

Ashford's Future

**Ashford Sustainable
Energy Feasibility
Study**

Pilot Sites Study

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FINAL ISSUE

Ashford's Future

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Energy Feasibility
Study**

Pilot Sites Study

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Job number 125575

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Executive Summary

This report examines the technologies required for a number of Pilot Sites modelled on the five key types of development coming forward in the Ashford Growth Area.

For each of these sites, two scenarios have been explored;

- 1) achieving the minimum level of CO₂ savings required to comply with CS10 and
- 2) mitigating 100% of the CO₂ emissions for the site.

These two extremes were selected to illustrate the full breadth of technical solutions with a view to informing future studies to set the buy out price for the Ashford Fund

For each scenario, our studies have examined the mix of technologies required and the increase in capital costs compared to buildings provided with conventional sources of heat and power.

In general, lower cost, mature technologies can be used to meet the minimum level of CO₂ savings required by CS10 for each pilot sites. However, mitigating 100% of CO₂ on-site requires the implementation of less mature, significantly more expensive technologies.

The report shows that the type and size of the development are key factors in determining the optimum technical solution for a given site. Supplying heat to buildings outside the immediate development offers the opportunity to operate energy generation plant more efficiently or to lower the cost of reducing CO₂ emissions.

The anticipated phasing of large scale energy generation technologies has been shown to be a factor of the size of the development, the build out rate and the technologies selected. For larger developments there is likely to be a lag in the implementation of CO₂ emission reduction measures. This allows for the energy demand to rise as the development is built out until it matches the scale necessary for CHP systems to operate efficiently. For the smaller developments, in particular those with lower levels of mixed use, the required level of CO₂ savings is unlikely to be achieved until the development nears completion.

1 Introduction

The purpose of this report is to explore the options available for reducing CO₂ emissions through the supply of low or zero carbon energy to a number of Pilot Sites in the Ashford Growth Area. After discussion with Ashford Borough Council and Ashford's Future regarding the key types of development coming forward in the Greater Ashford Development Area, the scale, mix of uses and location of the Pilot Sites were set so that the study would produce results representative for the majority of sites in the area.

This piece of work builds on the Cluster Analysis (Document DOC2) and reviews the most cost effective means of compliance with the CO₂ saving requirements of Ashford's CS10 policy for a number of Pilot Sites in the Ashford Growth Area, nominated by Ashford's Future.

The characteristics of the Pilot Sites are based on the LDF Core strategy and include build rates up to 2021. The conclusions of this study would not be affected significantly by the build out beyond 2021 and the technology options identified would be very similar at this time. Based on the current rate of development for renewable energy technologies any projections beyond 2021 based on the performance of current technologies is unlikely to be beneficial. Furthermore this study identifies that the technology roll-out is very likely to be phased with renewable generation being added in modules as the energy demand increases over time.

Key characteristics of the five Pilot Sites are shown in Table 1.

Pilot Site	1	2	3	4	5
Type	Mixed use	Mixed use	Residential	Mixed use	Mixed use
Location (CS10 definitions)	Urban Extension	Urban Extension	Urban Greenfield	Town Centre	Urban Extension
Minimum onsite CO ₂ reduction	30%	30%	30%	20%	30%
Number of dwellings	2,600	2,600	600	300	600
m ² of non-residential	90,000	6,000	0	17,000	5,000

Table 1: Details of the five Pilot Sites

The energy consumption requirement of each of the Pilot Sites was estimated and following this, the most cost effective means of achieving compliance with the CS10 carbon reduction targets was reviewed for each site. For each site two principal scenarios were modelled:

1. *Minimum CO₂ saving scenario*: The level of energy efficiency and onsite renewable energy generation is sized to comply with the minimum on-site CO₂ emissions reduction stated in CS10.
2. *High CO₂ saving scenario*: The level of energy efficiency and onsite renewable energy generation is maximised, approaching or achieving carbon neutrality as required by CS10.

The minimum and high CO₂ saving scenario have been specifically selected to provide a basis for future discussions regarding the value of the Ashford Fund.

There are numerous intermediate solutions which have not been explored; these can be approximated from the material presented in this report in conjunction with the data provided in the cluster analysis.

As the practical application of any solution will be dependent on the site characteristics a number of scenarios have been considered in each instance in addition to the most cost effective solution identified.

2 CO₂ Savings

2.1 Residential CO₂ Savings

Ashford Borough Council policy CS10 states that dwellings submitted for planning permission in urban areas between 2007 and 2014 must be either Code for Sustainable Homes (CfSH) Level 3 or Level 4 compliant. The policy also states that urban developments should deliver a reduction in CO₂ emissions of between 20% and 30% depending on the development location.

The minimum level of CfSH and CS10 CO₂ savings required are shown in Table 1 for each of the pilot sites considered.

The minimum overall reduction in emissions stipulated in CS10 for all of the Pilot Sites is greater than the relevant CfSH level specified. This analysis has therefore been based on the more stringent requirement of the CS10 policy, represented by the minimum CO₂ emission reduction requirements. The reasons for this are discussed in depth in the Background to the Study Report (Document DOC6).

2.2 Non-residential CO₂ Savings

CS10 calls for all non residential buildings to be constructed to BREEAM very good or excellent standards. As the BREEAM rating system does not stipulate minimum CO₂ reduction requirements the CS10 minimum CO₂ reductions represents the minimum target for any new non-residential development.

2.3 Carbon Dioxide Emission Factors

To calculate the quantity of CO₂ saved by means of good building practise and the use of low or renewable energy generation technologies the CO₂ emission indicators specified in the Part L building regulations have been used.

Details of these can be found in Appendix B.

3 Building Improvements

It has been assumed that building fabric improvements, such as high levels of insulation and air-tightness, would generally be implemented as a first priority means of CO₂ reduction as this is generally a more cost effective means of saving CO₂ than active energy generation technologies. Technical details of the performance of dwellings and non-residential buildings are given in Appendix B. The predicted total CO₂ emission savings due to building fabric improvements are outlined for each Pilot Site in the detailed analysis of each site in Appendix A.

4 Energy Generation Technologies

To meet the CO₂ reduction requirements for each site a range of technologies is available. Full details of each of the technologies considered are given in the Background to the Study report (Document DOC6). Given that some technologies generate heat, others generate electricity and several technologies generate both, the combinations of technologies selected should be complimentary to ensure that any investment made in technology is utilised effectively.

The plant selections made for this analysis are generally based on the module sizes currently available for each technology. Where the required scale of generation is considerably smaller than those available in the market, the technology has not been

considered for the development. The larger developments therefore have a greater range of technological solutions available. In addition to this they are able to take advantage of the fact that large capacity generation plant is generally more efficient than low capacity plant.

Due to the requirement to provide physical separation¹ between large wind turbines and dwellings, large wind turbines have not been considered for Pilot Sites which are predominantly residential (ie: little or no non residential areas where wind turbines could be located).

A number of the Pilot Sites were found to be urban extensions with a high proportion of non-residential development and in close proximity to busy highways or open space which suggests there may be greater opportunities for large scale wind turbines than suggested by the Cluster Analysis which was based on a typical urban context. The actual capacity of these sites to accommodate wind turbines will be highly dependent on the layout and density of each development.

5 Cost Estimates

For each site the increase in capital costs associated with each technological solution has been estimated compared to buildings supplied with conventional sources of heat and power. The conventional sources of heat and power are electricity supplied from the national grid and heat supplied by a condensing boiler fuelled by natural gas. All cost estimates quoted are installed costs. The cost of heat networks has been estimated based on a minimum density of 40 dwellings per hectare and is included in the cost calculations. Where a solution will require additional space compared to a conventional solution the estimated construction cost of this additional space has been accounted for; however, the land cost has not.

6 Renewable Energy Technology Rollout

For each site the rate of installation of each renewable energy technology will depend on the characteristics of the technology concerned. Electricity generating technologies are restricted by the availability of suitable sites for the technologies and the availability of local infrastructure. Electricity generating technologies are not restricted by the on-site demand as any surplus energy can be exported to displace electricity generated elsewhere by conventional means.

Large scale wind turbines can therefore be installed as soon as or before the first buildings are occupied. This could result in larger local CO₂ savings than required in the initial stages of development which can be credited, for example, against the embodied energy of construction

The installation of PV panels is primarily limited by the availability of roof space. CO₂ savings from PV can therefore be expected to follow the development build-out rate closely.

Unlike electricity generating technologies, heat generating technologies are limited by the local demand for heat. If heat dumping is to be avoided (in the context of resource efficiency) CHP plants would need to be installed retrospectively in modules as the development increases in size.

¹ A distance of 300-500m from dwellings is recommended for a first pass appraisal of potential sites for large wind turbines. Busy roads can mask much of the noise and therefore allow turbines to be located in closer proximity to dwellings. Shadow flicker may be an issue at this range, but this can be mitigated.

7 Delivery Risks

7.1 Low CO₂ Saving Scenarios

The minimum level of CO₂ emissions reductions can be achieved by a combination of fabric improvements, biomass boilers, large scale wind turbines and district heating networks supplied by relatively small capacities of either biomass gasification CHP or indirect air turbine CHP units. Any remaining heat demand would be supplied by conventional centralised or local gas boilers.

The implementation of the minimum levels of CO₂ emissions reductions is relatively low risk as there are solutions available based on well established technologies.

Whilst large wind turbines represent the most attractive option for achieving the required CO₂ emissions reductions there is a high risk of encountering difficulties in obtaining the necessary consents.

Individual biomass boiler heating in the majority of buildings could generate the minimum required CO₂ savings. However it may not be feasible to install biomass boilers in a large number of buildings due to, amongst other reasons, the logistics of delivering the wood fuel.

A district heating scheme which is used to distribute heat from centralised biomass boilers will require significant capital cost. It should be noted that project experience has shown that district heating networks supplying only heat are rarely economically viable so would require a degree of subsidisation by the developer.

With regards to biomass CHP technologies, recent experience has shown that Energy Service Companies (ESCOs) are currently extremely cautious when considering investing in and / or operating schemes involving relatively new technologies (eg: biomass gasification and indirect air turbine CHP technologies).

7.2 High CO₂ Saving Scenarios

To achieve 100% CO₂ mitigation on the Pilot Sites in a cost effective manner requires the implementation of biomass CHP technologies and a heat network in conjunction with fabric improvements, large scale wind turbines and/or significant areas of PV panels. The implementation of such a scheme is likely to be considerably more complex and carries much higher risks in addition to the risks outlined above for the low CO₂ saving scenarios

The level of risk of a 100% CO₂ saving scenario is partially dependant on the level of commercial maturity of the technologies selected. Organic Rankine Cycle (ORC) CHP technology is a mature technology which has been in operation for over a decade on numerous sites across Europe, albeit on few in the UK whereas biomass gasification and indirect air turbines are relatively new and less proven technologies. ORC based CHP solutions are therefore likely to be lower risk solutions than those based on gasification or indirect air turbines.

In order to optimise the cost of the energy systems it will be necessary to prioritise the provision of the renewable energy technologies for each new development area from the outset rather than considering these systems as add-ons.

7.3 Biomass Availability and Price

Effective planning of the energy provision to the Ashford Growth area sites will need to account for securing the required supply of biomass fuel at a price which would economically justify the investment in biomass technologies. The first aspect is related to

the available resources either produced locally or brought in from other (UK domestic or overseas) locations.

An assessment of the local biomass resource has been carried out assuming that biomass is used to serve 65% of the heat demand of the whole Ashford Growth Area. South East Wood Fuels Ltd. reports that 150,000 t/yr of biomass fuel from forestry residues are available in the South East England plus another 85,000 t/yr from clean wood residues for the same area. This availability exceeds the biomass fuel demand of 70,000 t/yr needed to cover the Ashford Growth area demand.

The price of biomass is a significant parameter affecting the viability of biomass technology developments. This price is highly dependent on supply and demand, as well as to the relative prices of other fuel prices (oil, gas etc.). In the short term, the rise of oil and gas prices shifts demand towards alternative energy fuels like biomass. This is expected to result in a rise in the price of biomass. However, in the medium and long term the price fluctuation of the different energy fuels should stabilise as fuel producers can vary their production rate according to demand and consumers can switch to alternatives.

Higher demand for biomass is expected to lead to an increase in imports from Scandinavia, North America and elsewhere within the UK. The expansion of a biomass trading system will eventually result in stabilisation of the price and therefore in the long-term there is likely to be a high correlation between fossil and biomass fuel price.

8 Summary of Findings

8.1 Lowest Cost Scenarios for Achieving CS10 Requirements

Overall, the most cost effective means of meeting the minimum level of compliance with CS10 for all five Pilot Sites is shown to be through fabric improvements and the installation of biomass boilers and/or large scale wind turbines.

The most cost effective means of providing 100% mitigation of the CO₂ emissions is through fabric improvements and a combination of large scale wind turbines, PV and gasification CHP, or where large scale wind turbines cannot be used, through the use of PV and gasification CHP alone.

A summary of the most cost effective scenarios identified shown in Table 3 below. Appendix A gives further details of the results for all 5 Pilot Sites and also includes suggestions for the phased implementation of renewables for each site.

	Cost for achieving CS10 minimum CO ₂ reductions	Cost for achieving CS10 maximum CO ₂ reductions	Cost differential between minimum and maximum CO ₂ reductions
Pilot Site 1	£5m	£35m	£30m
Pilot Site 2	£3m	£20m	£17m
Pilot Site 3	£2m	£9m	£7m
Pilot Site 4	£0.4m	£15m	£14.6m
Pilot Site 5	£1.3m	£8m	£6.7m

Table 3: Comparison of lowest cost scenarios for achieving CS10 requirements

A possible combination of technologies to achieve the lower and higher CO₂ mitigation targets is illustrated in Table 4, based on the lowest cost scenarios shown in Table 3.

	Minimum CO ₂ reduction scenario			Maximum CO ₂ reduction scenario			
	Fabric Improvement	Biomass Boiler	Large Wind	Fabric Improvement	Gasification CHP+ heat network	Large Wind	PV panels
Pilot Site 1	10%	×	>20%	10%	53%	33%	4%
Pilot Site 2	6%	×	>24%	6%	62%	32%	×
Pilot Site 3	5%	25%	×	5%	74%	×	21%
Pilot Site 4	16%	4%	×	16%	45%	×	39%
Pilot Site 5	9%	3%	18%	9%	65%	18%	8%

Table 4: Illustration of lowest cost technology combinations for achieving CS10 requirements

A high level analysis of the upper and lower boundaries of compliance with CS10 shows that in some instances different investment choices need to be made depending on the extent to which the carbon fund is used to make up any short fall.

Although investigating the detail of such tipping points is not possible without a robust strategy for the 'Ashford Fund', the results of the Pilot Studies are useful in that they provide an indication of the cost differential between meeting minimum and maximum targets.

Full details of the assessment of each individual Pilot Site is included in Appendix A with a summary of the numerical results in Appendix C.

Large scale wind turbines are the lowest cost technology, per unit of CO₂ mitigated. It has been assumed that the Pilot Sites which are urban extensions may offer greater opportunities for large scale wind turbines than suggested by the Cluster Analysis which was based on a typical urban context.

Where wind turbines are not feasible biomass boilers are the most cost effective solution for the minimum CO₂ scenarios although the practicality of installing independent boilers and fuel deliveries needs to be considered. Biomass CHP (in particular biomass gasification CHP) is the second most cost effective energy generation technology, in terms of capital outlay

Biomass boilers have not been considered as a primary heat source in conjunction with heat networks as project experience has shown that district heating networks which supply only heat are rarely economically feasible.

In the maximum CO₂ reduction scenario any shortfall in CO₂ emissions reduction has been met using photovoltaic (PV) panels as this is the most cost-effective remaining technology that is complimentary to all other technologies.

8.2 The Benefits of Exporting Heat to Existing Consumers

The results of this study highlight the benefits of exporting heat produced by CHP systems installed in the context of new developments.

Figure 1 shows a simplified representation of the results for the town centre site, (Pilot Site 4). The yellow circle on the bottom left ("A") illustrates that biomass boilers would be the most cost-effective technology for meeting the minimum CS10 requirements.

The blue/green circle at the top right ("B") illustrates the most cost-effective solution for mitigating 100% of the CO₂ emissions by using a combination of biomass gasification CHP plus significant areas of photovoltaic panels.

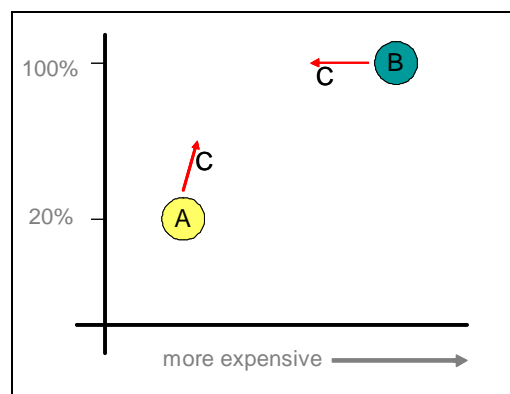


Figure 1: Town Centre site cost comparison

- A: Biomass Boilers
- B: Biomass Gasification CHP & PV
- C: Potential efficiency improvement with heat export to existing buildings stock

As PV is a comparatively expensive technology it would be preferable to install a larger capacity CHP plant to generate additional zero-carbon electricity in a more cost-effective way. However this would result in excess heat being generated which would need to be 'dumped' in the absence of a suitable heat sink.

However, if this excess heat can be exported to neighbouring buildings in the maximum CO₂ saving scenario then the biomass CHP can be operated more efficiently and the area of PV panels can be reduced accordingly, which will result in a net reduction in capital costs.

Likewise in the minimum CO₂ saving scenario, if the heat from the biomass boilers can be exported to neighbouring buildings and the operational hours and/or capacity of the biomass

boilers can be expanded, this would result in a significant increase in carbon saved for a relatively modest increase in cost.

These savings are shown by the red arrows ("C").

9 Conclusions

It has been shown that in many cases there is a limit to the level of CO₂ savings that can be achieved using lower cost technologies such as large wind turbines and CHP schemes. Therefore achieving a level of 100% CO₂ savings will require the use of higher cost technologies, such as PV panels which adds significant cost to the scheme.

The work also shows that achieving high levels of CO₂ emissions savings becomes more cost effective and lower risk as the developments increase in size and mix of building types.

It should be noted that the installation of a district heating scheme presents a high initial cost to the developer(s). However, the level of CO₂ savings afforded by such a scheme can be relatively easily increased by changing the type of heat generator, for example from a gas engine CHP plant to a biomass gasification CHP plant. Heat networks generally provide a more cost effective way of updating heat and electricity generation technologies as a small number of large capacity units will need to be replaced compared to a large number of smaller units installed in individual buildings. Consequently, a district heating network can also be seen as a form of future proofing.

The review of technology rollout timelines highlights the potential benefits from connecting existing buildings to a new heat network or linking together the heat networks on the various development sites.

It is anticipated that the extent of CO₂ savings targeted by developers will depend on the level of the CO₂ buy-out price set by Ashford Borough Council.

In order to achieve the levels of CO₂ savings required it will be necessary to prioritise the provision of the renewable energy technologies for each new development area from the outset rather than considering these systems as add-ons to ensure that sufficient land is made available and to ensure that the design and layout of buildings maximise the benefits of the selected technologies from the outset

Appendix A

**Pilot Site Technical and
Economic Analysis**

A1 Pilot Site One

A1.1 Development Particulars

Pilot Site One is an extensive, mixed use, urban extension development of the following composition:

- Residential 2,560 dwellings
- Retail and Commercial 90,000m²

Additional non-residential buildings have been assumed as follows:

- Primary school(s) 2,000m²
- Healthcare 500m²

The heat and electricity demand profiles of a development such as this are likely to be well suited to CHP technologies and the large area of non residential development may present opportunities for the use of large scale wind turbines.

A1.2 CO₂ Savings

The minimum reduction in CO₂ emissions required for Pilot Site One is 30%.

A review of the technologies capable of delivering the minimum (30%) and the maximum (100%) reduction in CO₂ emissions has been carried out. Table A1 summarises the technologies suited to meeting the minimum and maximum CO₂ requirements on-site.

The contributions (in %) required to deliver the most cost effective solution is shaded and using bold text. All scenarios considered include the maximum building fabric improvements considered feasible for the development profile.

Pilot Site 1	Low CO ₂ saving scenario (30% CO ₂ saving)			High CO ₂ saving scenario (100% CO ₂ saving)		
	Technology Capacity	CO ₂ saving	Additional Capital Cost	Technology Capacity	CO ₂ saving	Additional Capital Cost
Building fabric	HLP = 1.0	10%	-	HLP = 1.0	10%	-
Gasification CHP	700kWe	20%	£18m	1,600kWe	53%	£23m
Indirect air turbine CHP	500kWe	20%	£19m	700kWe	33%	£21m
Building integrated biomass boilers	19,000kW	29%	£13m	N/A	N/A	N/A
Large wind turbines	4,000kW	>20% (33%)	£5m	4,000kW	33%	£5m
PV Panels	5,000kW _{pk}	20%	36m	1,000-8,000kW _{pk}	4% - 32%	£7m to £57m
ORC CHP	N/A	N/A	N/A	700kWe	25%	£10m
Optimised Cost	£5m			£35m		

Table A1: Estimated technology capacity, CO₂ savings and associated costs for different technologies to achieve the low and high CO₂ saving scenario

A1.2.1 CO₂ Savings (Low CO₂ Saving Scenario)

It can be seen from Table A1 that the 30% level of onsite CO₂ reduction is best achieved with two 2MW wind turbines. Wind turbines can only be supplied in specific sizes therefore the size of the turbines identified in this scenario has been rounded up from the minimum requirement. Alternative solutions may be possible subject to the characteristics of the site and the emergency of new wind products.

Alternatively a combination of technology solutions will be required to achieve the 30% target:

- Building fabric improvements with gasification CHP
- Building fabric improvements with indirect turbine CHP
- Building fabric improvements with biomass boiler heating provided in every building in the development would result in a 38% reduction. To achieve no more than a 30% reduction would require biomass boiler heating provided in approximately 70% of the buildings in the development.

PV has not been considered for the low CO₂ saving scenario as PV is an expensive technology and the 30% CO₂ reduction target can be met using a number of lower cost technologies.

A1.2.2 CO₂ Savings (High CO₂ Saving Scenario)

There is no individual technology that can provide the full 100% level of CO₂ mitigation.

On the basis that as far as possible all heat production from CHP units should be used, biomass gasification CHP has the capacity to reduce CO₂ emissions by a maximum of around 53% while indirect air turbine biomass CHP will reduce emissions by around 33% without any heat being dumped. On a similar basis ORC CHP units will produce CO₂ savings of about 25%.

Electricity generating renewables (ie wind turbines and / or PV) are therefore required to provide the remaining savings.

It has been estimated that the maximum capacity of large scale wind turbines which can be installed on this development is 4,000kW. PV panels are therefore needed to provide the remaining CO₂ savings required. If maximum use is made of biomass gasification CHP and large scale wind turbines then 1,000kW_{pk} of PV panels will be required to provide the remaining CO₂ savings. If the capacity of large wind turbines can be increased then the requirement to install PV can be eliminated.

A1.3 Capital Costs

A1.3.1 Capital Costs (Low CO₂ Saving Scenario)

The lowest cost option for the low CO₂ saving scenario is 4MW of wind turbines, which would have an additional cost of around £5 million. With the potential to reduce CO₂ emissions by 33% the use of large wind turbines could potentially eliminate the need for fabric improvements. This scenario arises because wind turbines generally are only available in particular sizes.

Alternatively biomass boilers, which would have an additional cost of around £13 million if all buildings are heated using building integrated biomass boilers or £9 million if only sufficient buildings were provided with biomass heating to provide the minimum required CO₂ savings.

A1.3.2 Capital Costs (High CO₂ saving Scenario)

The lowest cost option for the high CO₂ saving scenario is biomass gasification CHP providing heat to all buildings in the development plus 4MW of wind turbines and 1,000kW_{pk}

of PV panels. This selection of technologies would have an additional capital cost of around £35 million.

An alternative selection of technologies, such as indirect air turbine CHP providing heat to all buildings in the development plus 4MW of wind turbines and 6,000kW_{pk} of PV panels, would increase the capital cost to around £69 million. The significant increase in costs is due to the much larger capacity of PV panels required on account of the lower electrical efficiency of the indirect air turbine CHP.

Project experience indicates that ESCOs operating biomass CHP schemes on developments of this size can be expected to contribute of the order of 20% of the additional capital required for a scheme.

A1.4 Renewable Energy Technology Rollout

An illustration of a possible technology phasing strategy in relation to the build-out rate is illustrated in Figure A1.

This shows the estimated cumulative CO₂ emissions from the Pilot Site that need to be mitigated and the estimated CO₂ savings if biomass gasification CHP, wind turbines and PV are used to mitigate 100% of the development's emissions.

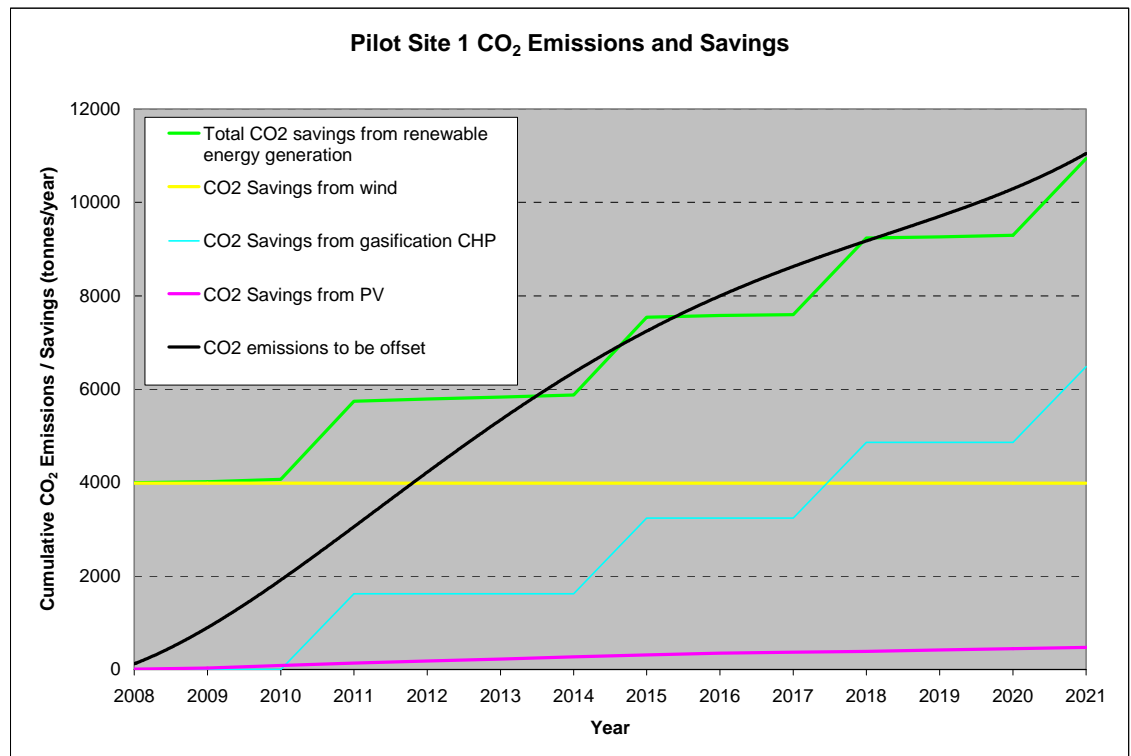


Figure A1: Timeline for CO₂ emissions and savings from renewable technologies to mitigate 100% of the estimated CO₂ emissions

Large scale wind turbines are assumed to be installed at the beginning of the project giving large initial CO₂ savings. These are supplemented by the savings from the installation of PV panels, which are assumed to be installed at a steady rate over the development construction period. The biomass gasification CHP is installed in modules every three years. The cumulative effect of this scenario is that this development would be able generate the required CO₂ savings ahead of demand associated with the completed buildings. This scheme would therefore be carbon neutral (or even carbon negative) for the majority of the build out period.

A2 Pilot Site Two

A2.1 Development Particulars

Pilot Site Two is a smaller mixed use, urban extension development than Pilot Site One.

Pilot Site Two has 2,600 dwellings and non residential buildings to provide 600 jobs. On the basis that each job requires 10m² of commercial floor area, the following non residential building schedule has been assumed:

- Retail 900m²
- Commercial 4,300m²
- Primary Schools 600m²
- Healthcare 200m²

The minimum level of CO₂ savings for an urban extension is 30%.

Although smaller than Pilot Site One, the heat and electricity demand profiles for Pilot Site Two are still likely to be well suited to biomass CHP technologies as there is a high proportion of mixed use development. The large area of non residential development may present opportunities for the installation of large scale wind turbines.

A2.2 CO₂ Savings

The minimum reduction in CO₂ emissions required for Pilot Site Two is 30%.

A review of the technologies capable of delivering the minimum (30%) and the maximum (100%) reduction in CO₂ emissions has been carried out. Table A2 summarises the technologies suited to meeting the minimum and maximum CO₂ requirements on-site.

The contributions (in %) required to deliver the most cost effective solution is shaded and using bold text style. All scenarios considered include the maximum building fabric improvements considered feasible for the development profile.

Pilot Site 2	Low CO ₂ saving scenario (30% CO ₂ saving)			High CO ₂ saving scenario (100% CO ₂ saving)		
	Technology Capacity	CO ₂ saving	Additional Capital Cost	Technology Capacity	CO ₂ saving	Additional Capital Cost
Building fabric	HLP = 1.0	6%	-	HLP = 1.0	6%	-
Gasification CHP	400kWe	24%	£14m	1,000kWe	62%	£17m
Indirect air turbine CHP	300kWe	24%	£14m	400kWe	44%	£15m
Building integrated biomass boilers	19,000kW	35%	£13m	N/A	N/A	N/A
Large wind turbines	2,000kW	>24% (32%)	£3m	2,000kW	32%	£3m
ORC CHP	N/A	N/A	N/A	300kWe	34%	£12m
PV Panels	2,200kW _{pk}	24%	23m	2,300 - 3,000kW _{pk}	18% - 28%	£17m to £26m
Optimised Cost			£3m			£20m

Table A2: Estimated technology capacity, CO₂ savings and associated costs for different technologies to achieve the low and high CO₂ saving scenario

A2.2.1 CO₂ Savings (Low CO₂ Saving Scenario)

It can be seen that a 30% reduction of onsite CO₂ emissions is best achieved with a large scale wind turbine. Wind turbines can only be supplied in specific sizes therefore the size of the turbines identified in this scenario has been rounded up from the minimum requirement. Alternative solutions may be possible subject to the characteristics of the site and the emergency of new wind products.

Alternatively a combination of technology solutions will be required to achieve the 30% target:

- Building fabric improvements with gasification CHP
- Building fabric improvements with indirect turbine CHP
- Building fabric improvements with biomass boiler heating provided in every building in the development would result in a 35% reduction. To provide the minimum required level of savings biomass heating would be required in approximately 70% of the buildings.

A2.2.2 CO₂ Savings (High CO₂ Saving Scenario)

There is no individual technology which can provide the full 100% level of CO₂ mitigation.

On the basis that all heat production from CHP units should be used, biomass gasification CHP has the capacity to reduce CO₂ emissions by a maximum of around 62% without any heat being dumped. On a similar basis ORC CHP units will produce CO₂ savings of about 34%.

Electricity generating renewables (ie wind turbines and / or PV) are therefore required to provide the remaining savings.

It has been estimated that the maximum capacity of large scale wind turbines which can be installed on this development is 2,000kW.

If maximum use is made of biomass gasification CHP and large scale wind turbines then 100% CO₂ savings can be provided in conjunction with fabric improvements of 6%

The use of indirect air turbine or ORC biomass CHP however would require large scale wind turbines (2,000kW) as well as PV (2,300kWpk and 3,000kWpk respectively) and fabric improvements to provide 100% CO₂ savings. If the capacity of large wind turbines can be increased then the capacity of PV will decrease.

Biomass boilers cannot be used as biomass boilers and biomass CHP are not complimentary technologies.

A2.3 Capital Costs

A2.3.1 Capital Costs (Low CO₂ Saving Scenario)

The lowest cost option for the low CO₂ saving scenario is 2MW of wind turbines, which would have an additional cost of around £3 million. With the potential to reduce CO₂ emissions by 32% the use of large wind turbines could potentially eliminate the need for fabric improvements. This scenario arises because wind turbines are generally only available in particular sizes.

Alternatively biomass boilers, which would have an additional cost of around £13 million if all buildings are heated using building integrated biomass boilers or £9 million if only sufficient buildings were provided with biomass heating to provide the minimum required CO₂ savings.

A2.3.2 Capital Costs (High CO₂ saving Scenario)

The lowest cost option for the high CO₂ saving scenario is biomass gasification CHP providing heat to all buildings in the development plus 2MW of wind turbines. This selection of technologies would have an additional capital cost of around £20 million.

An alternative selection of technologies, such as indirect air turbine CHP providing heat to all buildings in the development plus 2MW of wind turbines and 2,300kW_{pk} of PV panels, would have an additional capital cost of around £35 million. The significant increase in costs is due to the much larger capacity of PV panels required on account of the lower electrical efficiency of the indirect air turbine CHP.

Project experience indicates that ESCOs operating biomass CHP schemes serving 1,000 or more dwellings can be expected to contribute of the order of 20% of the additional capital required for a scheme.

A2.4 Renewable Energy Technology Rollout

An illustration of a possible technology phasing strategy in relation to the build-out rate is illustrated in Figure A2.

This shows the estimated cumulative CO₂ emissions from the Pilot Site that need to be mitigated and the estimated CO₂ savings if biomass gasification CHP, wind turbines and PV are used to mitigate 100% of the development's emissions.

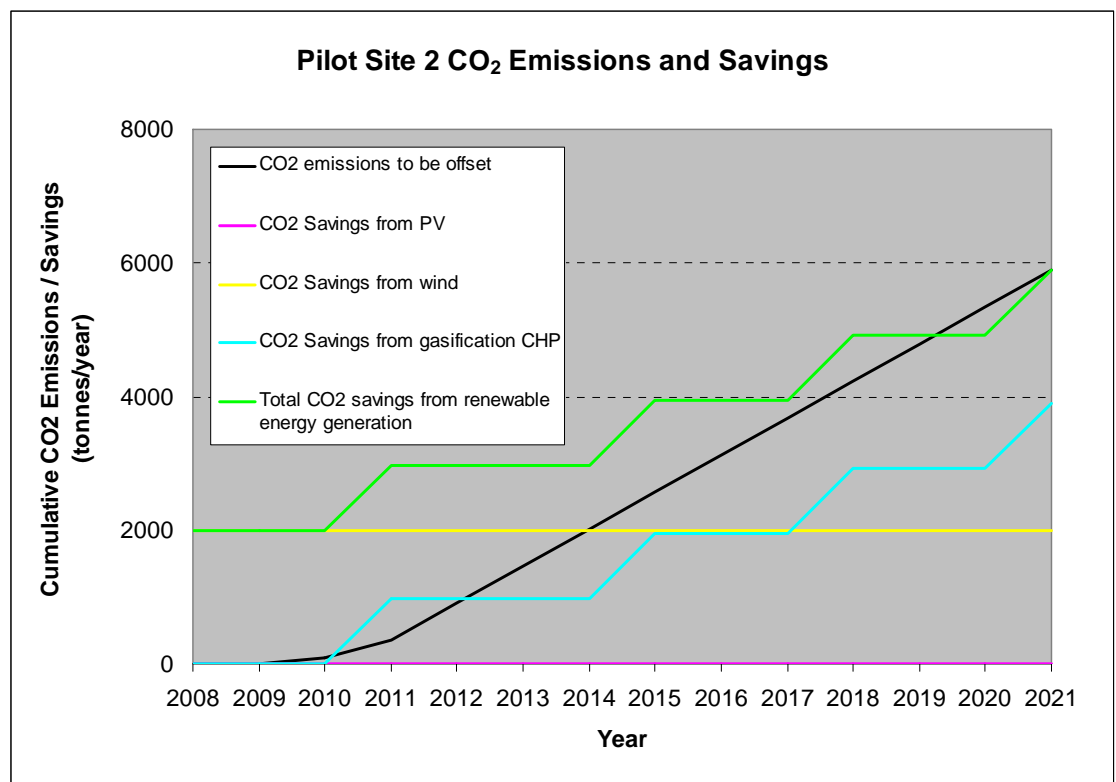


Figure A2: Timeline for CO₂ emissions and savings from renewable technologies to mitigate 100% of the estimated CO₂ emissions

Large scale wind turbines are assumed to be installed at the beginning of the project giving large initial CO₂ savings. These are supplemented by the savings from the installation of PV panels, which are assumed to be installed at a steady rate over the development construction period. The biomass gasification CHP is installed in modules every three years. The cumulative effect of this scenario is that this development would be able generate the required CO₂ savings ahead of demand associated with the completed buildings. This scheme would therefore be carbon negative for the majority of the build out period.

A3 Pilot Site Three

A3.1 Development Particulars

Pilot Site Three is a small, urban green field, residential only development with 600 units..

It has been assumed that there would be no associated non residential development such as primary schools or healthcare buildings at this scale of development.

The small size of this development will limit the range of technologies which can be used.

A3.2 CO₂ Savings

The minimum reduction in CO₂ emissions required for Pilot Site Three is 30%.

A review of the technologies capable of delivering the minimum (30%) and the maximum (100%) reduction in CO₂ emissions has been carried out. Table A3 summarises the technologies suited to meeting the minimum and maximum CO₂ requirements on-site.

The contributions (in %) required to deliver the most cost effective solution is shaded and using bold text. All scenarios considered include the maximum building fabric improvements considered feasible for the development profile.

Pilot Site 3	Low CO ₂ saving scenario (30% CO ₂ saving)			High CO ₂ saving scenario (100% CO ₂ saving)		
	Technology Capacity	CO ₂ saving	Additional Capital Cost	Technology Capacity	CO ₂ saving	Additional Capital Cost
Building fabric	HLP = 1.0	5%		HLP = 1.0	5%	
Indirect air turbine CHP	60kWe	25%	£4m	100kWe	46%	£4m
Building integrated biomass boilers	2,000kW	25% - 36%	£2m -£3m	N/A	N/A	N/A
Gasification CHP	N/A	N/A	N/A	300kWe	74%	£5m
PV Panels	N/A	N/A	N/A	600-1,700kW _{pk}	21% - 60%	£4mto £12m
Optimised Cost	£2m			£9m		

Table A3: Estimated technology capacity, CO₂ savings and associated costs for different technologies to achieve the low and high CO₂ saving scenario

A3.2.1 CO₂ Savings (Low CO₂ Saving Scenario)

It can be seen from Table A3 that the 30% level of onsite CO₂ reduction can be achieved in two ways:

- Building fabric improvements with indirect turbine CHP will achieve 30% CO₂ savings. The power output rating of the selected indirect air turbine CHP is slightly oversized to represent an actual model available.
- Building fabric improvements with biomass boiler heating provided in every building in the development will together result in a 41% reduction. To achieve the minimum required level of savings would require biomass boiler heating in approximately 70% of the buildings in the development.

- PV has not been considered for the low CO₂ saving scenario as PV is an expensive technology and the 30% CO₂ reduction target can be met using a number of lower cost technologies.
- Wind turbines have not been considered as an option as this site only comprises residential units and it is quite likely that the constraints for wind turbine installation will be prohibitive. The combination of noise, shadow flicker and visual impact generally excludes the use of large wind turbines in residential areas.
- Biomass gasification CHP has been also not considered for the low CO₂ saving scenario because the capacity required to meet the 30% CO₂ reduction requirement is considerably lower than the smallest gasification CHP module currently available.

A3.2.2 CO₂ Savings (High CO₂ Saving Scenario)

There is no individual technology which can provide the full 100% level of CO₂ mitigation required.

On the basis that all heat production from CHP units should be used, biomass gasification CHP has the capacity reduce CO₂ emissions by a maximum of around 74% while indirect air turbine biomass CHP will reduce emissions by around 46% without any heat being dumped.

Biomass boilers cannot be used as biomass boilers and biomass CHP are not complimentary technologies.

It has been estimated that PV panels are needed to provide the remaining CO₂ savings required. If maximum use is made of biomass gasification CHP then 600kW_{pk} of PV panels will be required to provide the remaining CO₂ savings. If maximum use is made of indirect air turbine then 1,400kW_{pk} of PV will be required to provide the remaining CO₂ savings.

As for the low CO₂ saving scenario, large wind turbines are not considered as part of a technological solution.

The smallest ORC CHP technology option which is currently available has a much higher power rating than is required in order to meet the criteria for CO₂ emission reduction for the high CO₂ saving scenario. Therefore, this technology has also been discounted.

A3.3 Capital Costs

A3.3.1 Capital Costs (Low CO₂ Saving Scenario)

The lowest cost option for the low CO₂ saving scenario is biomass boilers, which would have an additional cost of around £3 million if all buildings are heated using biomass boilers or £2 million if only sufficient buildings were provided with biomass heating to provide the minimum required CO₂ savings.

Alternatively an indirect air turbine CHP in conjunction with a heat network, providing heat to all buildings in the development would incur a cost of around £4 million to provide the minimum required CO₂ savings.

This option would allow other renewable technologies to be connected to the district heating network at a later date, enabling CO₂ emissions to be reduced further at relatively low cost.

A3.3.2 Capital Costs (High CO₂ saving Scenario)

The lowest cost option for the high CO₂ saving scenario is biomass gasification CHP providing heat to all buildings in the development plus 600kW_{pk} of PV panels. This selection of technologies would have an additional capital cost of around £9 million.

An alternative selection of technologies, such as an indirect air turbine CHP providing heat to all buildings in the development plus 1,500kW_{pk} of PV panels, would have an additional

capital cost of around £15 million. The significant increase in costs is due to the much larger capacity of PV panels required on account of the lower electrical efficiency of the indirect air turbine CHP.

As for the low CO₂ saving scenario, the wind turbine and ORC CHP options have not been considered for the high CO₂ saving scenario.

As any biomass CHP scheme in this development would be serving less than 1,000 dwellings, it is unlikely that any ESCo operating the scheme would be able to contribute much if any of the capital investment required.

A3.4 Renewable Energy Technology Rollout

An illustration of a possible technology phasing strategy in relation to the build-out rate is illustrated in Figure A3.

This shows the estimated cumulative CO₂ emissions from the Pilot Site that need to be mitigated and the estimated CO₂ savings if biomass gasification CHP and PV are used to mitigate 100% of the development's emissions.

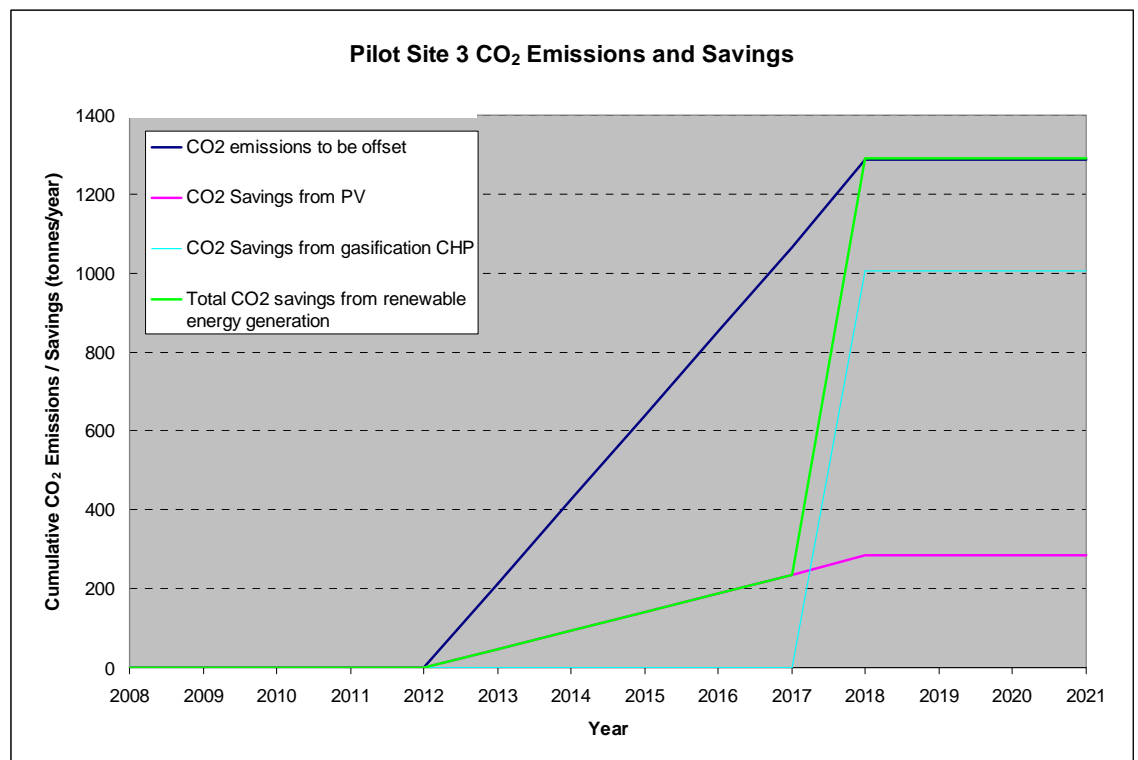


Figure A3: Timeline for CO₂ emissions and savings from renewable technologies to mitigate 100% of the estimated CO₂ emissions

PV panels are assumed to be installed at a steady rate over the development construction period, producing a gradual increase in the level of CO₂ mitigated.

It can be seen that the gasification CHP plant is only installed in the last year of the development build out as the heat demand of the site increases to match the heat output of the smallest available module size of gasification CHP.

This scheme will therefore not be carbon neutral until the build-out is complete.

A4 Pilot Site Four

A4.1 Development Particulars

Pilot Site Four is a small, mixed use development located in the town centre.

The development will consist of 300 dwellings and around 16,700m² of non residential buildings.

The 16,700m² of non residential buildings is assumed to consist of:

- Retail 2,800m²
- Commercial 13,000m²
- Primary school(s) 400m²
- Healthcare 500m²

The relatively low levels of energy consumption of Pilot Site 4 limits the selection of technologies for the low CO₂ saving scenario due to the minimum capacities of the different technologies available.

Although the scale of the development is small, there may be the potential to export heat to existing buildings surrounding the development. The opportunities presented by the town centre location are explored further in the following sections.

A4.2 CO₂ Savings

The minimum reduction in CO₂ emissions required for Pilot Site Four is 20%.

A review of the technologies capable of delivering the minimum (20%) and the maximum (100%) reduction in CO₂ emissions has been carried out. Table A4 summarises the technologies suited to meeting the minimum and maximum CO₂ requirements on-site.

The contributions (in %) required to deliver the most cost effective solution is shaded and in bold text. All scenarios considered include the maximum building fabric improvements considered feasible for the development profile.

Pilot Site 4	Low CO ₂ saving scenario (20% CO ₂ saving)			High CO ₂ saving scenario (100% CO ₂ saving)		
	Technology Capacity	CO ₂ saving	Additional Capital Cost	Technology Capacity	CO ₂ saving	Additional Capital Cost
Building fabric	HLP = 1.0	16%	-	HLP = 1.0	16%	-
Building integrated biomass boilers	2,300kW	4% - 22%	£0.4m to £2m	N/A	N/A	N/A
PV Panels	160kW _{pk}	4%	£1m	1,600 – 2,200kW _{pk}	39% – 56%	£11m to £16m
Gasification CHP	N/A	N/A	N/A	250kW _e	45%	£4m
Indirect air turbine CHP	N/A	N/A	N/A	100kW _e	28%	£3m
Optimised Cost	£0.4m			£15m		

Table A4: Estimated technology capacity, CO₂ savings and associated costs for different technologies to achieve the low and high CO₂ saving scenario

A4.2.1 CO₂ Savings (Low CO₂ Saving Scenario)

It can be seen that 20% of on-site CO₂ emissions reduction can be achieved in two ways:

- Building fabric improvements with biomass boiler heating provided in every building in the development will together result in a 38% reduction. To achieve no more than a 20% reduction using building fabric improvements and biomass boilers would require biomass boiler heating provided in just 20% of the buildings in the development.
- Building fabric improvements plus PV panels.

As this development is located within the town centre there is unlikely to be a suitable location for any large scale wind turbines.

A4.2.2 CO₂ Savings (High CO₂ Saving Scenario)

Biomass gasification CHP has the potential to reduce CO₂ emissions by a maximum of around 45% while indirect air turbine biomass CHP will reduce emissions by around 28% without any heat being dumped. PV is therefore required to provide the remaining savings.

As suggested above, if existing buildings in the surrounding area can be connected to the district heating scheme then larger capacities of biomass CHP can be installed and the area of PV required can be reduced accordingly. To achieve 100% CO₂ saving would require a doubling of the gasification CHP capacity, assuming that all the heat produced is consumed.

The new development in the town centre is likely to be highly fragmented. It would be highly desirable to establish a wider area network which allows the new development areas to be linked together whilst presenting the opportunity to provide heat to existing buildings.

Biomass boilers cannot be used as biomass boilers and biomass CHP are not complimentary technologies.

A4.3 Capital Costs

A4.3.1 Capital Costs (Low CO₂ Saving Scenario)

The lowest cost option for the low CO₂ saving scenario is biomass boilers fitted in around 20% of the buildings with an additional cost of approximately £400,000.

A4.3.2 Capital Costs (High CO₂ saving Scenario)

The town centre location offers few opportunities for renewable energy generation unless heat can be exported to existing buildings

The lowest cost option for the high CO₂ saving scenario is biomass gasification CHP providing heat to all buildings in the development plus 1,600kW_{pk} of PV panels. This selection of technologies would have an additional capital cost of around £15 million.

An alternative selection of technologies, such as indirect air turbine CHP providing heat to all buildings in the development plus 2,200kW_{pk} of PV panels, would have an additional capital cost of around £19 million. The significant increase in costs is due to the much larger capacity of PV panels required on account of the lower electrical efficiency of the indirect air turbine CHP.

These costs could be significantly lowered if the local buildings in the town centre can make use of any excess heat produced. This would allow a larger biomass CHP unit to be installed which could potentially remove the need for PV panels entirely. The density of the existing town centre buildings will be relatively high and the buildings will have much lower standards of insulation than the new buildings. It should therefore be cost effective to extend the heat network beyond the new development areas.

A4.4 Renewable Energy Technology Rollout

An illustration of a possible technology phasing strategy in relation to the build-out rate is illustrated in Figure A4.

This shows the estimated cumulative CO₂ emissions from the Pilot Site that need to be mitigated and the estimated CO₂ savings if biomass gasification CHP and PV are used to mitigate 100% of the development's emissions.

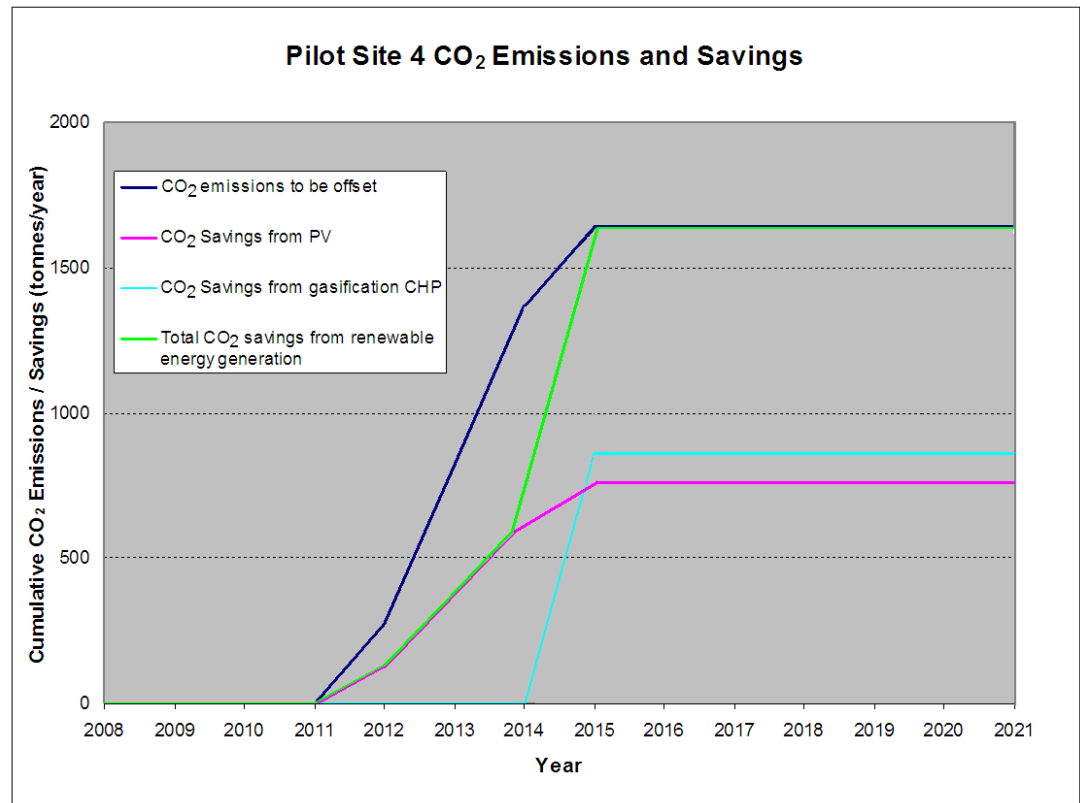


Figure A4: Timeline for CO₂ emissions and savings from renewable technologies to mitigate 100% of the estimated CO₂ emissions

PV panels are assumed to be installed at a steady rate over the development construction period, producing a gradual increase in the level of CO₂ mitigated.

Operation of the biomass gasification CHP will be dependant on there being sufficient demand for the available heat. As the proposed solution is based on the smallest available module size, the unit should only be installed as the last phase of dwellings is completed, when there will be sufficient heat demand to operate the unit.

This scheme will therefore not be carbon neutral until the build-out is complete.

A5 Pilot Site Five

A5.1 Development Particulars

Pilot Site Five is understood to be a mainly greenfield site on the outer boundary of the Ashford Growth Area. Pilot Site Five is planned to have 600 dwellings and non residential buildings to provide 500 jobs. This scheme will therefore not be carbon neutral until the build-out is complete.

- Retail 800m²
- Commercial 3,600m²
- Primary Schools 500m²
- Healthcare 130m²

Pilot Site Five is on the lower end of the scale of developments (in terms of size) suitable for the installation of biomass CHP technologies. However, the presence of non residential buildings and the location of the development on the outer boundary of the Ashford Growth area suggests that locations suitable for large scale wind turbines may be available.

A5.2 CO₂ Savings

The minimum reduction in CO₂ emissions required for Pilot Site Five is 30%.

A review of the technologies capable of delivering the minimum (30%) and the maximum (100%) reduction in CO₂ emissions has been carried out. Table A5 summarises the technologies suited to meeting the minimum and maximum CO₂ requirements on-site.

The contributions (in %) required to deliver the most cost effective solution is shaded and using bold text. All scenarios considered include the maximum building fabric improvements considered feasible for the development profile.

Pilot Site 5	Low CO ₂ saving scenario (30% CO ₂ saving)			High CO ₂ saving scenario (100% CO ₂ saving)		
	Technology Capacity	CO ₂ saving	Additional Capital Cost	Technology Capacity	CO ₂ saving	Additional Capital Cost
Building fabric	HLP = 1.0	9%	-	HLP = 1.0	9%	-
Indirect air turbine CHP	70kWe	22%	£4m	100kWe	29%	£4m
Building integrated biomass boilers	4,000kW	3% - 32%	£300k - £3m	N/A	N/A	N/A
PV Panels	90kW _{pk}	3%	£0.7m	300-1,500kW _{pk}	8% - 44%	£2m to £11m
Large wind turbines	500kW	18%	£1m	500kW	18%	£1m
Gasification CHP	N/A	N/A	N/A	300kWe	65%	£5m
Optimised Cost	£1.3m			£8m		

Table A5: Estimated technology capacity, CO₂ savings and associated costs for different technologies to achieve the low and high CO₂ saving scenario

A5.2.1 CO₂ Savings (Low CO₂ Saving Scenario)

It can be seen from Table A5 that the 30% level of onsite CO₂ reduction can be achieved in a number of ways:

- Building fabric improvements with indirect turbine CHP will achieve at least 30% CO₂ savings.
- Building fabric improvements with biomass boilers to provide heating in all buildings would achieve CO₂ savings of about 41%. To provide the minimum required level of savings would require biomass heating to be provided in approximately 66% of the buildings, assuming the building fabric is also improved.
- Although the level of non residential development on the site is relatively small and the site is on the outer boundary of the Ashford Growth Area, it is anticipated that a location may be identified for a large scale wind turbine. The use of building fabric improvements and a 500kW wind turbine is estimated to reduce the CO₂ emissions by 27%. To provide the minimum required level of savings would additionally require biomass heating to be provided in approximately 10% of the buildings.
- ORC and gasification CHP technology options have not been included in the options list as the required power capacity is much lower than the smallest ORC and gasification CHP modules currently available.

A5.2.2 CO₂ Savings (High CO₂ Saving Scenario)

There is no individual technology which can provide the full 100% level of CO₂ mitigation.

Biomass gasification CHP has the capacity to reduce CO₂ emissions by a maximum of around 65% while indirect air turbine biomass CHP will reduce emissions by around 29% without any heat being dumped. Electricity generating renewables (ie wind turbines and / or PV) are therefore required to provide the remaining savings

It has been estimated that the maximum capacity of wind turbine which can be installed on this site is 500kW. In order to achieve 100% carbon mitigation PV panels with a capacity 300kW_{pk} or 1,500kW_{pk} will be required when using biomass gasification CHP and indirect air turbine, respectively.

ORC CHP cannot be used as the currently available model in the market has higher power rating relative to the power required to meet the CO₂ emission reduction target.

Biomass boilers cannot be used either, as biomass boilers and biomass CHP are not complimentary technologies.

A5.3 Capital Costs

A5.3.1 Capital Costs (Low CO₂ Saving Scenario)

The lowest cost option for the low CO₂ saving scenario is the use of large scale wind turbines and biomass boilers with an additional cost of around £1.3 million.

Biomass boilers, which would have an additional cost of around £3 million if all buildings are heated using building integrated biomass boilers or £2 million if only sufficient buildings were provided with biomass heating to provide the minimum required CO₂

Alternatively, an indirect air turbine CHP in conjunction with a heat network, providing heat to all buildings in the development would incur an additional cost of around £4 million to provide the minimum required CO₂ savings.

This option would allow other renewable technologies to be connected to the district heating network at a later date, enabling CO₂ emissions to be reduced further at relatively low cost.

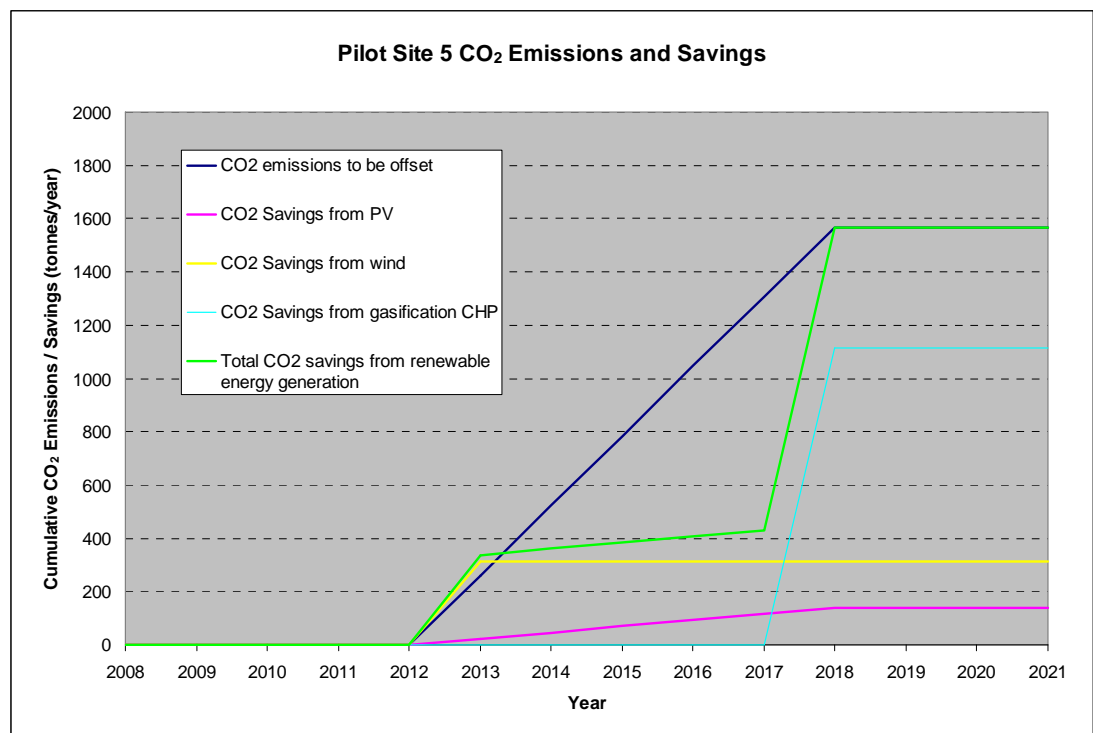
A5.3.2 Capital Costs (High CO₂ saving Scenario)

The lowest cost option for the high CO₂ saving scenario is biomass gasification CHP providing heat to all buildings in the development plus 500kW of wind turbines and 300kW_{pk} of PV panels. This selection of technologies would have an additional capital cost of around £8 million.

An alternative selection of technologies, such as indirect air turbine CHP providing heat to all buildings in the development plus 500kW of wind turbines and 1,500kW_{pk} of PV panels, would have an additional capital cost of around £16 million. The significant increase in costs is due to the much larger capacity of PV panels required on account of the lower electrical efficiency of the indirect air turbine CHP.

A5.4 Renewable Energy Technology Rollout

An illustration of a possible technology phasing strategy in relation to the build-out rate is illustrated in Figure A5.



This shows the estimated cumulative CO₂ emissions from the Pilot Site that need to be mitigated and the estimated CO₂ savings if biomass gasification CHP, large scale wind and PV are used to mitigate 100% of the development's emissions.

Figure A5: Timeline for CO₂ emissions and savings from renewable technologies to mitigate 100% of the estimated CO₂ emissions

Large scale wind turbines are assumed to be installed at the beginning of the project giving large initial CO₂ savings. PV panels are assumed to be installed at a steady rate over the development construction period, producing a gradual increase in the level of CO₂ mitigated.

The biomass gasification CHP is installed in two stages based on the smallest available module size for this technology. The cumulative effect of this scenario is that this development would generate the required CO₂ savings ahead of time at the beginning of the build out. In the later stages of the implementation this scenario would lag behind the demand curve. The second biomass gasification CHP module is installed during the last year of the development build-out when the heat demand matches the heat output of the CHP.

Appendix B

Technical Appendix

B1 Carbon Dioxide Emissions Factors

The Carbon Dioxide Emission indicators specified in the Part L building regulations have been used. These are as follows:

- | | |
|---------------------------------|--------------|
| • Gas | 0.194kg/kWh |
| • Grid electricity | 0.422kg/kWh |
| • Locally generated electricity | -0.568kg/kWh |
| • Biomass | 0.025kg/kWh |

B2 Fabric Improvements

B2.1 Residential Buildings

Dwellings will typically be constructed to have a heat loss parameter of no more than 1.0 with windows having a U value $1.2\text{Wm}^{-2}\text{K}^{-1}$ and walls, roof and ground floor having a U value of $0.11\text{Wm}^{-2}\text{K}^{-1}$. The dwellings will be required to have an air tightness of no less than $3\text{m}^3\text{m}^2\text{h}^{-1}$ @ 50Pa.

It should be noted that for levels 1 to 5 the Code for Sustainable Homes does not specify what proportion of the required level of CO₂ abatement should be met using fabric improvements and what proportion should be met using renewable energy generation.

B2.2 Non-residential Buildings

It has been assumed that non residential buildings will be required to reduce CO₂ emissions regulated by the Building Regulations by 20% compared to 2006 standards, which will be achieved through the use of measures such as improved facades and high efficiency heating and cooling systems.

Appendix C

Summary of Results

C1 Pilot Site Results Summary

Overview of the estimated CO₂ savings and associated costs for different technologies to achieve the low and high CO₂ saving scenario. The constituents of the lowest cost option to make up the required CO₂ reduction are highlighted.

C1.1 Pilot Site 1

Pilot Site 1	Low CO ₂ saving scenario (30% CO ₂ saving)			High CO ₂ saving scenario (100% CO ₂ saving)		
	Technology Capacity	CO ₂ saving		Technology Capacity	CO ₂ saving	Additional Capital Cost
Building fabric	HLP = 1.0	10%	Building fabric	HLP = 1.0	10%	-
Gasification CHP	700kWe	20%	Gasification CHP	700kWe	53%	£23m
Indirect air turbine CHP	500kWe	20%	Indirect air turbine CHP	500kWe	33%	£21m
Building integrated biomass boilers	19,000kW	29%	Building integrated biomass boilers	19,000kW	N/A	N/A
Large wind turbines	4,000kW	>20% (33%)	Large wind turbines	4,000kW	33%	£5m
PV Panels	5,000kW _{pk}	20%	PV Panels	5,000kW _{pk}	4%-32%	£7m to £57m
ORC CHP	N/A	N/A	ORC CHP	N/A	25%	£10m
Optimised Cost	£5m			£35m		

C1.2 Pilot Site 2

Pilot Site 2	Low CO ₂ saving scenario (30% CO ₂ saving)			High CO ₂ saving scenario (100% CO ₂ saving)		
	Technology Capacity	CO ₂ saving		Technology Capacity	CO ₂ saving	
Building fabric	HLP = 1.0	6%	Building fabric	HLP = 1.0	6%	Building fabric
Gasification CHP	400kWe	24%	Gasification CHP	400kWe	24%	Gasification CHP
Indirect air turbine CHP	300kWe	24%	Indirect air turbine CHP	300kWe	24%	Indirect air turbine CHP
Building integrated biomass boilers	19,000kW	35%	Building integrated biomass boilers	19,000kW	35%	Building integrated biomass boilers
Large wind turbines	2,000kW	>24% (32%)	Large wind turbines	2,000kW	>24% (32%)	Large wind turbines
ORC CHP	N/A	N/A	ORC CHP	N/A	N/A	ORC CHP
PV Panels	2,200kW _{pk}	24%	PV Panels	2,200kW _{pk}	24%	PV Panels
Optimised Cost	£3m			£20m		

C1.3 Pilot Site 3

Pilot Site 3	Low CO ₂ saving scenario (30% CO ₂ saving)			High CO ₂ saving scenario (100% CO ₂ saving)		
	Technology Capacity	CO ₂ saving	Additional Capital Cost	Technology Capacity	CO ₂ saving	Additional Capital Cost
Building fabric	HLP = 1.0	5%		HLP = 1.0	5%	
Indirect air turbine CHP	60kWe	25%	£4m	100kWe	46%	£4m
Building integrated biomass boilers	2,000kW	25% - 36%	£2m -£3m	N/A	N/A	N/A
Gasification CHP	N/A	N/A	N/A	300kWe	74%	£5m
PV Panels	N/A	N/A	N/A	600-1,700kW _{pk}	21% - 60%	£4mto £12m
Optimised Cost	£2m			£9m		

C1.4 Pilot Site 4

Pilot Site 4	Low CO ₂ saving scenario (20% CO ₂ saving)			High CO ₂ saving scenario (100% CO ₂ saving)		
	Technology Capacity	CO ₂ saving	Additional Capital Cost	Technology Capacity	CO ₂ saving	Additional Capital Cost
Building fabric	HLP = 1.0	16%	-	HLP = 1.0	16%	-
Building integrated biomass boilers	2,300kW	4% - 22%	£0.4m to £2m	N/A	N/A	N/A
PV Panels	160kW _{pk}	4%	£1m	1,600 – 2,200kW _{pk}	39% – 56%	£11m to £16m
Gasification CHP	N/A	N/A	N/A	250kW _e	45%	£4m
Indirect air turbine CHP	N/A	N/A	N/A	100kW _e	28%	£3m
Optimised Cost	£0.4m			£15m		

C1.5 Pilot Site 5

Pilot Site 5	Low CO ₂ saving scenario (30% CO ₂ saving)			High CO ₂ saving scenario (100% CO ₂ saving)		
	Technology Capacity	CO ₂ saving	Additional Capital Cost	Technology Capacity	CO ₂ saving	Additional Capital Cost
Building fabric	HLP = 1.0	9%	-	HLP = 1.0	9%	-
Indirect air turbine CHP	70kWe	22%	£4m	100kWe	29%	£4m
Building integrated biomass boilers	4,000kW	3% - 32%	£300k - £3m	N/A	N/A	N/A
PV Panels	90kW _{pk}	3%	£0.7m	300-1,500kW _{pk}	8% - 44%	£2m to £11m
Large wind turbines	500kW	18%	£1m	500kW	18%	£1m
Gasification CHP	N/A	N/A	N/A	300kWe	65%	£5m
Optimised Cost	£1.3m			£8m		