Energy Report

Energy | Energy Use | Lean | Clean | Green

April 2011

Stambridge Mills

Rochford, Essex

Carried out for:
Stock Woolstencroft

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About XCO2 Energy

XCO2 Energy are a Low-Carbon Consultancy working in the Built Environment. This multidisciplinary company comprises both architects and engineers, with specialists including CIBSE Low Carbon consultants, Code for Sustainable Homes, EcoHomes, BREEAM and LEED Assessors.

The XCO2 Energy team has developed low-carbon schemes in the UK and abroad, varying from single buildings to large masterplans. XCO2 Energy are at the forefront of low-carbon and sustainability practices in the built environment, regularly participating in industry-wide efforts such as the developers of the methodology for CarbonBuzz, a scheme with CIBSE and RIBA participation, and sitting on the TCPA advisory board for the government's EcoTowns scheme.

	Issue 01	Issue 02	Issue 03	Issue 04
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Executive Summary

This report assesses the predicted energy performance and carbon dioxide emissions of the proposed development situated at Stambridge Mills, based on the information provided by the design team.

The design team have followed the three-step strategy, 'be lean', 'be clean', 'be green', to reduce the CO_2 emissions of the development.

Be Lean

The development at Stambridge Mills strives to reduce CO_2 emissions by incorporating a range of energy efficiency measures including efficient lighting, levels of insulation beyond building regulation requirements and high performance windows.

Through the implemention of these measures, annual CO_2 emissions for this development are close to levels set out in the current Part L building regulations (2010), prior to considering any potential savings through the use of renewables.

Once renewable technology is taken into account, CO_2 savings for Stambridge Mills are significantly below the baseline CO_2 emissions for Part L 2010 building regulations. The table on the following page outlines CO_2 savings and emissions for this development.

Be Clean

Hot water and space heating will be supplied by high efficiency condensing gas boilers to each dwelling.

CHP and communal heating were considered for this project however they were deemed to be unsuitable.

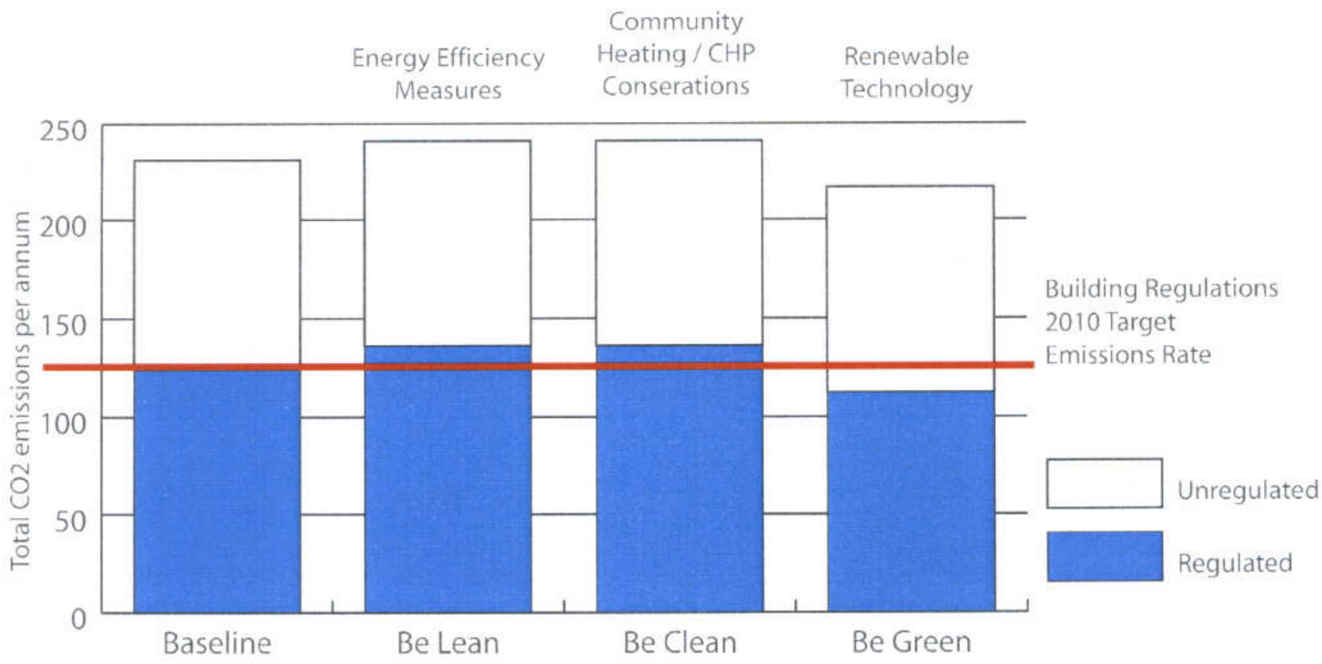
Be Green

A variety of low carbon technologies and systems were analysed, including a biomass heating system, solar thermal, ground-source heat pump, air-source heat pump, photovoltaics and wind turbines.

The use of photovoltaic panels as a renewable energy source was considered to be the optimum solution for reducing CO_2 emissions for this project, with a potential savings of 10.0%. This would be achieved through the installation of 353 m^2 (3.7m^2 per dwelling) of photovoltaics (53.0 kWp) across the site.

Conclusion

In total, the development is expected to reduce CO_2 emissions by 6.2% when compared with a building built to current Part L 2010 Building Regulations.



Carbon dioxide emissions and savings (tonnes CO[2] per annum)

	Carbon dioxide emissions (tonnes CO_2 per annum)		
	Regulated	Unregulated	Total
Building Regulations 2010 Part L Compliant Development	126.3	104.8	231.1
After energy demand reduction	136.0	104.8	240.8
After CHP	136.0	104.8	240.8
After Renewables	112.0	104.8	216.8

	Carbon dioxide savings (tonnes CO_2 per annum)		Carbon dioxide savings (%)	
	Regulated	Total	Regulated	Total
Savings from energy demand reduction	-9.7	-9.7	-7.7%	-4.2%
Savings from CHP	0.0	0.0	0.0%	0.0%
Savings from renewables	24.1	21.1	17.7%	10.0%
Total Cumulative Savings	14.3	14.3	11.3%	6.2%

Introduction

Stambridge Mills is a residential development located in the Rochford District Council of Essex, North of Southend-on-Sea. The development comprises 96 dwellings which include a mixture of 45 houses, and 51 flats. In total, the development has an gross internal area of approximately 7,900m^2.

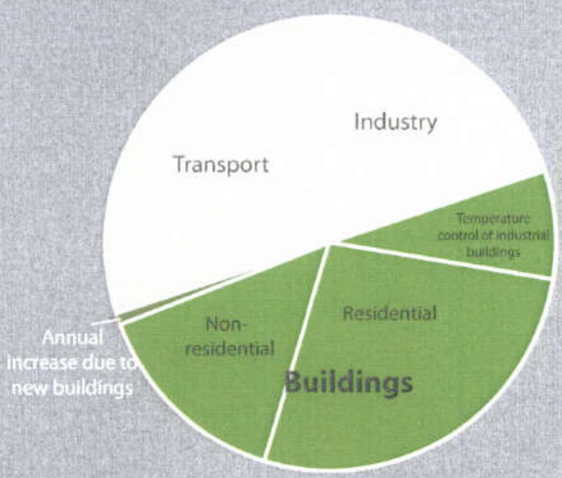
This document highlights the measures considered for the proposed development with regard to energy efficiency, renewable energy, and low carbon technologies.

This document discusses how the development addresses the council's energy efficiency and low carbon technology strategy required for new developments.

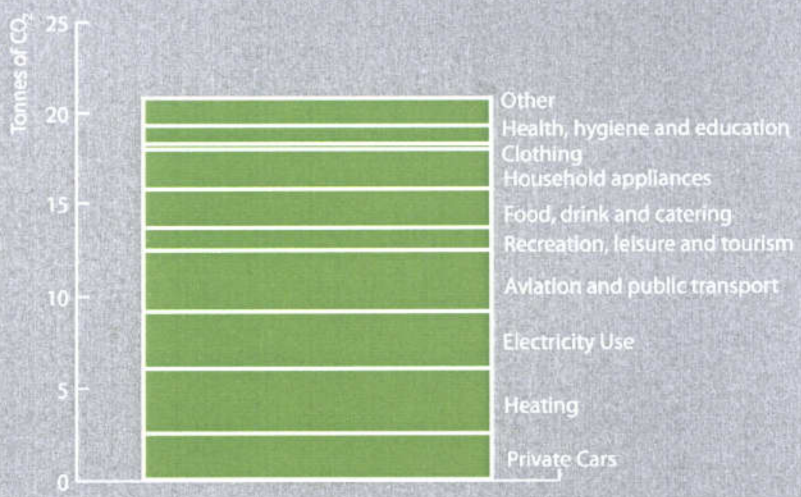
A major requirement of the East of England Plan is for all new developments to reduce the emissions to help achieve the Government's targets for reducing carbon emissions. The development will aim to meet Policy ENV8 of Rochford's Local Development Sustainability Appraisal of securing at least 10% of energy through from decentralised and renewable or low-carbon sources.

This report addresses the energy performance of Stambridge Mills by analysing the development over three stages:

- **Be Lean** - Improve the energy efficiency of the scheme
- **Be Clean** - Supply as much of the remaining energy requirement with low-carbon technologies such as combined heat and power (CHP)
- **Be Green** - Offset a proportion of the remaining carbon dioxide emissions by using low or zero carbon technologies.



Distribution of energy consumption in the UK
(Source: DTI Energy Statistics)



CO_2 emissions associated with household consumption
(Source: Defra Stockholm Environment Institute)

Energy

The new version of Part L came into force in October 2010 with the aim of further reducing the energy consumption and CO_2 emissions.

Our analysis uses the methodology set forth in Part L 2010 of the building regulations, by performing preliminary SAP 2009 assessments to calculate the baseline for the energy consumption of eight typical dwellings within the development.

The results from this dwelling were extrapolated across the whole development to predict the energy consumption for all 96 dwellings in order to pass Part L. In addition, the Target Emissions Rate (TER) for the typical dwelling was also calculated.

The SAP assessment was also used to calculate the energy consumption and CO_2 emissions of all dwellings taking into account the following energy efficiency measures:

- Improving the building fabric
- Reducing air infiltration
- Passive design features
- Low energy lighting

Heat Loss

By reducing heat loss though the fabric of the building during the heating season, the energy required for space heating is minimised. The heat loss through the different elements of the building is dependent upon the U-value of these elements.

The development will achieve the following U-values by incorporating very high levels of insulation.

Element	Building regulations	Proposed	Improvement
Walls	0.35	0.15	57%
Floor	0.25	0.10	60%
Roof	0.25	0.10	60%
Windows	2.2	1.4	36%

All U-values are in W/m^2K

Additional heat loss from buildings occurs due to air infiltration. Although this cannot be eliminated altogether, it can be minimised through good construction detailing and using best practice construction techniques.

Current Part L building regulations set a maximum air permeability of $10m^3/m^2$ at 50Pa. By adopting good practice construction technique, the development is likely to improve upon this to achieve an air permeability rate of $5\ m^3/m^2$ at 50Pa.

Efficiency

The development incorporates measures and systems to ensure that energy is efficiently generated, distributed and used within the development. Efficiency measures considered include low energy lighting.

Low Energy Lighting and Control

100% of lighting will be specified with dedicated low energy light fittings throughout the dwellings, ensuring only compact fluorescent (CFL's) or fluorescent luminaries. are used.

Internal and external areas of infrequent use will be fitted with occupant sensors, whereas daylit areas will receive daylight sensors.

High-efficiency condensing gas boilers

All dwellings will be fitted with high-efficiency condensing gas boilers (SEDBUK rating A).

Passive Design

The development will reduce the need for active cooling systems, artificial lighting and take advantage of winter solar gains through the incorporation of passive design techniques.

Daylighting

The development has been designed to provide good levels of daylight whilst also ensuring excessive solar gain does not cause overheating. This will mitigate any requirement of mechanical cooling, while avoiding the need for energy-intensive artificial lighting.

Particular daylighting initiatives include generous window sizing and interior walls which are painted in light colours to reflect light into rooms.

	Baseline (Part L 2010)			Lean		
	Energy (kWh/year)	CO_2 emissions ($kgCO_2$/year)	CO_2 ($kgCO_2/m^2$)	Energy (kWh/year)	CO_2 emissions ($kgCO_2$/year)	CO_2 ($kgCO_2/m^2$)
Hot Water	347,070	41,232	5.2	213,267	42,227	5.3
Space Heating	488,137	63,484	8.0	351,903	69,677	8.8
Cooling	0	0	0.0	0	0	0.0
Auxiliary	16,800	4,341	0.5	12,480	6,452	0.8
Lighting	52,320	16,230	2.0	34,199	17,681	2.2
Equipment (not inc. in Part L)	202,633	104,761	13.2	202,633	104,761	13.2
Total Part L	**904,328**	**125,287**	**15.8**	**611,849**	**136,037**	**17.2**
Total (inc Equip)	**1,106,961**	**230,049**	**29.0**	**814,482**	**240,798**	**30.4**

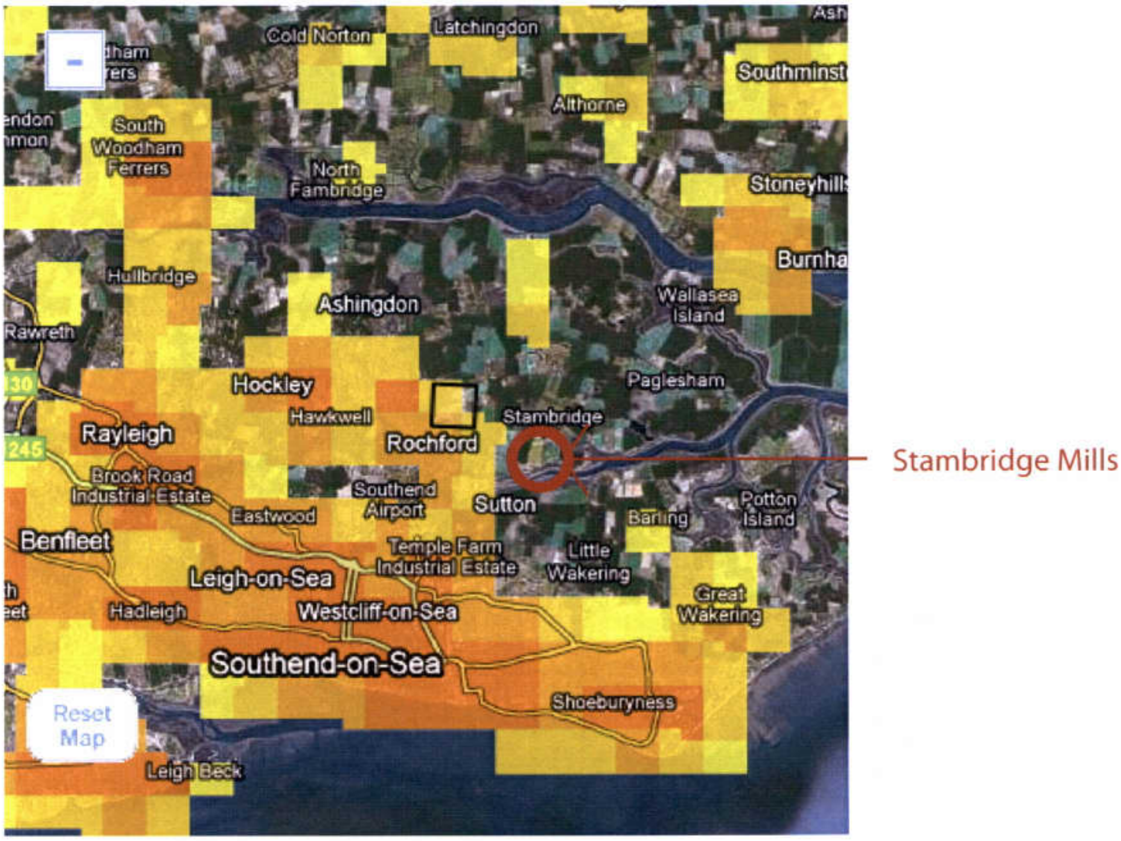
Primary energy and associated CO_2 emissions for Stambridge Mills pre and post efficiency measures

District Heating

Stambridge Mills is located in the Rochford District Council. Below in an excerpt from the Department of Energy & Climate Change, showing areas with potential connection to a district heating network.

As indicated by the lack of colouring on the map below, the site is located in a low heat density area. The data assumes no sites with small CHP or Large heat load sites exist within 1 square kilometre. Therefore a district heating network would not be feasible in this location.

In addition, there are no district heating systems currently existing or proposed in the near future within the vicinity of the development.



UK Heat Map, Source: DECC

CHP and Trigeneration

CHP, or Cogeneration, is the production of electricity and useful heat from a single plant, improving the overall energy conversion efficiency from between 25-35% to around 80%.

For a wide range of buildings, CHP can offer an economical method of providing heat and power which is less environmentally harmful than conventional methods.

However, the economic viability of CHP is heavily dependent on the demand for heat and power. For small scale residential developments, the use of a CHP engine is not likely to be feasible.

The major obstacle to implementing CHP at this type of development is the low density of the site. As the dwellings are spread out, a district heating network would have to be installed which would result in heat losses in the distribution network.

Smaller units, designed for individual dwellings, are only just coming to market now and are yet to be proven. Studies from the Carbon Trust have shown that they may not be effective at reducing CO_2 emissions and have a much higher capital cost than conventional gas boilers.

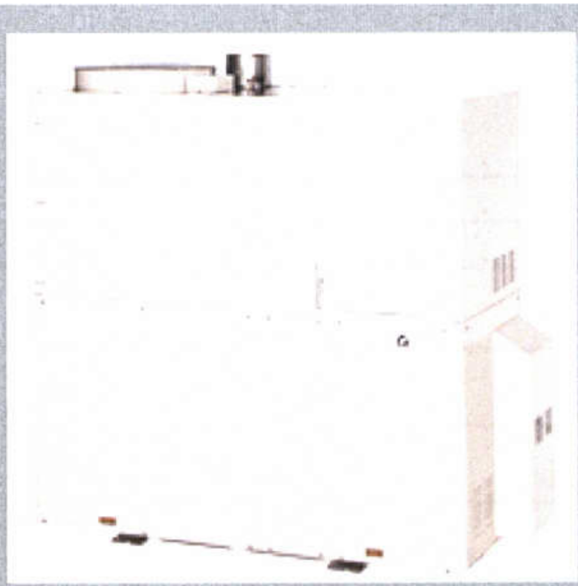
It is generally recommended that a CHP system would only be worth investigating for schemes with a baseload heat demand of more than 6,000 hours per year.

As residential heat loads tend to be concentrated in the early morning, due to the hot water demand for showering, a large thermal store would have to be installed on site.

For a CHP system at this development to operate for more that 6,000 hours per year, it would have a thermal output of approximately 35 kW.

As the site would require a district heating network and a large thermal store, it was decided that CHP was not technically, environmentally or financially feasible for the project.

Gas CHP		
Split (CHPt/CHPe)	1.5	
Electrical Efficiency	30	%
Heating Efficiency	46	%
Backup System Efficiency	90	%
Hot Water Produced	106,600	kWh/yr
Electricity Produced	63,980	kWh/yr
Total CO_2 savings	13.7	t/yr
Percentage CO_2 reduction due to Gas CHP	5.7	%



Ener-G 25y micro CHP unit

Renewables

Once energy demand reductions have been minimised, methods of generating low and zero carbon energy can be assessed.

As previously discussed, it is proposed that a renewable system is used in conjunction with high-efficiency condensing gas boilers to each dwelling. The system is estimated to provide the vast majority of space heating and domestic hot water for the development.

The following low carbon technologies were reviewed for the development. These technologies can all contribute to the 10% renewables target:

- Biomass
- Ground Source Heat Pumps
- Air Source Heat Pumps
- Wind Turbines
- Photovoltaic Panels
- Solar Thermal Collectors

Where possible, each system has been sized to meet the council's planning policy of reducing the total CO_2 emissions of the development by at least 10%.

A summary and comparison of the technologies is provided at the end of this document.

	Carbon dioxide emissions (tonnes CO_2 per annum)		
	Regulated	Unregulated	Total
Baseline	126.3	104.8	231.1
Lean	136.0	104.8	240.8
Clean	136.0	104.8	240.8

CO2 emissions prior to the incorporation of renewable technologies for Stambridge Mills

Biomass Heating

For Stambridge Mills, an appropriate biomass system would likely be fuelled by wood pellets due to the small plant space available. Wood pellets have a greater energy content per unit of weight, therefore they require a lower storage volume. Pellet boilers also require less maintenance and produce considerably less ash residue.

Realistically, individual biomass boilers located in each dwelling would not feasible due to cost, space and technical limitations. Therefore, similarly to CHP (see page 8), a district heat network would be required to distribute hot water to each dwelling from a large centralised biomass plant.

Analysis shows that there are several reasons why biomass is not an appropriate technology for this development:

- a district heat network would be required to distribute the heat from a central plant to the individual dwellings.
- there may be issues in finding a local biomass supplier;
- there are concerns over local air quality and the increase of NOx emissions as a result of burning wood as fuel.

Example of pellet boiler and pellet storage room. Source: Energy Crops Limited

Example of wood pellet fuel

Biomass Heating	
% of heat supplied	25 %
Biomass System Efficiency	90 %
Carbon Intensity of Biomass	0.028 $kgCO_2/kWh$
Backup System Efficiency	90 %
Carbon Intensity of Backup	0.198 $kgCO_2/kWh$
Heating Demand Met	79,200 kWh/yr
Total CO_2 savings	24.0 t/yr
Lean CO_2	240.8 t/yr
Percentage CO_2 reduction	10.0 %

Ground Source Heat Pumps

Ground heat exchangers can either be horizontal, (buried in trenches) or vertical (boreholes). Due to the density of the development, a horizontal trench system would not be suitable and, therefore, a borehole system would be required.

A suitable closed ground loop (ground to water heat exchanger) system for the site would include a number of boreholes containing pipe work with a liquid which is passed around to absorb heat from the ground and relay this heat via an electrically run heat pump into the building.

The system would deliver space heating through a low-temperature efficient distribution network such as underfloor heating. Approximately 90% of the space heating demand can be supplied by the ground source heat pump if it is sized to approximately 50% of the peak load.

If the domestic hot water demand were also to be addressed by the heat pump, higher temperatures would need to be achieved, therefore decreasing the efficiency (coefficient of performance) of the system.

Because of the low CO_2 savings possible with the technology, GSHP was not considered further for the this development.

A borehole being drilled

GSHP	
COP Heat	4.0
Carbon Intensity of electricity	0.517 $kgCO_2/kWh$
Proportion of space heating met by GSHP	90 %
Proportion of hot water met by GSHP	0 %
Space heating demand met by GSHP	285,040 kWh/yr
Electricity used by GSHP	71,260 kWh/yr
Total CO_2 savings	25.9 t/yr
Clean CO_2	240.8 t/yr
Percentage CO_2 reduction	10.7 %

Air Source Heat Pumps

Air source heat pumps employ the same technology as GSHPs. However, instead of using heat exchangers buried in the ground, heat is extracted from the external ambient air.

A benefit of ASHP is that they produce space heating and hot water through electricity, thereby negating the need for a gas connection to each unit.

ASHPs tend to have a lower COP than GSHPs due to variable air temperature throughout the year, when compared to ground temperature. This is because heat pumps are more efficient when the temperature difference between the heat source (the air in this instance) and the space demand is lower.

Another factor to consider is the location of ASHP evaporators. These need to be located outside of the building. Any noise associated with the units, could potentially be an issue, particularly at night. In addition, outdoor plant space would be required for this option.

Because of the low CO_2 savings as well as the outdoor space required with this technology, ASHP was not considered further for the Stambridge Mills development.

ASHP external unit

ASHP	
COP Heat	3.2
Carbon Intensity of electricity	0.517 $kgCO_2/kWh$
Proportion of space heating met by ASHP	90 %
Proportion of hot water met by ASHP	0 %
Space heating demand met by ASHP	285,040 kWh/yr
Electricity used by ASHP	89,075 kWh/yr
Total CO_2 savings	16.7 t/yr
Clean CO_2	240.8 t/yr
Percentage CO_2 reduction	6.9 %

Wind Turbines

The area designated for the Stambridge Mills development is relatively small and does not appropriate space for a stand-alone turbines. Therefore, building-integrated turbines would be required.

Wind turbine outputs are based on the mounting height, turbine wind curve and wind data for the site from the BERR website. This was used in the Carbon Trust Wind Yield Estimation Tool.

The average annual wind speed at a mounting height of 10m above the building canopy is estimated as 4.7 m/s. It is not generally recommend that wind turbines should be installed in any area where average wind speeds fall beneath 5m/s.

Calculations are shown below for 2.5kW and 6kW turbines mounted on the roof. To achieve 10% reduction in CO_2 emissions, approximately 20 no. 2.5kW turbine would be required or alternatively 9 no. 6kW turbines.

Due to the number of wind turbines required and site restrictions on site, this technology is not considered to be suitable for Stambridge Mills.

A building-mounted 6kW Proven wind turbine

A 2.5kW Merlin Wind turbine

Wind Power - 2.5kW		
Average windspeed at site	4.7	m/s
Electricity offset by turbine	2,519	kWh/yr
Carbon intensity of offset electricity	0.529	$kgCO_2$/kWh
Total CO_2 savings	1.2	t/yr
Clean CO_2	240.8	t/yr
Percentage CO_2 reduction by 2.5kW wind turbine	0.5	%
Number of turbines required to meet target	20	turbines

Wind Power - 6kW		
Average windspeed at site	4.7	m/s
Electricity offset by turbine	6,296	kWh/yr
Carbon intensity of offset electricity	0.529	$kgCO_2$/kWh
Total CO_2 savings	3	t/yr
Clean CO_2	240.8	t/yr
Percentage CO_2 reduction by 6kW wind turbine	1.2	%
Number of turbines required to meet target	9	turbines

Photovoltaic Panels
Currently, there are four types of solar cells available: mono-crystalline, poly-crystalline, thin film and hybrid. Mono-crystalline and hybrid cells are the most expensive to produce but are the most efficient (12-20%), poly-crystalline cells are cheaper but their efficiency is lower (9-15%) and thin film cells are only 5-8% efficient but can be produced as thin flexible sheets.

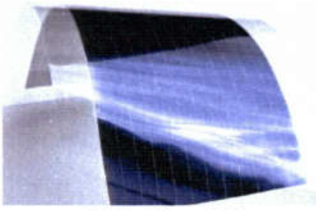
Photovoltaic panels are best orientated to the south and inclined between 30° and 40°. Panels can be placed on the roofs of flat buildings and inclined to the optimum angle through the use of a mounting frame.

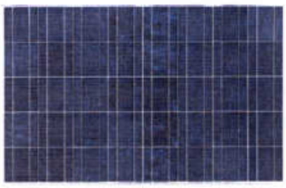
A high efficiency mono-crystalline panel system sized to meet the 10% reduction in CO_2 emissions required for the Stambridge Mills development would result in 350 m² of photovoltaic panels, rated at about 62.3 kWp.

The proposed PV installation can be situated on the roofs of each individual house - it is estimated that 1000 m² of PV can be mounted on the south facing roof area available of all of the houses on site. Alternatively, the PV can be installed on the flat roof of the four apartment blocks, it is estimated that a PV area of 400 m² can be mounted on the flat roof areas provided.


A hybrid PV Panel


A monocrystalline PV Panel


Thin film PV


A polycrystalline PV Panel

Due to the potential CO_2 savings, adequate roof space and limited overshadowing, this technology is considered suitable for the Stambridge Mills development.

Photovoltaic Panels Distributed Across Site	
Orientation	South-Facing
Predicted site solar energy	1073 kWh/m²/yr (S facing)
System losses	20 %
System peak power	53.0 kWp
Total array area (to be distributed across site)	353 m²
Primary electricity offset by PV array	45,452 kWh/yr
Total CO_2 savings	24.0 t/yr
Clean CO_2	240.8 t/yr
Percentage CO_2 reduction	10.0 %

Solar Thermal

Solar thermal modules act in a similar way to PV arrays in terms of their orientation and inclination. South facing arrays with an optimum inclination of about 35° would achieve the best performance.

Evacuated tube and flat plate collectors are both commercially available. Although more expensive than flat plate collectors, their higher efficiencies and higher temperatures make evacuated tube collectors a better choice for the UK climate.

The proposed system would be used for domestic hot water only, not space heating since this is not required during the season when solar thermal is the most effective.

A suitable solar thermal system would supply approximately 50% of the annual hot water consumption (the maximum feasible due to seasonal variations), and would be topped up with high efficiency gas boilers. Given a solar fraction of 50% this would achieve a CO_2 savings of 6.9%.

A cost comparison between solar thermal and PVs was carried out and it was found that PVs would be more cost efficient. Due to the cost implications and CO_2 savings, PV would be the optimum solar technology at Stambridge Mills instead of a solar thermal system.

Evacuated Shell and Tube Solar Thermal Panel

Solar Thermal	
System Efficiency	35 %
Orientation	South-facing
Predicted site solar energy	1073 kWh/m²/yr
Solar fraction	35 %
Total collector area	335 m²
Primary gas energy offset by Solar Thermal system	83,460 kWh/yr
Total CO_2 savings	16.5 tonnes
Clean CO_2	240.8 t/yr
Percentage CO_2 reduction	6.9 %

Renewable Energy Summary

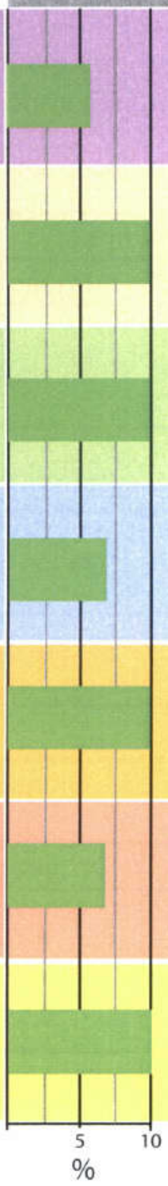
The table below summarises the renewable systems analysed and the different aspects taken into consideration, including estimated capital cost, simplified payback, lifetime, level of maintenance and level of impact on external appearance.

The final column (site feasibility) indicates how viable the technology is for the development (10 being the most feasible and 0 being unfeasible).

It is important to note that the information provided is indicative and costs are based upon initial estimates. Payback calculations do not take into consideration any grants or inflation. Current feed in tariffs have been included.

Where the payback is N/A this means the simple payback is greater than the lifetime of the system.

	% CO_2 Reduced	Simple Payback	Tonnes CO_2 per year	Lifetime	Maintenance	Impact on External Appearance	Site Feasibility
CHP		15-20 yrs	13.7	20yrs	High	Low	3
Biomass		10-15yrs	24.0	15yrs	Med	Low	3
GSHP		10-15yrs	25.9	20yrs	Low	Low	3
ASHP		10-15yrs	16.7	25yrs	Med	High	5
Wind		N/A	24.0	25yrs	Med	High	2
Solar Thermal		10-15yrs	16.5	20yrs	Med	Low	7
PV		10-15yrs	24.0	25yrs	Low	Low	8



Renewable Energy Strategy Conclusion

Due to the location of the site, density of the individual dwellings, available roof space and cost of the technology, photovoltaics have been considered to be the most feasible renewable technology for Stambridge Mills.

A 53.0 kWp photovoltaic system distributed throughout the development will provide a 10% CO_2 reduction. This will meet the planning requirements set out by Rochford District Council.

The following technologies have been ruled out for integration into the project:

- Biomass - the impact on local air pollution and difficulties surrounding fuel deliveries to the site mean that biomass is not suitable for this location.
- Wind turbines - this technology is not suitable for the site due to the low predicted annual mean wind speed and the aesthetic implications of building mounted turbines.
- GSHP - The high capital cost for such a system means that the economic feasibility of a ground source system is poor. When combined with a low estimated CO_2 savings this technology is considered to be a poor choice for this project.
- ASHP - While ASHP is a very low cost technology, it provides very low CO_2 savings and therefore make no significant contribution in reducing CO_2 emissions.
- Solar thermal - although solar thermal is a feasible technology for this project, the cost of solar thermal arrays in comparison to PVs is high. A complete 10% savings on energy cannot be made through solar thermal alone. Solar thermal also requires additional plumbing. For these reasons, PV technology has been considered to be the optimum solution for this project.

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Total Cumulative Savings	14.3	14.3	11.3%	6.2%