the baseline (solar PV and solar thermal the closest to baseline energy costs but note comments below regarding technical constraints) **Conclusions** For developments consisting mostly or entirely of flats the lack of roof space for solar systems and land area for GSHP could be a constraint, in which case it may not be possible to achieve 10% reductions via micro renewables.	**Technologies** Depending on the proportion of flats it may be possible to approach 20% emissions reductions by use of solar PV, solar thermal and/or GSHP. Communal systems required to go significantly beyond 10% in many cases though. However not all technologies will be feasible for development of this scale. Biomass CHP is unsuitable, but gas CHP and biomass heating may have potential in a small apartment block for example. Where feasible emissions reductions of 30-35% from gas CHP or biomass heating can be expected. **Costs** Additional build costs of circa 10% are expected for gas CHP and biomass. However, the long term energy cost is predicted to be around 50% higher than the baseline. **Conclusions** Going beyond a 20% reduction in emissions will be challenging for sites with individual houses as communal systems will not generally be viable. For developments consisting largely of flats a communal system may be viable though energy costs are likely to be high.	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming a development suitable for biomass heating to deliver a 35% reduction, there would be a need to offset emissions by a further 65% (pending government's final adopted definition of zero carbon)	10% reduction in emission could be achievable on some sites using solar PV supplemented by solar thermal or ground source heat pumps The main challenge to achieving a 10% reduction on this type of site will be the amount of roof space to accommodate solar PV panels and land area for GSHP Cost of communal systems similar to micro renewable options but with significantly greater carbon reductions. However the very small scale of this type of development means a communal system will not be feasible in many cases, and energy costs likely to be relatively high One option to explore would be the ability to connect to a nearby existing or planned heating network which may be better suited technically and more cost effective than installing a dedicated system

Table 4.2 Summary of Options Appraisal by Key Site

Key Site	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
CH2 - Midwinter	**Technologies** Options to achieve circa 10% include: i. Solar PV alone could achieve up to 15% ii. Combination of solar PV and solar thermal (likely to be cheaper option) **Costs** Solar PV and solar thermal present additional build costs of 5-10%. PV forms the majority of the additional costs. Energy costs are predicted to be 10-30% above the baseline. **Conclusions** Roof space and orientation for solar options will determine the actual emissions reductions possible, with 15% being a realistic upper limit. Based on the housing mix, achieving 10% should be achievable at this site.	**Technologies** The use of PV in conjunction with GSHP and/or solar thermal could achieve emissions reductions of around 20%, though this is a likely upper limit. If buildings are not super-insulated then a communal systems are required to go much beyond 20% Gas CHP or biomass could achieve a 30-35% reduction in emissions. Could achieve a maximum of approximately 80% reduction via combination of biomass CHP and solar PV. **Costs** Gas CHP or biomass has additional build costs of around 10% Biomass CHP and solar PV has much higher additional build costs of 20-25%, which may constrain viability in some cases. Biomass CHP without PV has an additional build cost of around 15%. All communal systems would present additional long term energy costs of circa 50% above the baseline. However costs (and hence viability) are very sensitive to the building density and layout, so where properly designed additional costs may be significantly lower. **Conclusions** Emissions reductions above 20% are possible at this site, with a range of technologies feasible. The building design, especially level of insulation, will have a major impact (super-insulated properties combined with micro renewables may give reductions well in excess of 20%).	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP and solar PV to deliver an 80% reduction, there would be a need to offset emissions by a further 20% (pending government's final adopted definition of zero carbon)	This site is modelled reasonably well by Typology E (Suburban – Residential Led). There is little or no potential for wind or hydro to contribute to the energy supply of this site. 10% reduction relies on combination of solar thermal and solar PV which should be feasible given the building mix, and are likely to be viable based on the estimated build costs. Communal system (gas CHP and biomass) could achieve two to three times the carbon savings at a similar additional build cost to solar PV and thermal. However energy costs may be more than 50% above the baseline so there may be viability concerns. The costs are highly dependent on building layout, so a carefully designed development may help to significantly reduce long-term costs. Zero carbon not currently achievable on site.

Key Site	**Viability of Achieving 10% Reduction in CO_2 Emissions**	**Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)**	**Achieving 'Zero Carbon' Development On-site**	**General Conclusions**
CH9 - Leckhampton	**Technologies** Options to achieve circa 10% include: iv. Solar PV v. Solar PV and solar thermal vi. Solar PV and GSHP (heat only) **Costs** Additional build costs are predicted to be around 10% for PV alone and around 5% for the combined systems. PV forms the majority of the additional costs. Energy costs are predicted to be similar to or slightly above the baseline (up to approximately 20% higher) **Conclusions** Roof space and orientation for solar options will determine the actual emissions reductions possible, with 15% being a realistic upper limit.	**Technologies** Communal systems required to go significantly beyond 15% Gas CHP or biomass could achieve circa 20-30% reduction in emissions Could achieve a maximum of 60% reduction in emissions via combination of biomass CHP and solar PV **Costs** Gas CHP or biomass have additional build costs of around 10% Biomass CHP and solar PV has much higher additional build costs of 20-25%, which is likely to constrain viability. Biomass CHP without PV has an additional build cost of around 15%. All communal systems have predicted long term energy costs of 10-30% above the baseline. However costs (and hence viability) are very sensitive to the building density and layout, so where properly designed additional costs may be significantly lower **Conclusions** Emissions reductions above 20% possible with micro renewables if combined with very high levels of insulation. Without this, a communal system will be required which should be technically feasible, but viability will be dependent on the details of the design and building layout which are not known at present.	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP and solar PV to deliver a 60% reduction, there would be a need to offset emissions by a further 40% (pending government's final adopted definition of zero carbon)	This site is modelled well by Typology F (Greenfield Urban Extension). There is little or no potential for wind or hydro to contribute to the energy supply of this site. A 10% reduction relies on a combination of solar thermal and solar PV, which should be feasible and viable at this site. A communal system (gas CHP and biomass) could achieve two to three times the carbon savings at a similar additional build cost to solar PV and thermal. Energy costs are slightly higher than the baseline, but may still be viable. The costs are highly dependent on building layout, so a carefully designed development may help to significantly reduce long-term costs Zero carbon not currently achievable on site without allowable solutions.

Key Site	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
Gloucester Business Park	**Technologies** Options to achieve circa 10% include: i. Solar PV in combination with either solar thermal *or* GSHP (heating only) ii. GSHP providing heating *and* cooling iii. Wind, if commercially viable The options above may not be technically feasible in some cases – will be dependent on the character and mix of the employment units proposed. **Costs** In the case where it is technically feasible to achieve 10% emissions reductions, additional build costs are estimated to around 10% above the baseline for PV options but only around 1% for the GSHP option. Wind is also predicted to be low cost with an additional build cost of approximately 1%. Energy costs are predicted to be similar to the baseline for the PV and wind options, but around 25% *below* the baseline for the GSHP (heat and cooling option) **Conclusions** Though GSHP is identified as the cheapest option, this technology may in reality contribute less than 10%. Offices can be heated and cooled via GSHP, but the available space may restrict the contribution. Solar PV should be generally feasible, but solar thermal will not in all cases as many buildings will have electric hot water systems due to the low demand. Wind may be feasible, but appears unlikely to be commercially viable due to low wind speeds.	**Technologies** A combination of wind and solar or GSHP could give emissions reductions of up to 20%. However if not viable a communal system would be required to go much beyond 10%. Communal systems could theoretically achieve savings of up to 20-25%, limited by the high electrical to heat ratio of the offices. Gas CHP may be the most appropriate communal system; biomass CHP is unlikely to be feasible due to the demand profile. **Costs** Communal systems are relatively cheap with an additional build cost of only 2-4% due to the low pipe lengths required. Energy costs are predicted to be similar to or slightly below the baseline, so a communal system could be a viable option. **Conclusions** Maximum carbon savings may be limited to approximately 20-30% on this site. Highest realistic savings by a combination of gas CHP and solar PV.	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for gas CHP and wind to deliver a 30% reduction, there would be a need to offset emissions by a further 70% (pending government's final adopted definition of zero carbon)	This site is closest to Typology G (Expanded Business Park), but there are differences in that Gloucester Business Park is made up almost entirely of offices. 10% reduction is potentially achievable via a combination of GSHP, solar PV or solar thermal. In addition some potential for wind has been identified which could supply sufficient electricity to reduce carbon emissions by 10%, though this may not be a commercially viable option. Though GSHP is among the cheapest option in terms of additional build costs and cost of energy in relation to the baseline, achieving 10% emissions reductions using this technology alone may not be feasible. Communal heating systems using biomass or gas CHP should be viable with good long term energy costs predicted, but carbon emissions reductions are modest at approximately 20-25%. Absolute maximum emission reductions of 30-35% may be possible via a combination of a communal heating/CHP system, PV and a wind turbine

Key Site	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
CH9 - Tuffley	**Technologies** Options to achieve circa 10% include: i. Solar PV ii. Solar PV and solar thermal iii. Solar PV and GSHP (heat only) iv. Wind, if commercially viable **Costs** Additional build costs are predicted to be around 5-10% for PV alone and around 5% for the combined systems. PV forms the majority of the additional costs. Energy costs are predicted to be similar to or slightly above the baseline (up to approximately 20% higher) **Conclusions** Roof space and orientation for solar options will determine the actual emissions reductions possible, with 15% being a realistic upper limit from micro renewables. There is potential to install a large wind turbine on or close to the site, but it appears unlikely to be commercially viable due to low wind speeds.	**Technologies** Communal systems required to go significantly beyond 20% Gas CHP or biomass could achieve circa 20-30% reduction in emissions Could achieve a maximum of 75% reduction in emissions via combination of biomass CHP, PV and wind, but this is unlikely to be viable due to very high cost. **Costs** Gas CHP or biomass have additional build costs of around 10% Biomass CHP and solar PV has much higher additional build costs of 20-25%, which is likely to constrain viability. All communal systems have predicted long term energy costs of 10-30% above the baseline. However costs (and hence viability) are very sensitive to the building density and layout, so where properly designed additional costs may be significantly lower **Conclusions** Emissions reductions above 20% may be possible with micro renewables but only if combined with very high levels of insulation. Without this, a communal system will be required which should be technically feasible, but viability will be dependent on the details of the design and building layout which are not known at present.	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP, PV and wind to deliver a 75% reduction, there would be a need to offset emissions by a further 25% (pending government's final adopted definition of zero carbon)	This site is closely approximated by Typology F (Greenfield Urban Extension). There is little or no potential for wind or hydro to contribute to the energy supply of this site. A 10% reduction could be achieved by a combination of solar thermal, PV or GSHP, which should be feasible and viable at this site. In addition there is technical potential for a wind turbine to give up to 15% emissions reductions, but this is unlikely to be viable. A communal system (gas CHP and biomass) could achieve two to three times the carbon savings at a similar additional build cost to solar PV and thermal. Energy costs are expected to be slightly higher than the baseline, but may still be viable. The costs are highly dependent on the building layout, so a carefully designed development may help to significantly reduce long-term costs Zero carbon not currently achievable on site without allowable solutions.

Key Site	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
CH1 – North West Cheltenham Urban Extension	**Technologies** Options to achieve circa 10% include: i. Solar PV ii. Solar PV and solar thermal iii. Solar PV and GSHP (heat only or heat and cooling) iv. Wind, if commercially viable **Costs** Additional build costs are predicted to be around 5-10% for PV alone and around 5% for the combined systems. PV forms the majority of the additional costs. Energy costs are predicted to be similar to or slightly above the baseline (up to approximately 20% higher) **Conclusions** Roof space and orientation for solar options will determine the actual emissions reductions possible, with 15% being a realistic upper limit from micro renewables. There may be potential to install a large wind turbine on or close to the site, but it appears unlikely to be commercially viable due to low wind speeds.	**Technologies** Communal systems required to go significantly beyond 20% Gas CHP or biomass could achieve circa 20-30% reduction in emissions Could achieve a maximum of 70% reduction in emissions via combination of biomass CHP, PV and wind, but this is unlikely to be viable due to very high cost. **Costs** Gas CHP or biomass have additional build costs of around 5-10% Biomass CHP and solar PV has much higher additional build costs of 20%, which is likely to constrain viability. All communal systems have predicted long term energy costs of around 30% above the baseline. However costs (and hence viability) are very sensitive to the building density and layout, so where properly designed additional costs may be significantly lower **Conclusions** Emissions reductions above 20% may be possible with micro renewables but only if combined with very high levels of insulation. Without this, a communal system will be required which should be technically feasible, but viability will be dependent on the details of the design and building layout which are not known at present.	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP, PV and wind to deliver a 70% reduction, there would be a need to offset emissions by a further 30% (pending government's final adopted definition of zero carbon)	This site is closely approximated by Typology F (Greenfield Urban Extension). A 10% reduction could be achieved by a combination of solar thermal, PV or GSHP, which should be feasible and viable at this site. In addition there may be technical potential for a wind turbine which could give up to 15% emissions reductions, but this is unlikely to be commercially viable. A communal system (gas CHP and biomass) could achieve two to three times the carbon savings at a similar additional build cost to solar PV and thermal. Energy costs are expected to be slightly higher than the baseline, but may still be viable. The costs are highly dependent on the building layout, so a carefully designed development may help to significantly reduce long-term costs Zero carbon not currently achievable on site without allowable solutions.

Key Site	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
CT7 – Land at Crahams	**Technologies** Options to achieve circa 10% include: i. Solar PV alone could achieve up to 15% ii. Combination of solar PV and solar thermal (likely to be cheaper option) **Costs** Solar PV and solar thermal present additional build costs of 5-10%. PV forms the majority of the additional costs. Energy costs are predicted to be 10-30% above the baseline. **Conclusions** Roof space and orientation for solar options will determine the actual emissions reductions possible, with 15% being a realistic upper limit. Based on the housing mix, achieving 10% should be achievable at this site.	**Technologies** The use of PV in conjunction with GSHP and/or solar thermal could achieve emissions reductions of around 20%, though this is a likely upper limit. If buildings are not super-insulated then a communal systems are required to go much beyond 20% Gas CHP or biomass could achieve a 30-35% reduction in emissions. Could achieve a maximum of approximately 80% reduction via combination of biomass CHP and solar PV. **Costs** Gas CHP or biomass has additional build costs of around 10% Biomass CHP and solar PV has much higher additional build costs of 20-25%, which may constrain viability in some cases. Biomass CHP without PV has an additional build cost of around 15%. All communal systems would present additional long term energy costs of circa 50% above the baseline. However costs (and hence viability) are very sensitive to the building density and layout, so where properly designed additional costs may be significantly lower. **Conclusions** Emissions reductions above 20% are possible at this site, with a range of technologies feasible. The building design, especially level of insulation, will have a major impact (super-insulated properties combined with micro renewables may give reductions well in excess of 20%).	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP and solar PV to deliver an 80% reduction, there would be a need to offset emissions by a further 20% (pending government's final adopted definition of zero carbon)	This site is modelled reasonably well by Typology E (Suburban – Residential Led). There is little or no potential for wind or hydro to contribute to the energy supply of this site. 10% reduction relies on combination of solar thermal and solar PV which should be feasible given the building mix, and are likely to be viable based on the estimated build costs. Communal system (gas CHP and biomass) could achieve two to three times the carbon savings at a similar additional build cost to solar PV and thermal. However energy costs may be more than 50% above the baseline so there may be viability concerns. The costs are highly dependent on building layout, so a carefully designed development may help to significantly reduce long-term costs. Zero carbon not currently achievable on site.

Key Site	Viability of Achieving 10% Reduction in CO_2 Emissions	Viability of Going *Significantly* Beyond 10% Reduction in CO_2 Emissions (i.e. 20% or more)	Achieving 'Zero Carbon' Development On-site	General Conclusions
ST5 – North Cam	**Technologies** Options to achieve circa 10% include: iii. Solar PV alone could achieve up to 15% iv. Combination of solar PV and solar thermal (likely to be cheaper option) **Costs** Solar PV and solar thermal present additional build costs of 5-10%. PV forms the majority of the additional costs. Energy costs are predicted to be 10-30% above the baseline. **Conclusions** Roof space and orientation for solar options will determine the actual emissions reductions possible, with 15% being a realistic upper limit. Based on the housing mix, achieving 10% should be achievable at this site.	**Technologies** The use of PV in conjunction with GSHP and/or solar thermal could achieve emissions reductions of around 20%, though this is a likely upper limit. There may be potential to install a large wind turbine on or close to the site, but it appears unlikely to be commercially viable due to low wind speeds. However this could achieve a 30% reduction in emissions if viable. Gas CHP or biomass could achieve a 30-35% reduction in emissions. Could achieve a maximum of approximately 80% reduction via combination of biomass CHP and solar PV, and over 100% if wind installed as well, though this scenario is highly unlikely. **Costs** Gas CHP or biomass has additional build costs of around 10% Biomass CHP and solar PV has much higher additional build costs of 20-25%, which may constrain viability in some cases. Biomass CHP without PV has an additional build cost of around 15%. All communal systems would present additional long term energy costs of circa 50% above the baseline. However costs (and hence viability) are very sensitive to the building density and layout, so where properly designed additional costs may be significantly lower. **Conclusions** Emissions reductions above 20% are possible at this site, with a range of technologies feasible. The building design, especially level of insulation, will have a major impact (super-insulated properties combined with micro renewables may give reductions well in excess of 20%).	Would need allowable offsite carbon emissions reductions to achieve zero carbon Assuming the technical potential for biomass CHP and solar PV to deliver an 80% reduction, there would be a need to offset emissions by a further 20% (pending government's final adopted definition of zero carbon)	This site is modelled reasonably well by Typology E (Suburban – Residential Led). 10% reduction relies on either PV or a combination of PV and solar thermal which should be feasible given the building mix, and is likely to be viable based on the estimated additional build costs. Communal system (gas CHP and biomass) could achieve two to three times the carbon savings at a similar additional build cost to solar PV and thermal. However energy costs may be more than 50% above the baseline so there may be viability concerns. The costs are highly dependent on building layout, so a carefully designed development may help to significantly reduce long-term costs. Zero carbon not currently achievable on site.

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5. Key Points and Next Steps

5.1 Key Points

The data and supporting analysis in this report is intended to support decision making and policy formulation in relation to renewable and low carbon energy potential at future development sites. Long term energy costs associated with renewable and low carbon technologies are generally predicted to be somewhat higher than the baseline, but in some cases costs may be equal to or even lower despite relatively high capital costs, implying that many of the systems may be competitive in the long term.

The typology appraisal demonstrates that potential CO_2 reductions vary significantly depending on the characteristics of a development site. Some sites offer definite potential to achieve CO_2 reductions of 70% or more, whereas for others even achieving 10% reductions may be challenging. To enable higher levels of on site CO_2 reductions it is vital that developments are carefully designed to accommodate communal systems and minimise pipe lengths as far as possible. To achieve 100% CO_2 reductions on site will not be viable in almost all case and will require allowable off site solutions, i.e. wind, to achieve.

The key sites analysis demonstrated little potential for wind or hydro power and the analysis provided similar results to that which was obtained for some of the site typologies. Energy from waste could make a significant contribution to carbon reductions at relatively low cost, but it is not possible to consider in detail in this study. At a point where additional development detail is known, such as site layout and more detailed usage type, the potential for renewable and low carbon energy can be assessed more accurately.

5.2 Next Steps

This study sets out the potential for on site renewable and low carbon energy on typical development sites in Gloucestershire. The report has a number of potential uses which we set out in the following sections of the report. Entec would be happy to discuss these in more detail on request.

Planning Principles for Low-carbon Development

The typology assessments set out in this report show in a generic way how different technology mixes can be deployed in development to reduce carbon emissions. Planning authorities can use these typologies as a decision making tool to make an informed decision on the amount of renewable and low carbon technology that will generally be expected of new development based on a pragmatic balance between emissions reductions and capital cost. The findings set out in this study can be used to give a first impression of the likely balance of renewables and low carbon technology once the type of any new development is known and can be used to inform the principles on which new developments are designed.

Site-specific Carbon Reduction Targets

If the overall size and mix of new development is known (e.g. density, layout, location, boundaries) are known the site assessments can be modified to give a better prediction of the mix of technology and associated costs for that site in order to obtain a given carbon reduction. This site specific target will be particularly useful for those sites that do not conform to any of the existing site typologies set out in this report and will allow individual site technical constraints to be considered in the overall target. This will help to inform the viability of particular site reduction targets.

Renewable Energy Infrastructure Study including County or Sub-regional Carbon Reduction Targets and Economic Impacts

This report can be used to help inform the production of a Renewable Energy Infrastructure Study for Gloucestershire by allowing the contribution of renewable and low carbon technologies in new developments to be considered. This could be done my matching the typology assessments with the future plans for development in the county. By estimating the size and number of each typology likely to be developed over a particular timescale, the total carbon impact can be calculated. This assessment will then show the county-wide opportunities for carbon reduction. This information could be used to help set guiding development principles or emissions reductions targets.

Since the assessment presented here also shows the increase in costs associated with each option, it can also be used to produce other economic parameters such as the likely jobs required to service new plant, the cost implications for the local economy and the long-term competitiveness (say on fuel use) of the county compared with others. This is valuable because it takes into account the long-term benefits of low-carbon technologies, rather than the shorter term consequences of increased build costs.

The infrastructure study could also review overall renewable energy infrastructure that could be provided in Gloucestershire up to 2026 and what its contribution could be in terms of energy generation and reduction in carbon emissions. Different technology options, such as wind farm developments, could be considered and the results integrated with the findings of this study to provide an overview of options for renewables and low carbon delivery in the county as a whole.

Elements that GCC may be considered for this study include:

- an assessment of energy demand (broken down into heat, transport, electricity elements) up to 2026 and 2050;
- a map of potential energy generation infrastructure that could be provided in the county and its potential output; and
- an analysis of the deliverability of the identified renewable energy infrastructure.

Bringing together the outputs of such an infrastructure study with this report will provide Gloucestershire with a good evidence base for planning for renewable and low carbon energy in the county.

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Appendix A
Technology, Financial and Development Assumptions used in this Report

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Appendix A

Technology Assumptions

System Efficiency

The assumed efficiencies of each system are set out in Table A.1. Estimates are typical of well designed and maintained systems, so represent a best case based on current technology. Where systems are poorly designed or inherently unsuited to a particular development's demand profile, efficiencies may be significantly lower.

Table A.1 Efficiency by Technology

Technology	Thermal Efficiency	Electrical Output per unit of Bought Fuel Input
Boiler - Gas	90%	N/A
Boiler - Biomass	90%	N/A
CHP - Gas	50%	35%
CHP - Biomass	50%	20%
GSHP - Heating	N/A	420%
ASHP - Heating	N/A	300%
Waste	100%*	N/A
Solar Thermal	- **	N/A
Absorption chiller	90%	0%
Air cooled chiller	N/A	350%
GSHP - Cooling	N/A	600%
Grid Electricity	N/A	100%

* Third party is assumed to be the owner/operator of the plant, with heat delivered to development so no efficiency loss on site

** Solar thermal assumed to provide 20% of hot water in flats, 50% of hot water in all other buildings

Financial Assumptions

Capital Cost

Table A.2 Capital Cost Assumptions for the Systems Used

Technology	CAPEX (£/kWth)	CAPEX (£/kWe)	Source
Gas boilers commercial	45	n/a	SPONS Mechanical and Electrical Services Price Book, 2008
Air cooled chiller	125	n/a	SPONS Mechanical and Electrical Services Price Book, 2008
Absorption chiller	120	n/a	SPONS Mechanical and Electrical Services Price Book, 2008
Biomass boiler	368	n/a	Potential and Costs of District Heating Networks, Poyry – April 2009
CHP gas	460	657	Entec estimate (large >1MWe)
CHP biomass	1400	3500	Potential and Costs of District Heating Networks, Poyry – April 2009 (>1000kW)
Ground Source Heat Pump	500	n/a	Entec estimate
Wind power - Large (2.5MW)	n/a	1100	Based on experience within industry supported by estimates from Renewables UK
Solar PV	n/a	5000	Costs quoted from Segen supported by broad estimates made by EST
Solar thermal	1429	n/a	Potential and Costs of District Heating Networks, Poyry – April 2009
Waste	0	0	Entec assume the cost to the development will be 0 as the owner/operator is assumed to be a third party.

Fuel Prices

Table A.3 Cost of Fuel Required per Unit of Energy Generated

Fuel/Energy Prices	Cost (p/kWh)	Source
Gas	3.4	International Energy Agency
Oil	5.2	International Energy Agency
Biomass (wood chip)	2.3	Biomass Energy Centre

Fuel prices are based on figures obtained in November 2009.

Energy Sale Prices

Table A.4 Income from Energy Sales per Unit Generated

Source	Income (p/kWh)	Source (to be completed)
Avoided cost of on site elec. generation and use	12	Market price as at Jan 2010
Income from imported elec.	12	Market price as at Jan 2010
Income from elec. exported	14.4	Entec assumption of 20% uplift over imported cost
Income from Heat/Cooling	4.1	Entec assumption

Support Mechanisms

Renewables Obligation Certificates

The main market incentive for renewable energy in the UK is the Renewables Obligation (RO). This is an obligation on licensed suppliers of electricity to source an increasing proportion of the electricity they supply from renewable energy sources. To validate these renewable energy sources, generators receive Renewable Obligation Certificates (ROCs); the number of ROCs received is banded according to the technology used in generation. Though primarily applicable to larger scale electricity generation, it is possible to claim this benefit at any scale (one ROC is equivalent at present to approximately 4p/kWh).

Feed-in Tariffs

This scheme is an additional support mechanism for renewable electricity designed particularly to encourage take-up of small-scale systems. A fixed rate is paid per kWh of electricity generated (regardless of where or how it is used), with the rate paid depending on the technology and fuel type and the scale of the system.

Renewable Heat Incentive

Under the Energy Act 2008 the RHI will be introduced to provide financial assistance to generators of renewable heat, and producers of renewable biogas. This will take the form of a feed-in tariff where a fixed rate is paid per kWh of useful heat generated, with the rate paid depending on the technology and fuel type and the scale of the system as per the Feed-in Tariff. A consultation including proposed tariffs was published in February 2010, and the scheme is planned to be introduced in April 2011.

Table A.5 Level of Support by Technology

Technology	Level of support	Note
Solar PV	2 ROCs/MWh OR 30p/kWh	Based on information available April 2010.
Wind	1 ROC/MWh 4p/kWh	Based on information available April 2010.
Biomass CHP	2 ROCs/MWh	Will not be eligible for FiTs until 2013 at the earliest. Based on information available April 2010.

Carbon Dioxide Emissions Assumptions

The following table shows the assumed emissions values per fuel type based on a report published by Defra in September 2009.

Table A.6 Carbon Emissions Factor by Fuel

Fuel	CO_2 Emission Factor (kg of CO2 per kWh)	Source
Gas	0.184	Defra September 2009 – represents best 2010 estimate
Grid Electricity	0.554	Defra September 2009 – represents best 2010 estimate
Oil	0.265	Defra September 2009 – represents best 2010 estimate
Biomass	0.028	SAP 2009 (no Defra equivalent figure)
Waste	0	Assumes heat would otherwise be rejected to atmosphere

Development Assumptions

Benchmark assumptions for all buildings are detailed in the following tables.

Table A.7 Building Specific Assumptions - Part 1

Type	Electricity Demand kWh/m²	Fossil Fuel Demand kWh/m²	Heat Demand kWh/m²	Space Heating kWh/m²	Domestic Hot Water kWh/m²	Process Hot Water kWh/m²	Comfort cooling kWh/m²	Computer room/close control cooling kWh/m²	Lighting kWh/m²	Other Electricity kWh/m²
Offices - Type 1: naturally ventilated, cellular	51	143	129	116	13	0	0	0	22	29
Offices - Type 2: naturally ventilated, open plan	81	143	129	116	13	0	7	0	36	43
Offices - Type 3: air conditioned, standard	203	160	144	130	14	0	98	57	49	111
Offices - Type 4: air conditioned, prestige	312	171	154	138	15	0	122	312	51	137
Industrial mixed use - Type 1: cellular naturally ventilated office	51	143	129	116	13	0	0	0	22	29
Industrial mixed use - Type 2: naturally ventilated, open plan	81	143	129	116	13	0	7	0	36	43
Industrial mixed use - Type 3: air conditioned, standard	189	160	144	130	14	0	98	0	49	112
Industrial mixed use - Type 4: air conditioned, prestige	219	179	161	145	16	0	123	0	51	133
Industrial mixed use - Type 5: distribution and storage	43	185	167	150	17	0	4	0	25	17
Industrial mixed use - Type 6: light manufacturing	70	300	270	243	27	0	7	0	50	18
Industrial mixed use - Type 7: factory office	100	225	203	182	20	0	21	0	60	34
Industrial mixed use - Type 8: general manufacturing	85	325	293	263	29	0	21	0	45	34
Refrigerated warehouses	142	80	72	65	7	0	10	338	28	14
Retail - Supermarkets	626	159	143	136	7	0	219	657	250	125
Retail - clothes stores	192	72	65	62	3	0	202	0	77	58

Type	Electricity Demand kWh/m^2	Fossil Fuel Demand kWh/m^2	Heat Demand kWh/m^2	Space Heating kWh/m^2	Domestic Hot Water kWh/m^2	Process Hot Water kWh/m^2	Comfort cooling kWh/m^2	Computer room/close control cooling kWh/m^2	Lighting kWh/m^2	Other Electricity kWh/m^2
Retail - small food shops	350	70	63	50	13	0	123	123	88	193
Retail - Distribution warehouses	45	113	102	92	10	0	16	0	18	22
Retail - Fast food restaurants	890	670	603	482	121	0	312	312	267	445
Retail - Restaurants with bar	730	1250	1125	900	225	0	256	128	219	402
Hotel	200	400	360	279	81	0	98	0	65	107
Cinema	160	620	558	502	56	0	168	0	32	64
Education - Residential, self-catering, flats	54	240	216	173	43	0	0	0	14	41
Local authority - Residential care homes	71	371	333	267	67	0	0	0	18	53
Local authority - Day centres	51	262	236	212	24	0	10	0	13	35
Long term residential accommodation	65	420	378	265	113	0	0	0	16	49
General accommodation	60	300	270	189	81	0	0	0	15	45
Call centre	312	171	154	138	15	0	122	312	51	137
Houses - (Long term residential accommodation)	40	96	87	61	26	0	0	0	8	32
Flats - (General accommodation)	41	106	95	67	29	0	0	0	8	33

Table A.8 Building Specific Assumptions - Part 2

Type	Peak space heating/hw load - kW/m^2	Peak cooling load kW/m^2	Baseline CAPEX £/m^2	Assumed Number of Stories	Proportion of roof suitable for PV	Diversity Factor	Pipe Length per unit (m)	Typical unit size (m^2)
Offices - Type 1: naturally ventilated, cellular	0.07	0.00	1568	2	25%	0.50	30	500
Offices - Type 2: naturally ventilated, open plan	0.07	0.12	1568	2	25%	0.50	30	500
Offices - Type 3: air conditioned, standard	0.06	0.16	1568	2	25%	0.50	30	500
Offices - Type 4: air conditioned, prestige	0.06	0.15	1568	2	25%	0.50	30	500
Industrial mixed use - Type 1: cellular naturally ventilated office	0.08	0.00	1568	2	25%	0.50	30	500
Industrial mixed use - Type 2: naturally ventilated, open plan	0.08	0.13	1568	2	25%	0.50	30	500
Industrial mixed use - Type 3: air conditioned, standard	0.08	0.18	1568	2	25%	0.50	30	500
Industrial mixed use - Type 4: air conditioned, prestige	0.08	0.18	1568	2	25%	0.50	30	500
Industrial mixed use - Type 5: distribution and storage	0.08	0.01	733	2	25%	0.50	30	1000
Industrial mixed use - Type 6: light manufacturing	0.08	0.01	680	2	25%	0.50	30	500
Industrial mixed use - Type 7: factory office	0.08	0.01	680	2	25%	0.50	30	500
Industrial mixed use - Type 8: general manufacturing	0.08	0.01	680	2	25%	0.50	30	500
Refrigerated warehouses	0.04	0.30	733	1	25%	0.50	30	500
Retail - Supermarkets	0.11	0.14	1049	1	25%	0.50	30	500
Retail - clothes stores	0.11	0.14	1049	2	25%	0.50	30	250

Type	Peak space heating/hw load - kW/m^2	Peak cooling load kW/m^2	Baseline CAPEX £/m^2	Assumed Number of Stories	Proportion of roof suitable for PV	Diversity Factor	Pipe Length per unit (m)	Typical unit size (m^2)
Retail - small food shops	0.11	0.10	1049	2	25%	0.50	30	100
Retail - Distribution warehouses	0.11	0.14	733	1	25%	0.50	30	1000
Retail - Fast food restaurants	0.11	0.22	1049	2	25%	0.50	30	100
Retail - Restaurants with bar	0.11	0.22	1049	1	25%	0.50	30	100
Hotel	0.90	0.23	1342	4	25%	0.50	30	100
Cinema	0.90	0.14	1049	2	25%	0.50	30	2000
Education - Residential, self-catering, flats	0.06	0.00	n/a	2	25%	0.50	not used	not used
Local authority - Residential care homes	0.06	0.00	n/a	3	25%	0.50	not used	not used
Local authority - Day centres	0.09	0.40	n/a	2	25%	0.50	not used	not used
Long term residential accommodation	0.06	0.00	n/a	2	25%	0.50	not used	not used
General accommodation	0.06	0.00	n/a	2	25%	0.50	not used	not used
Call centre	0.06	0.15	1568	1	25%	0.50	not used	not used
Houses - (Long term residential accommodation)	0.06	0.00	759	2	25%	0.50	20	calculated
Flats - (General accommodation)	0.06	0.00	1342	5	25%	0.50	5	calculated

Residential assumptions derived from CLG's 2008 report – Research to Assess the Costs and Benefits of the Government's Proposals to Reduce the Carbon Footprint of New Housing.
Non-residential assumptions derived from Energy Efficiency in Buildings, CIBSE Guide F, Chartered Institute of Building Services Engineers 2004.

Heat demand is calculated from fossil fuel demand assuming that fossil fuel systems have an efficiency of 90%.
Cooling demand is calculated assuming that electric cooling systems have an efficiency of 350%.

Build Costs

The costs of the energy system are calculated using a combination of the appropriate system size and the figures in the financial assumptions section. In order to estimate the impact on the overall cost of the development, the total cost has been estimated using the floor area of the buildings and the figures in the table below. These figures represent typical costs for building construction and do not include costs associated with site preparation, roads, Section 106 agreements etc.

Table A.9 Baseline Build Costs

Building Type	CAPEX (£/m^2)
Flats	1342
Houses	759
Retail	1049
Office	1568
Industrial	680
Storage/ Distribution	733

Residential figures from Research to Assess the Costs and Benefits of the Government's Proposals to Reduce the Carbon Footprint of New Housing, and Entec estimates, CLG 2008

Commercial figures from Indicative Building Costs 3rd Quarter 2006, EC Harris