Winchester District Renewable & Low Carbon Energy

An Assessment of Opportunities

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1 Executive Summary

This report is the product of a study commissioned by WinACC (Winchester Action on Climate Change) on behalf of the Winchester District Strategic Partnership Climate Change Programme and was funded by the Department of Energy and Climate Change (DECC) Local Energy Assessment Fund (LEAF). Instruction to proceed with the study was given on 15th February 2012 with the understanding that the study should be completed before the end of 31st March 2012.

Its purpose was to identify specific opportunities for the deployment of renewable and low carbon energy solutions within the Winchester District. The scope of work specifically excluded measures to improve building energy performance and transport. The objective was to identify energy sources that are available and under-utilised that can be used to displace energy supplied from the combustion of fossil fuels.

Energy and Greenhouse Gas Emissions in Winchester

Energy is at the heart of all human activity; whether to drive the movement of electrons across a computer chip or a super tanker across the oceans. It is used to heat our homes, provide light, entertainment and sustenance. Energy is fundamental to all human activity.

However, in the UK 89% of all our energy is generated from the combustion of just three main types of fossil fuel (coal, gas and oil)[1]. Just 4% comes from renewable sources with the remainder from nuclear (6%). And this combustion accounts for 82% of the UK's greenhouse gas (GHG) emissions.

Winchester is no different. The District requires some 3,500 GWh of energy[2] each year. This is used to meet its transport needs (46%), provide heat for its building and processes (33%) and power its electrical devices (19%).

This contributes to the District's emissions[3] of 1,078 kilo tonnes of carbon dioxide (CO_2)and a further emission of 5,071 tonnes of methane (CH_4)[4].

Winchester City Council wants to cut its GHG emissions by 30% by 2015 and has commissioned WinACC to manage a programme of change that will deliver this. Some of this reduction will come from energy efficiency and conservation. WinACC believes that a shift to locally sourced renewable energy could deliver a reduction of 100 kilo tonnes in GHG emissions, and that this could be achieved in the next four years.

[1] Source: Digest of UK Energy Statistics 2012 DECC; equivalent to an average power of 400 MW.
[2] This is in terms of final demand for energy. A considerably greater amount of energy is required as a primary input to generate the energy required. The differences between final and primary demand is largely accounted for by thermal and distribution losses in electrical power generation.
[3] Source: National Air Emission Inventory
[4] This is equivalent to 126,000 tonnes of carbon dioxide.

However more detailed estimates of renewable energy outputs are required. This report provides these estimates and aims to be the catalyst that will enable action to follow.

Our Approach

Many opportunities have been identified for the deployment of renewable and low carbon energy conversion within the Winchester District (which includes 26 wards covering 668 sq km).

A number of data sources, discussion with stakeholders and reviews of prior studies were used to identify:

- where in the District there is demand for heat and power (at a resolution of approximately 500 – 1,000 households/business per unit area) and the quantum of that demand (in GWh);
- the GHG emissions created by fuel use or waste at a resolution of one kilometre squares and in terms of both CO_2 and CH_4 ;
- sources of renewable feedstocks available in the District in terms of location, quantity and the energy they could deliver (both in terms of heat and electricity);
- technologies that should be used to convert the feedstocks into fuels and subsequently the fuels into useable energy;
- the reduction, in terms of tonnes of CO_{2e}, that the deployment of these technologies could achieve to the District's current level of GHG emissions;
- locations of these technologies could be optimally deployed for conversion of feedstock into fuels and fuels into energy (heat and or power);
- the potential costs of deployment.
- Opportunities for community ownership of large schemes either in part with other forms of funding or exclusively.

The Results

The study concludes that there are significant opportunities for delivery of renewable and low carbon energy that can be sourced from within the District. Converting some of these into a productive and reliable supply for the District may take more than five years. However, many of these opportunities can be deployed rapidly and could contribute the progress needed to achieve the 2015 target.

In terms of energy the District uses 3,517 GWh per annum, 1,605 GWh of which is used in transport as shown in Figure 1. 34% is used to heat its buildings and 19% as electrical power.

The District's GHG emissions (from carbon dioxide and methane) are 1,204 kilo tonnes of CO_{2e}. 41% of which is CO_2 from transport, 11% from CH_4 and 48% from CO_2 from heat and power.

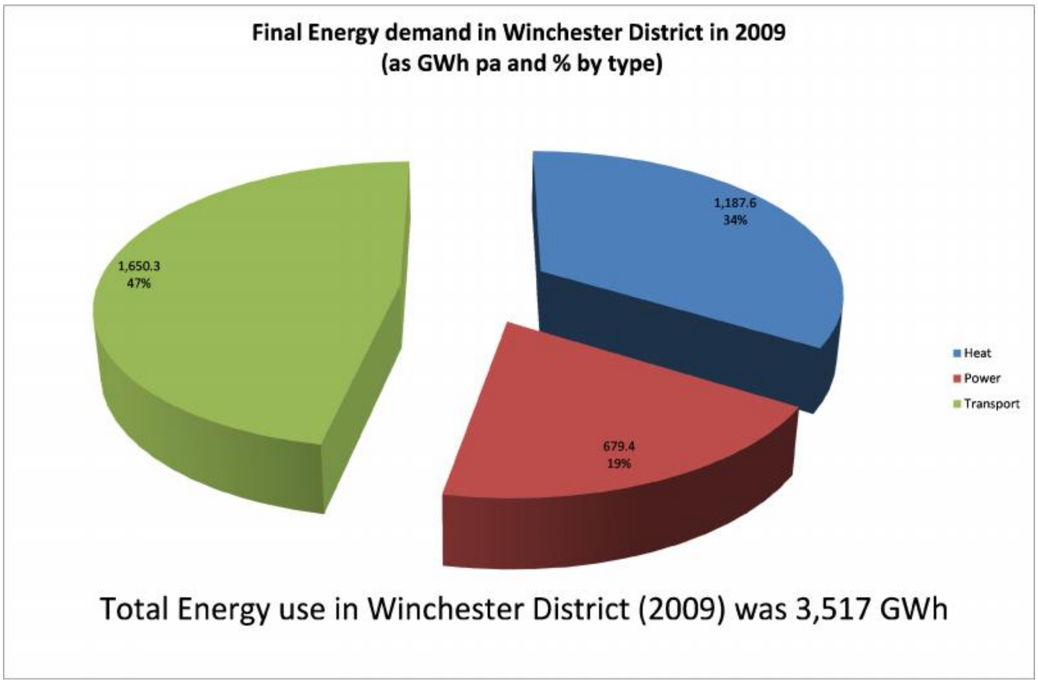

Figure 1 Final Energy Demand (GWh per Annum)

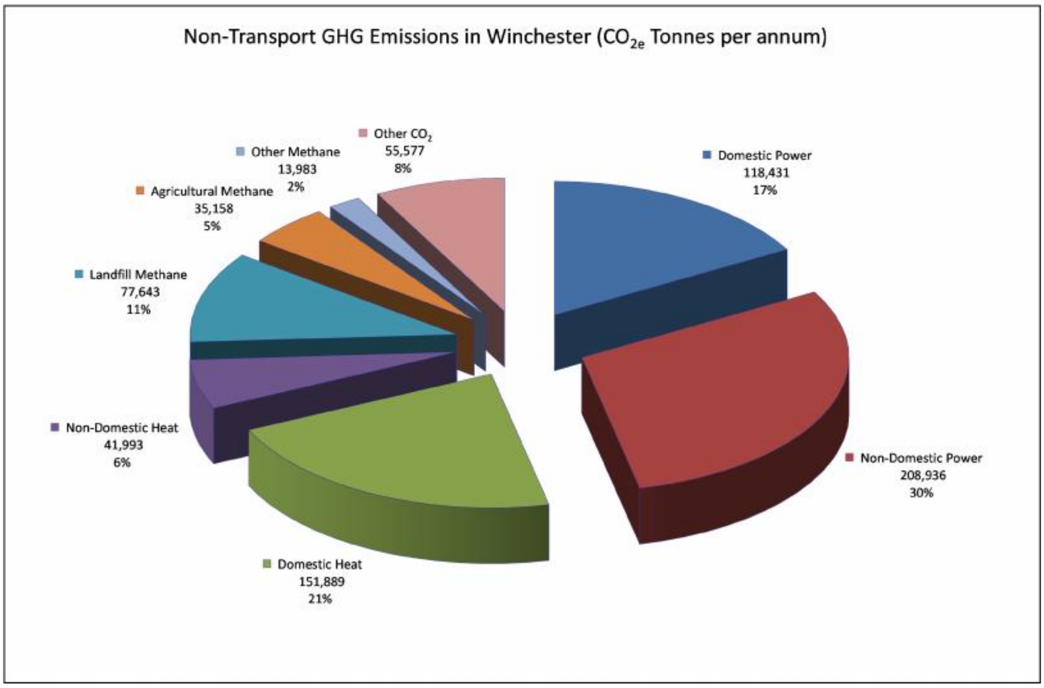

Figure 2 Non Transport GHG Emissions

The geographic locations of these emissions can be quite clearly seen from the following two maps.

As expected, CO_2 emissions are concentrated in and around the major towns within the District. However CH_4 emissions come from a number of closed landfill sites in and around Wickham and from major concentrations of cattle farms in the District.

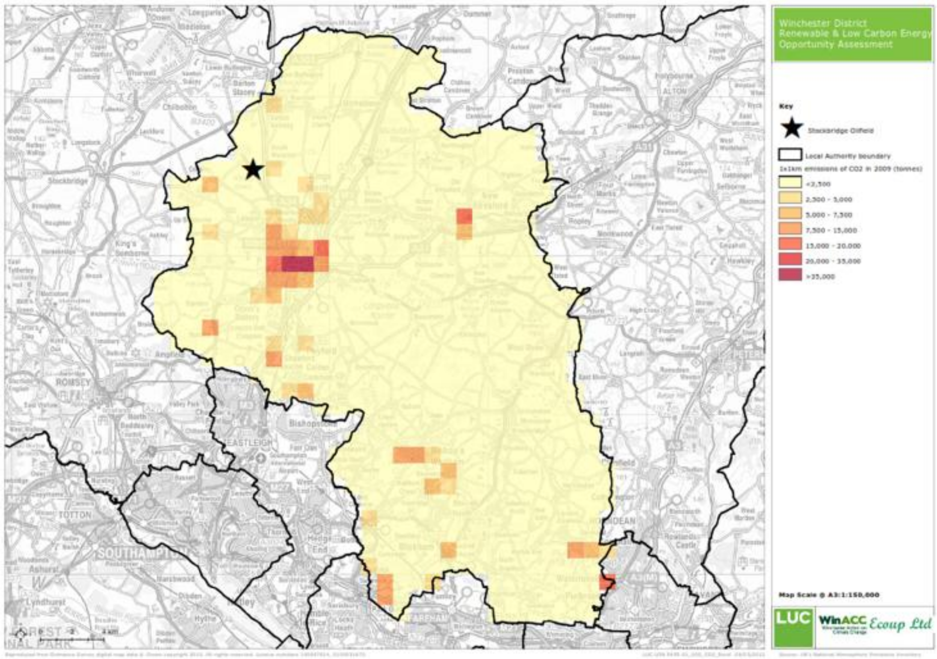

Figure 3 Map of Carbon Dioxide Emissions

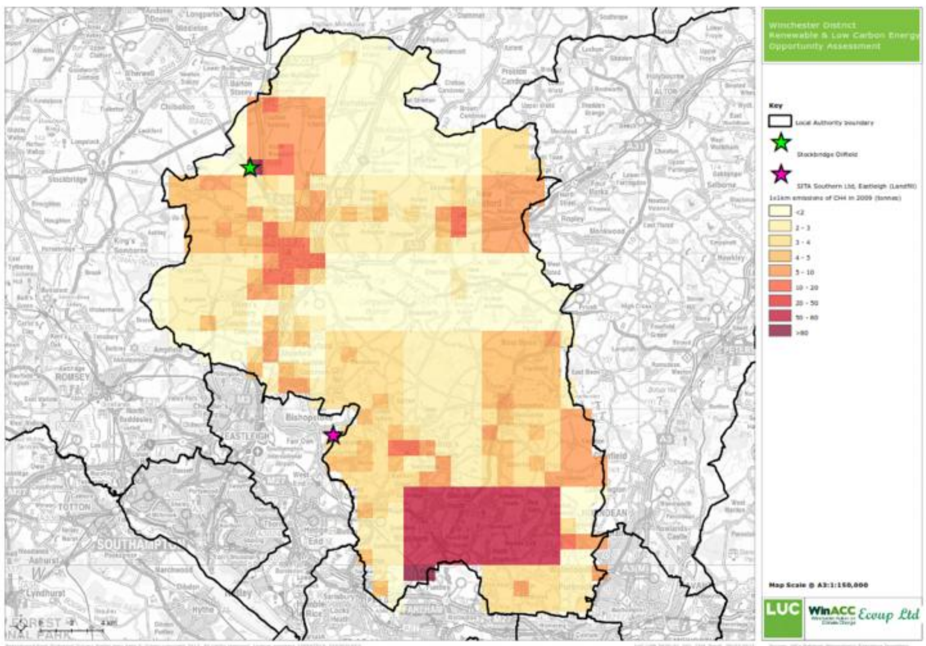

Figure 4 Map of Methane Emissions

Results from the analysis of the availability and impact of renewable sources are summarised in Table 1 below.

DECC Primary Fuel Type	Fuel Feedstock	Energy Production							Tonnes CO_{2e} Displaced		Reduction in CH_4 emission (in Tonnes CO_{2e})
		CHP		Power Only	Heat Only	Installed capacity	Average power		Max	Min	
		GWh_e	GWh_{th}	GWh_e	GWh_{th}	MW_p	MW		T CO_{2e}	T CO_{2e}	T CO_{2e}
Wind	Small Scale			0.7		1.3	0.3		3,110	1,800	
	Commercial Scale			8.6		9.0	3.0		218,408	15,242	
Plant Biomass	Managed Woodland for Combustion	10.4	19.9	16.6	33.2		4.7		10,615	7,436	
	Energy Crops for Combustion	11.4	21.8	18.2	36.3		5.2		11,631	8,148	
	Agricultural Arisings for Combustion	38.5	73.9	61.5	123.1		17.6		39,393	27,595	
	Agricultural Arising for AD	14.2	27.2	22.7	45.3		6.5		11,243	5,738	
	Heating Oil Replacement	7.7	14.8	12.3	24.6		3.5		5,512	5,512	
Animal Biomass	Wet Organic Waste for AD	11.1	21.4	17.8	35.6		5.1		8,841	4,513	7,289
	Poultry Litter for Combustion	16.8	32.3	27	53.9		7.7		17,253	12,086	
Municipal Solid Waste	Landfill Gas	0.8	1.6	1.3	2.7		3.3		10,542	2,948	44,795
	Sewage Gas	0.2	0.3	0.3	0.5		0.7		1,040	605	
Commercial And Industrial Waste	Waste Wood for Combustion	6.5	12.5	10.4	20.8		3		6,652	4,660	
Micro-generation	Solar PV			69.6		80.3	7.9		146,874	41,322	
	Solar Thermal				1.8	2.0	0.4		1,190	395	
	Ground Source Heat Pumps				78	18.9	8.9		34,172	12,706	
	Air Sourced Heat Pumps				78	18.9	8.9		37,342	9,598	
Total[1]		118	226	267	456		78		515,089	147,598	52,084

[1] Individual columns do not add to total as Poultry Litter and Straw can either be incinerated or used as AD feedstock but not both. Totals assume these feedstocks are incinerated

Table 1: Potential Energy Generation and GHG Emission Reductions

Overall we have identified opportunities to reduce direct CO_2 emissions by up to 515,000 tonnes. In addition a further 52,000 tonnes of equivalent emissions can be removed via the capture and use of furtive methane emissions from animal waste and landfill.

Whilst micro-generation technologies are mainly retro-fitted into new and existing buildings, and waste derived feedstocks are already available, wind and energy crop derived biomass technologies require significant allocations of land.

The above results would require an additional 5% of the existing farmed land area of the District to be planted with energy crops (mainly short rotation willow, miscanthus and oil seed rape)[5] and a further 600 ha devoted to wind farms[6]. However much of the energy can be produced from the use of commercial/domestic, animal and plant waste requiring minimal changes in land use.

Location of Opportunities

Analysis of ward and Lower Layer Super Output Area data has identified the locations that are not well served by the mains gas network. These areas would most benefit from the deployment of combined heat and power and district heating systems or replacing heating oil with bio-diesel. The authors could not access data to convert LLSOA areas to specific post codes but have listed the LLSOA name and indicated the associated wards. These are:

1. LLSOA Winchester 001A (part of Wonston & Micheldever ward) – 532 houses are not connected to mains natural gas.
2. LLSOA Winchester 004A (part of Cheriton & Bishops Sutton Ward) – 806 houses are not connected to mains natural gas.
3. LLSOA Winchester 010E (part of Owslebury and Curdridge ward) - 532 houses are not connected to mains natural gas.
4. LLSOA Winchester 011C (part of Swanmore and Newton ward) – 591 houses are not connected to mains natural gas.
5. LLSOA Winchester 011E (part of Upper Meon Valley ward) – 720 houses are not connected to mains natural gas.
6. LLSOA Winchester 014A (part of Boarhunt and Southwick ward) - 600 houses are not connected to mains natural gas.

The study also identified ten areas where there is potentially a high enough heat demand to justify the installation of CHP (combined heat and power scheme). These are centred on:

1. North and West of Peninsula Square, Winchester, SO22 5HG.
2. Friars Gate, Winchester, SO23 8EE.
3. Wellington Gate, Waterlooville, PO7 7ZY.[7]
4. Winnall Industrial Estate, Winchester, SO23 7UD.
5. Bath Place, Winchester, SO22 5HD.

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[5] 2,634 ha of new planting would be required from the existing farmed area of 46,133 ha
[6] Although up to 90% of this land can still be used for crops and/or grazing
[7] Although not in Winchester it borders the district and offers an opportunity for joint development with Havant Borough Council

6. Perins School, Alresford, SO24 9BS.
7. Peter Symonds College, Winchester, SO22 6AJ.
8. Area east of J9, M27, PO15 7JD.
9. Bishops Waltham town centre, SO32 1AL.
10. Stanmore Lane, Winchester. SO22 4DB.

Renewable Technologies and feedstocks

The demand for heat and power in these areas, and the rest of the District, can be met by the use of a number of feedstocks (or fuels) used in a variety of conversion technologies. Whilst there are numerous ways of converting fuel into energy, they fall into three broad categories:

1. The production of electricity only; which necessitates the rejection of large amounts of low grade heat[8] but at an overall efficiency of between 45-60%. The electricity can then be distributed to areas of demand.

2. The production of heat only which can occur at far higher efficiencies (85% or better) but requires a nearby source of demand.[9]

3. Combined production of heat and power where both forms of energy are co-produced. As with point 2 this requires a nearby base demand for heat but at a lower level. However there is a loss of overall efficiency as neither conversion process can be optimised.

Table 1 above shows the energy conversion rates that can be achieved for each fuel in each conversion technology.

Combustion of Agricultural Waste

Incineration of agricultural waste (particularly straw, poultry litter, residuals from managed woodland) offers the opportunity to reduce emissions by 73,000 tonnes. Whilst this has the downside of producing significant amount of smoke (and associated particulate emissions), incineration technologies are well proven. However the main feedstocks are straw and poultry litter, the sources of which are not co-located with heat demand. This either requires significant movement of low density feedstock for combustion at the source of demand or the conversion to electricity on site which substantially reduces the emissions savings (by 30,000 tonnes). Winchester District also contains 4,800 ha of ancient woodland. Waste and residuals from this area have been excluded from our analysis. However a further 10,000 tonnes could be saved if this resource was utilised.

As with most biomass feedstocks, agricultural waste is not normally co-located with significant heat demand therefore will require transport to CHP facilities. Electricity production would require the construction of small scale power plants (sub 1 MW) in or close to the feedstock source which may lead to planning issues. This may limit the feedstock to use in small scale

[8] This is a consequence of the laws of thermodynamics.
[9] Whilst transporting electricity over large distances is relatively efficient, transporting heat is not.

biomass burners (domestic and industrial) and therefore reduce emissions savings. In addition, unlike anaerobic digestion (AD), which produces high quality fertiliser, incineration only provides limited quantities of poorer quality ash. DECC estimates that biomass produced heat will be in the range of 4.3 -10p KWh. Whilst this is competitive with oil and electric (resistance) heating systems, the thermal output produced is more expensive than would be available from heat pumps or grid supplied natural gas burners. Therefore its use in district heating systems in areas with mains gas will be limited.

Anaerobic Digestion of Agricultural Waste

There is a substantial opportunity to use agricultural waste (mainly straw, poultry litter and cattle manure) and waste food as feedstock for AD plants. Current economics suggest these plants should have an installed capacity in the range of 200 - 500 kW. Winchester District could support 15-30 AD plants. Whilst specific sites have not been identified they need to be located near to feedstock. The highest concentration of feedstock is in the SE of the District but other areas also have potential. To achieve a minimum scale several farms would need to feed into 'hubbed', and possibly co-operatively owned AD plants. AD could reduce emissions by 18,000 tonnes. However feedstocks are not co-located with heat demand. Maximising the GHG reduction may require liquefaction of bio-methane at source for onward transport to City/Town based CHP plants.

AD has a number of advantages over combustion technologies in that:

- It produces a valuable digestate which can be used to re-fertilise the land used to generate the feedstock i.e. it is a much more closed system.
- There are no emissions of particulate matter (smoke).
- The bio-methane produced can be liquefied on site and transported to centres of heat demand and effectively used in CHP and district heating systems.

The economics of AD are also favourable. DECC estimates that AD produced bio-methane will cost in the range of 2.2-13.8p kWh (with natural gas in the range 3.2-4.8p kWh). Therefore it is more likely to be competitive with mains gas for heat production.

Electricity from AD facilities is expected to cost in the range of 7-17.3p kWh (with fossil fuelled electricity in the range 8.7 - 9.1p kWh). This makes AD one of the more competitive renewable technologies.

Bio-Fuel

Technologies now exist to replace heating oil with bio-diesel; doing so in Winchester could save 5,500 tonnes of emissions and replace 10% of the heating oil used, but would require 1,300 ha of land[10]. However better savings can be achieved through the use of energy crops. It is unlikely that bio-diesel will be cost competitive with heating oil.

Energy Crops

[10] This provides enough bio-diesel to provide 30.7 GWh of heat out of the 300 GWh of heating oil used in the District.

Combustion of energy crops (willow and miscanthus) can reduce emissions by 11,100 tonnes (in CHP schemes) but will require the use of 1,300 hectares of farmland. However (on an emissions savings basis) it is advisable that energy crops are also planted on land set aside for bio-diesel heating oil replacement. This increases the net saving by a further 5,600 tonnes. It is unlikely that small scale (1 MW) power stations could be constructed on energy crop farms. Therefore its use may be restricted to smaller scale biomass burning (homes and industry) in areas close to the farms. DECC indicates costs for this form of biomass will be in the range 4.3 – 10p KWh which is similar to electrical resistive heating and oil fired systems.

Methane Reduction

Methane is a substantial contributor to the District's GHG footprint[11]. The main controllable sources of methane are landfill sites and natural decomposition of animal manure in farm yards. The study has identified five opportunities for landfill gas capture, four of which are in the District and the fifth on the border with Eastleigh. Landfill gas capture could reduce emissions by the equivalent of 45,000 tonnes of CO_2 per annum. As bio-methane can be liquefied on site it can be transported to centres of heat demand for use in CHP. However a liquefaction plant is expensive. There may be advantages of co-locating AD facilities at landfill sites to ensure there is sufficient bio-methane to make liquefaction worthwhile.

Wind Power

A review of the District was undertaken to identify areas with the best potential for wind energy; the results are presented as a map of wind potential Figure 17. Fifteen sites were evaluated in some detail as a sample to demonstrate what could be achieved with this resource. There are a few other locations (reserve sites) on the District borders that may have further potential. Modelling of the annual generating capacity for the sites considered was based on four turbine sizes. Results indicate that large scale wind farms with a few large turbines could deliver a good investment on returns. If all the sites were developed the annual power delivered to the grid would be 126 GWh pa with a saving of 217 kilo tonnes of CO_{2e} emissions pa.

It is recommended that a detailed feasibility study is commissioned for three main sites: Portsdown Hill, Martyr Worth/Itchen Stokes Down and Micheldever/Freefolk Wood. If all seven zones at these three locations were developed the turbines would deliver 54 GWh pa with a saving of 106 kilo tonnes of CO_{2e} emissions pa.

The study's conclusions have been based on the assumption that only one of these sites will be developed. If the Portsdown Hill site alone was developed the electricity generated from wind power would be 25.7 GWh pa and a CO_{2e} emissions reduction would be 15,242 tonnes pa.

Solar Photovoltaic

[11] About 127,000 of CO_2 equivalent per year

The report presents the case for a substantial number of photovoltaic (PV) installations on industrial and commercial roofs. It also identifies two large sites on the south facing elevations of hills that could accommodate arrays of $0.5km^2$.

Solar PV has the potential for 226 MW_p installed on existing buildings and 59 MW_p installed on ground mounted systems. This scale of PV installation is unlikely to be realised. It would require $2.5km^2$ of installation on non-domestic roofs, $2.1km^2$ of installations on domestic roofs and $1km^2$ of stand-alone installations. The calculations for domestic and non-domestic installations are based on the DECC methodology for assessing renewable and low carbon energy potential in a region (DECC/SQW Energy (2010)).

The programme recommended for Winchester District has focused on a more pragmatic target for delivery by end of 2015. This assumes that the focus should be on the highest concentration of roof space by Lower Level Super Output Area; based on land use statistics. This approach reduces the target for installation to 51 MW_p of installed capacity on existing buildings, and 29.5 MW_p of installed stand-alone capacity.

Another opportunity for stand-alone PV system installation that was not considered in detail but complements the approach of this report is to use closed landfill sites. These sites are typically not available for agriculture and are not ideal for construction of dwelling space. Installation of stand-alone PV would complement the co-location of AD hubs and landfill gas recovery schemes. This concept of multiple land use should be a priority when evaluating locations for large scale PV installations.

Solar Thermal

Solar thermal use will play a very small part in actions to deliver the Winchester Climate Change Programme but should be deployed as part of the Winchester West district energy network (DEN) and heating for the swimming pools (River Park, Kings School and the Winnall Swimming club).

Heat Pumps

Heat pumps offer an excellent alternative to heating buildings by oil, LPG (liquified petroleum gas) or electric resistance heaters. Three types of heat pumps should be considered. GSHP (ground source heat pumps) and ASHP (air source heat pumps) are sensible alternatives to heating domestic property with oil. This is a clear benefit in ground sourced systems on the basis of performance and the existing RHI incentive scheme. Gas engine driven air source heat pumps (GED ASHP) is an efficient alternative for large buildings with mains gas supplies.

Main conclusions

The study has identified:

- The availability of renewable fuel resources in the District.
- The technologies that should be used to convert them into the form of energy required.
- The locations of heat and power demand within the District.
- Where renewable energy conversion technologies could be located to give the best match between the fuel available and demand.

It is clear that renewable and low carbon energy resources exist and if deployed will reduce GHG emissions from within Winchester District by more than 100,000 tonnes pa. Harnessing these will enable the Climate Change Programme target for reduced GHG emissions to be achieved by 2015.

Specific communities within Winchester District could benefit by significant cost savings by switching from existing heating methods to heat supplied by mini, community or larger scale district energy networks.

Community ownership of large scale renewable or low carbon energy systems is a viable option to be considered when seeking to fund these developments.

Current levels of methane emissions in the Winchester District are a significant factor that should be addressed as part of the Climate Change Programme.

Main Recommendations

Further action should be undertaken to engage with stakeholders in Winchester District that could make available resources (in the form of land and/or finance) for the purpose of renewable or low carbon energy conversion.

A detailed plan should now be created for actions that will lead to the deployment of large scale renewable and low carbon energy conversion projects in the Winchester District.

The Climate Change Programme should invite the specific communities identified in this study to engage in dialogue about how community energy projects could be deployed.

This study has identified a number of opportunities to deploy renewable energy conversion technologies. This deployment should now commence. The opportunities are for:

- Three large scale wind farms.
- Ten community based CHP systems (fuelled from waste and/or bio-methane or energy crops).
- Six district heating networks (fuelled by waste and/or bio-methane), in addition to the two city centre district energy networks (DENs) currently being considered.
- 15 -30 hubbed AD plants centred in and around the main dairy and poultry farms to produce either power (on-site), or liquefied bio-methane for onward transport to CHP/district heating networks.
- Between two and three landfill gas capture plants in and around the closed landfill sites at Wickham and one shared development (with Eastleigh) at the still open Fair Oak landfill site.
- That consideration should be given for co-locating AD at landfill gas capture sites.
- A number of small scale 1 MW or below biomass fired power plants.
- 125 community based large scale >120kW solar PV installations, with an average size of 300kWp.

2 Contents

3 Introduction

Ecoup Ltd was instructed by WinACC to carry out a study with the objective of "identifying a prioritised presentation of specific measures that could be adopted in Winchester District to reduce GHG emissions". This study was funded by an award under the DECC LEAF programme and undertaken in March 2012. WinACC has been formally commissioned by Winchester City Council to manage the Winchester District Strategic Partnership Climate Change Programme in order to enable the District to deliver its target.

Winchester City Council has set itself the target of reducing GHG by 30% by 2015 (against a 2004 baseline). To date, emissions have fallen by 8.8%, however to reach the 2015 target a further reduction of 207 kilo tonnes of CO_{2e} [12] is required. WinACC estimate the 100 kilo tonnes of this reduction can be made by shifting from fossil-fuel to renewable energy sources over the next four years.

Significant progress has been made by WinACC and its partners in delivery of the Climate Change Programme. Many initiatives have been implemented, largely with a focus on behaviour change and insulation, resulting in substantial reductions to GHG emissions from Winchester District. The progress thus far can be summarised in Table 2:

Reductions Achieved & Yet To Deliver Kilo Tonnes CO		
2004 Baseline (Without M Roads)	976.7	KTonnes
Estimated 2011 Emissions	891.1	KTonnes
Actual saving Achieved		
Reduction in CO_2e emissions	85.6	KTonnes
As proportion of 2004 Baseline	8.80%	
Target Reduction		
Reduction in CO_2e emissions	293	KTonnes
As proportion of 2004 Baseline	30%	
Remaining Reduction (to deliver)		
Reduction in CO_2e emissions	207.5	KTonnes
As proportion of 2004 Baseline	21.20%	

Table 2: Summary of progress with Climate Change Programme[13]

3.1 Exclusions

WinACC have other programmes underway that are aimed at reducing GHG emissions from transport and from building retrofit/energy demand management. Therefore emissions reduction in these areas has been excluded from this study.

[12] CO_{2e} is CO_2 equivalent. GHG are a mixture of compounds that induce radiative forcing within the Earth's atmosphere. CO_2 is the main actor but other GHGs are also present. Methane (CH_4) and Nitrous Oxide (N_2O are the main other compounds. Emissions targets (under the Kyoto Treaty) are cited in terms of CO_{2e}.
[13] Sourced from WinACC

Preparation of a detailed business case for the solutions identified is beyond the scope of this study. Costs to implement have been established based on industry knowledge and dialogue with Original Equipment Manufacturers (OEMs) and installers but significantly influenced by DECC. These costs are presented as an indication of the relative merits rather than an absolute guide for budgets to implement one or more of the solutions presented.

3.2 The context

Energy is at the heart of all human activity; whether to drive the movement of electrons across a computer chip or a super tanker across the oceans. It is used to heat our homes, provide light, entertainment and sustenance. Energy is fundamental to all human activity.

However, in the UK 89% of all our energy is generated from the combustion of just three main types of fossil fuel (coal, gas and oil) (DECC 2012). The remainder is produced from renewable sources (4%) and nuclear (6%). And this combustion accounts for 82% of the UK's greenhouse gas (GHG) emissions.

Winchester is no different. The District requires some 3,500 GWh of energy[14] each year. This is used to meet its transport needs (46%), provide heat for its building & processes (33%) and power its electrical devices (19%).

The vast majority of this energy is derived from the combustion of oil, coal and gas.

Increasingly, there are a number of pressures on the UK energy supply system. We rely extensively on imported gas, coal and oil to fuel our energy requirements. Much of this fuel is sourced in regions of significant, and growing, geo-political uncertainty.

A combination of insecurity of supply and dwindling reserves has led to both increasing and unstable prices for fossil fuels.

There is now scientific consensus (and near political consensus) that the release of GHG has already caused significant levels of global warming. If unabated, the continued release of GHGs will have catastrophic effects on our atmosphere, seas and on the human race.

These three factors (energy security, increasing prices and climate change) have led to successive UK governments to conclude that the UK energy system must reduce its reliance on fossil fuelled energy. A number of financial incentives have also been introduced to encourage businesses, households and local authorities to de-carbonise its energy production. The current government has a legally binding target of meeting 15% of the UK's energy needs via renewable sources by 2020 and reducing our carbon emissions by 80% by 2050. It has also agreed to reduce emissions by 30% before 2020.

The Government has introduced a number of incentives and policies to ensure these targets are met.

[14] This is in terms of final demand for energy. A considerably greater amount of energy is required as a primary input to generate the energy required. The differences between final and primary demand is largely accounted for by thermal and distribution losses in electrical power generation.

At the heart of these incentives are feed-in-tariffs, which provide payments for the production of renewable electricity, and renewable heat incentives to encourage the production of heat from renewable sources. Feed-in-tariffs are already available. Heat incentives will become widely available for domestic installations from October this year and are already in place for commercial applications.

Many councils (and businesses) have, or are taking, advantage of these incentives. They have, or are, installing renewable technologies to generate energy for their own use in and on their own buildings. The councils with greatest foresight are investing in (or encouraging) larger scale schemes to provide energy in their local communities. These community energy schemes promise lower cost, more secure and de-carbonised energy supplies for local business and citizens.

An opportunity exists to take advantage of Government financial incentives to produce renewable energy within the Winchester District area. The incentives come in three forms:

1. Feed-in-tariffs paid for the production of electricity.
2. Renewable Heat Incentive paid for the production of heat.
3. Grants to pay for (partially or fully) the capital costs of installing such technology.

It is likely the largest incentives will come from the feed-in tariff (FiT) and renewable heat incentive (RHI).

4 Assessment method

This section describes in detail the processes and methods used to identify:

- where in the District there is demand for heat and power (at a resolution of approximately 500 – 1,000 households).
- the emissions this energy use creates (at a resolution of one kilometre squares and in terms of both CO_2 and CH_4).
- sources of renewable feedstocks in the District.
- technologies that should be used to convert the feedstocks into fuels and then the fuels into useable energy.
- locations of the conversion of feedstock into fuels and fuels into energy.
- potential costs of doing so.

Previous studies (eg LUC 2010) have indicated that there may be substantial resource of renewable feedstock in the District of Winchester. However little specific detail of what, and where, was made available.

This study established a process to identify the most desirable solutions that will reduce CO_{2e} emissions to the level required by Winchester's Climate Change Programme. The proposition was that the benefit of renewable energy sources would be more feasible (and acceptable) if deployed near points of significant demand. There were four stages to the study:

- Data collection on energy demand and GHG emissions by area.
- Review of renewable and low carbon energy technologies.
- Review of potential costs of deployment.
- Assessment of renewable resources in District in terms of feedstock, energy generation and GHG emission reductions.

Each stage is described below.

4.1 Data Collection

This comprised of secondary research and data mining to identify and quantify potential sites for further detailed assessment where load profile could reasonably be matched with a renewable energy source. Major sources of data included review of the Mid and Lower Super Output Area[15] data and the National Air Emissions Inventory Database for CO_2 and CH_4 emissions. Subsequent analysis of geographic locations at each 1km square with a significant emission burden was undertaken to identify a portfolio of loads within the District.

[15] MSOA and LSOA are the two of the three lowest levels of data collection by the Government. Broadly MSOA collects data at a sub-local authority level and LSOA at a sub-ward level. Not all statistics are disaggregated to this level, but many are including energy demand. GHG emissions data is disaggregated further to a resolution of 1km squares.

An additional review of data on relative deprivation for individual wards within the District was undertaken. The purpose of this stage of the study was to identify candidate neighbourhoods that might benefit from district heating installations. However, the main thrust of this investigation was to find areas that included daytime base loads for heat and power that are above normal domestic load profiles. The assumption that domestic loads for heat and power will normally peak in early morning and evening and reduce during the day was the basis of this analysis may not apply in areas of high deprivation index.

4.2 Technology Review

This stage reviewed the range of renewable energy technologies that might reasonably be deployed in the District.

It included a review of previous work DECC's Renewable Energy Strategy and 2050 Roadmap (DECC 2010), The Royal Academy of Engineering's study on low carbon energy (RAE 2010), The UK Energy Research Centre's report on de-carbonising the UK Energy Supply System (UKERC 2009), Centre for Alternative Technology's Zero Carbon Britain 2030 (CAT 2010), David Mackay's Sustainability without Hot Air (MacKay 2009), Land Use Consultants' Review of Renewable and Decentralised Energy Potential in South East England (LUC 2010). Some site visits were included and, where appropriate, consultation with a sample of key stakeholders and dialogue with other specialists equipment suppliers and installers.

Consultation took the form of telephone interviews and face to face meetings where they could be scheduled in the period of study. The main focus of this study centred on data searching and therefore site visits were kept to a minimum and only used where other access to data could not be arranged.

4.3 Costs and benefits

This stage assessed the likely costs of producing energy from the renewable sources identified. DECC has conducted a number of detailed studies into the likely costs of renewable energy generation[16] e.g. DECC (2011, 2011a) Mott MacDonald (2010). A number of these were reviewed and indicative assessments were made of the potential costs of electricity and heat technologies.

Where information relating to our study is in the public domain we have provided references. Other details that include intellectual property or sensitive data have been kept confidential but can be discussed with the authors on request.

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[16] Costs for renewable electricity are based on capital and operating costs, including fuel costs, provided by Arup (ARUP 2011) and Ernst & Young (E&Y 2011). Costs for CCGT are based on work by PB Power. Cost ranges are based on varying capital costs. Costs for 2020 for offshore wind reflect both Round 2 project and Round 3 projects/projects in Scottish Territorial Water projects, whereas the figures for 2010 reflect only Round 2. There is no data for marine in 2010 as the marine technologies which are of interest for 2020 have not yet been fully commercially deployed.

10 Cost ranges for heat are based on capital, borrowing, operating, fuel and barrier costs provided by AEA Technology to support development of the Renewable Heat Incentive.

The DECC Renewable & Low Carbon Energy Methodology (DECC/SQW (2010) has been at the core of our approach to this study. The assumptions in DECC's method are based on high level analysis at national level and therefore cannot be applied without scrutiny to the opportunity assessment for Winchester District. Where possible the assumptions have been tested and adjusted where we have found more locally appropriate information. In addition, and in light of more recent developments, we have assessed some renewable technologies that were not covered by the DECC method e.g. anaerobic digestion of poultry litter. The LUC (2010) report applied the DECC assumptions in most instances however when other data was available they have used other sources. For instance they have examined managed woodland and deployed all the wood harvested. It can be shown that the majority of wood harvested from managed woodland is currently and should be put to productive use however only the waste is used for biomass production.

The AEA (AEA 2010) report followed the DECC methodology but with changed assumptions based on their own sources of data. However they only looked at national level. It seems that it is generally accepted that the process defined by DECC in the Renewable & Low Carbon Energy Methodology is good but the variables are open to local adjustment. Key variables that have been adjusted in the preparation of this report relate to:

- Chicken litter productivity has been tested with local farmers to verify the rate in Winchester District.
- Chicken litter calorific value has been examined as a feedstock to Anaerobic Digestion along with conversion process efficiencies. Calculations in this report have assumed 25000T chicken litter equates to 2.1 MWe.
- Energy conversion Factors

5 Energy demand analysis by Super Output Area

The previous section described the process used in our analysis. This section describes the results of the geographic analysis of energy demand.

Super output areas are broadly based on the enumeration districts and contain about 20 -100 households. Data on energy use is collected at the super output area level by DECC. However results are published at a higher level. Lower level super output area (LLSOA) data consolidates data into areas broadly consistent with wards – where each ward will contain between 1 and 4 LLSOA. LLSOA data is further consolidated to a high mid-level (MLSOA data). The details presented in this section relate to data gathered for reporting national statistics. The highest level of data considered is the sub national data and this is subsequently compared with the MLSOA data and the LLSOA data for Winchester District.

5.1 Energy demand overview for Winchester District

DECC issues sub national level data for energy demand which can be used to provide a comprehensive view of energy use at sub-district level. This data is presented both in terms of energy demand, type of fuel and CO_{2e} emissions.

Figure 5 presents the overall distribution of demand for various energy sources:

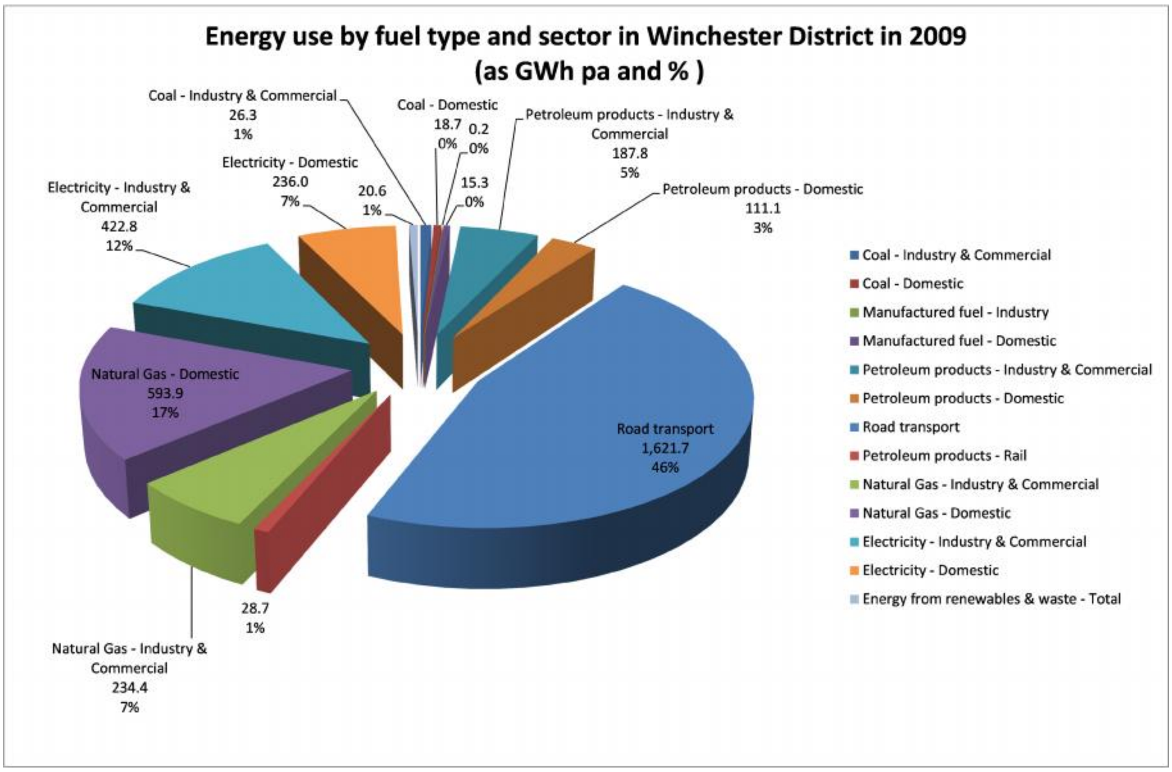


Figure 5 Energy use by fuel type and sector in Winchester District (2009 data set)

It is clearly seen that energy use for road transport is a significant part of the challenge in this District. The relatively small proportion of energy supply that is related to Industrial/commercial heat provides an indication that there is relatively little heavy, heat intensive industry in this District. The significant proportion that is accounted for by domestic heat, ranking in second place only to road transport, confirms the view that development of solar thermal and district energy networks is well justified. However, taken in the context of this study it is necessary to focus on CO_2 emissions rather than energy demand on its own.

Figure 6 demonstrates the proportions of energy use by the three main sectors in the District of Winchester:

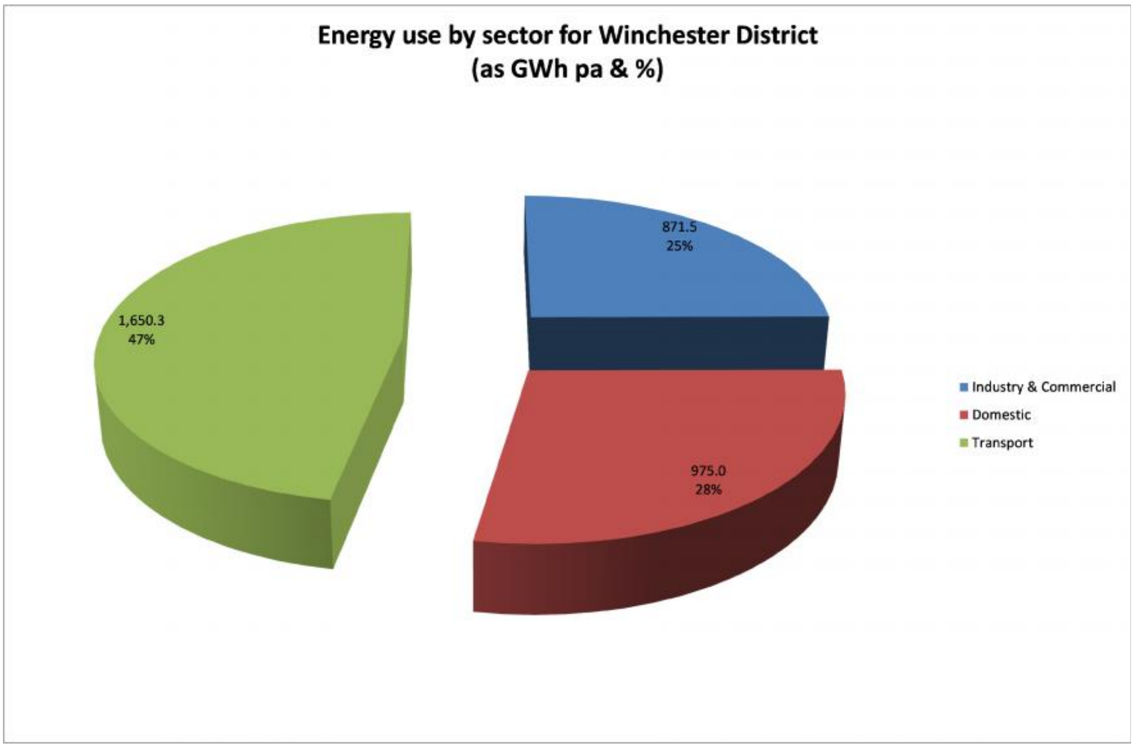


Figure 6: Energy use by sector in Winchester District

5.2 Natural Gas demand review (MLSOA data set)

Middle Layer Super Output Area Data from DECC was reviewed to provide a detailed indication on the distribution of energy demand within the District. The raw data was consolidated to provide a 'best fit' approximation by ward. However this data excludes the larger 'interval metered' electricity supplies. Therefore a high ratio of demand totals will be higher where large commercial/industrial electricity is concentrated in clusters.

Figure 7 clearly shows that there are two wards with a particularly high demand for natural gas. Winchester 007 is an area in the centre of the City of Winchester which represents the largest demand for natural gas in the District. 90% of the demand in this Super Output Area comes from St Michael ward and St Bartholomew ward with a further 10% found from St Paul ward. The proportion of each ward in this MLSOA is 79%, 55% and 19% respectively. The ratio of gas demand to electricity demand in this area is 2.8.

The second highest demand for heat comes from MLSOA Winchester 013. The demand in this area is much more evenly spread among four wards; Wickham ward 33%, Owslebury & Curdridge ward 26%, Whitley ward 26% and Shedfield ward 15%. The proportion of each ward in this MLSOA is 100%, 64%, 100% and 33% respectively. The ratio of gas demand to electricity demand in this area is 2.8.

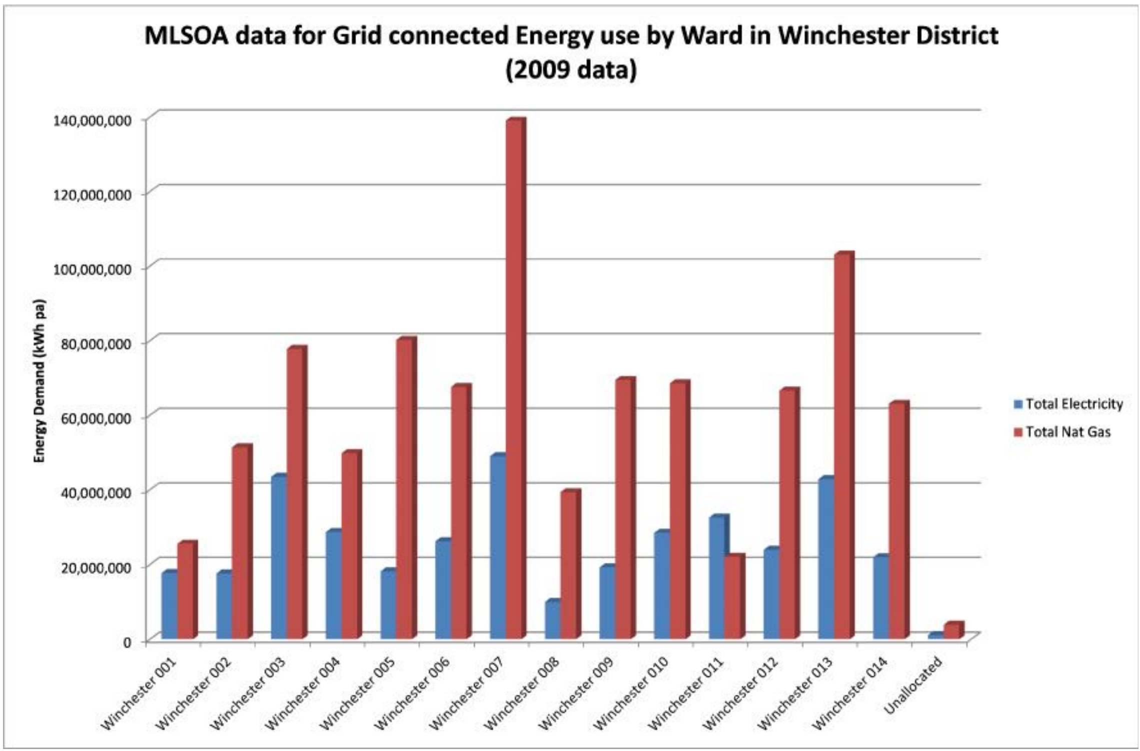


Figure 7: MLSOA data for Grid connected Energy use in Winchester by ward (2009)

The following areas are described as the 'second tier' which represents the band between 60GWh and 80GWh pa of heat demand. The highest heat demand in this tier is found in Winchester 005 which relates to the majority of St Barnabas and St Paul wards. It is likely that the metered energy supplies associated with this area include a significant proportion of those related to the Royal Hampshire Hospital, HM Prison and various University buildings. This area also has the highest ratio of demand totals; consistent with a concentration of >100KVA electricity supplies.

Also included in the second tier is Winchester 006 which includes all of St John & All Saints ward and some of St Bartholomew ward. This area might be considered as centred on Winnall and has a significant part devoted to an Industrial Estate/retail park; explaining the high natural gas demand.

Winchester 003 appears to be an area largely devoted to residential properties as indicated by the low ratio of demand totals. The high demand for natural gas in this area might reasonably be assumed to relate to poor thermal properties of the buildings. There may be an opportunity for a CHP to serve Sir John Moore Barracks (MoD), The Army Technical Foundation College (MoD), Flowerdown Care Home (Four Seasons) and Harestock Lodge Hotel. Sparsholt Agricultural College is included in this area.

Winchester 009 includes all of Oliver's Battery & Badger Farm ward but includes half of Compton & Otterbourne ward and part of St Luke ward. The ratio of demand totals is relatively high which may be a reflection of the large IMB facility at Hursley Park.

MLSOA Winchester 010, 012 & 014 all present a similar mix of domestic and industrial/commercial metered demands. Winchester 010 is the area to the North of Eastleigh including all of Colden Common & Twyford ward plus the Eastern half of Compton & Otterbourne ward and the North West part of Owslebury and Curdridge ward. Winchester 012 is the whole of Bishops Waltham ward and 75% of Shedfield ward. Winchester 014 is in the extreme South East of the District and includes all of Denmead ward and all of Boarhunt & Southwick ward.

Two areas (Winchester 001 and Winchester 011) have a high proportion of buildings not served by the mains gas network. Further consideration in later sections will inform the opportunities that could exist for CO_{2e} emissions reduction in these areas.

Table 3 presents the data supporting the fit between MLSOA and wards in the District. Each ward is divided into a substantial number of Output Areas but fuel and energy demand data was only available at the Super Output Area resolution.

Ward Name	Name for assigned MLSOA	MLSOA code	MLSOA Data #1	This code in Ward	Total codes in Ward	Assignment Certainty	Note	Total Nat Gas (kWh pa)	Total Electricity (kWh pa)	Ratio of demand totals Gas:Elec
Wonston and Micheldever Ward	Winchester 001	E02004829	Yes	16	16	100%	16/16 LOA codes in this ward	20,627,759	17,716,906	1.164
Kings Worthy Ward	Winchester 002	E02004830	Yes	13	13	65%	13 LOA codes in this ward	51,414,000	17,600,836	2.921
Itchen Valley Ward	Winchester 002	E02004830	Yes	7	7	35%	7 LOA codes in this ward			
Littleton & Harestock Ward	Winchester 003	E02004831	Yes	11	11	38%	11 LOA codes in this ward			
St Barnabas Ward	Winchester 003	E02004831	Other	5	19	17%	5/19 LOA codes in this ward	77,800,260	43,459,316	1.790
St Bartholomew Ward	Winchester 003	E02004831	Other	5	22	17%	5/22 LOA codes in this ward			
Sparsholt Ward	Winchester 003	E02004831	Yes	8	8	28%	8/8 LOA codes in this ward			
The Arelsfords Ward	Winchester 004	E02004832	Yes	21	21	75%	21 LOA codes in this ward	49,795,838	28,692,168	1.736
Cheriton and Bishops Sutton Ward	Winchester 004	E02004832	Yes	7	7	25%	7 LOA codes in this ward			
St Barnabas Ward	Winchester 005	E02004833	Yes	14	19	52%	14/19 LOA codes in this ward	80,206,233	18,149,207	4.419
St Paul Ward	Winchester 005	E02004833	Yes	13	16	48%	13/16 LOA codes in this ward			
St Bartholomew Ward	Winchester 006	E02004834	Other	5	22	19%	5/22 LOA codes in this ward	67,596,943	26,222,679	2.578
St John and All Saints Ward	Winchester 006	E02004834	Yes	21	21	81%	21 LOA codes in this ward			
St Bartholomew Ward	Winchester 007	E02004835	Yes	12	22	40%	12/22 LOA codes in this ward			
St Paul Ward	Winchester 007	E02004835	Other	3	16	10%	3/16 LOA codes in this ward	139,027,230	49,001,685	2.837
St Michael Ward	Winchester 007	E02004835	Yes	15	19	50%	15/19 LOA codes in this ward			
St Michael Ward	Winchester 008	E02004836	Other	4	19	24%	4/19 LOA codes in this ward	39,350,404	9,979,992	3.943
St Luke Ward	Winchester 008	E02004836	Yes	13	17	76%	13/17 LOA codes in this ward			
St Luke Ward	Winchester 009	E02004837	Other	4	17	17%	4/17 LOA codes in this ward			
Oliver's Battery and Badger Farm Ward	Winchester 009	E02004837	Yes	14	14	58%	14/14 LOA codes in this ward	69,460,791	19,243,806	3.610
Compton and Otterbourne Ward	Winchester 009	E02004837	Yes	6	12	25%	6/12 LOA codes in this ward			
Compton and Otterbourne Ward	Winchester 010	E02004838	Other	6	12	21%	6/12 LOA codes in this ward			
Colden Common and Twyford Ward	Winchester 010	E02004838	Yes	18	18	64%	18 LOA codes in this ward	68,567,223	28,477,518	2.408
Owslebury and Curdridge Ward	Winchester 010	E02004838	Other	4	11	14%	4/11 LOA codes in this ward			
Upper Meon Valley Ward	Winchester 011	E02004839	Yes	7	7	27%	7 LOA codes in this ward			
Droxford, Soberton and Hambledon Ward	Winchester 011	E02004839	Yes	6	6	23%	6 LOA codes in this ward	22,070,018	32,552,051	0.678
Swanmore and Newton Ward	Winchester 011	E02004839	Yes	13	13	50%	13 LOA codes in this ward			
Bishops Waltham Ward	Winchester 012	E02004840	Yes	21	21	72%	21 LOA codes in this ward	66,623,620	23,933,088	2.784
Shedfield Ward	Winchester 012	E02004840	Other	8	12	28%	8/12 LOA codes in this ward			
Owslebury and Curdridge Ward	Winchester 013	E02004841	Yes	7	11	26%	7/11 LOA codes in this ward			
Shedfield Ward	Winchester 013	E02004841	Other	4	12	15%	4/12 LOA codes in this ward			
Whiteley Ward	Winchester 013	E02004841	Yes	7	7	26%	7 LOA codes in this ward			
Wickham Ward	Winchester 013	E02004841	Yes	9	9	33%	9 LOA codes in this ward	103,088,789	42,851,927	2.406
Denmead Ward	Winchester 014	E02004842	Yes	20	20	80%	20 LOA codes in this ward			
Boarhunt and Southwick Ward	Winchester 014	E02004842	Other	5	5	20%	5 LOA codes in this ward	63,072,989	19,683,784	3.204

Table 3: Overview of annual energy demand by MLSOA with ward detail shown

5.3 Natural gas demand review (LLSOA data set)

The domestic natural gas demand was reviewed by LLSOA dataset as shown in Table 4

	HEADING	All People	Area (Hectares)	Density (Persons/Ha)							
	MEASUREMENT_UNIT	Count	Hectares	Rate							
	STATISTICAL_UNIT	Persons	Areas	Persons			2009 Natural Gas demand data for domestic properties				
LSOA_NAME	Wards partially or completely within this MLSOA	SAPF 2011 DATA VALUE	2001 Census DATA VALUE	2001 Census DATA VALUE	LSOA_CODE	LSOA code assignment to gas demand data	Domestic gas consumption	Domestic gas number of meters	Average domestic gas consumption per meter	Average people per gas meter	Average annual gas demand per person
Winchester 001A	Wonston & Micheldever Ward	1461	2963	0.43	E01023286						
Winchester 001B		2997	525	5.37	E01023287	E01023288, E01023287	17,706,182	1,043	16,976	3.83	4145.676
Winchester 001C		1274	4250	0.28	E01023288	merged					
						unallocated	99,845	9	11,094		
Winchester 002A	Kings Worthy Ward & Itchen Valley Ward	1877	7271	0.25	E01023236	E01023236	10,868,242	438	24,813	4.13	5790.219
Winchester 002B		1248	43	25.15	E01023237	E01023237	6,123,017	516	11,866	2.09	4906.264
Winchester 002C		1606	696	2.06	E01023238	E01023238	8,590,600	539	15,938	2.66	5349.066
Winchester 002D		1650	156	9.8	E01023239	E01023239	10,766,496	595	18,095	2.57	6525.149
						unallocated	716,272	71	10,088		
Winchester 003A	Littleton & Harestock Ward, St Barnabas Ward, St Bartholomew Ward, & Sparsholt Ward	2368	78	29.43	E01023240	E01023240	14,107,287	892	15,815	2.58	5957.469
Winchester 003B		1572	446	3.37	E01023241	E01023241	9,535,797	456	20,912	3.29	6066.029
Winchester 003C		1670	67	22.05	E01023248	E01023248	11,895,468	634	18,763	2.34	7123.035
Winchester 003D		1541	103	14.4	E01023253	E01023253	9,826,884	667	14,733	2.23	6376.953
Winchester 003E		1840	3671	0.49	E01023274	E01023274	7,825,633	342	22,882	5.24	4253.061
						unallocated	280,755	18	15,598		
Winchester 004A	The Alresfords Ward & Cheriton and Bishops Sutton Ward	2214	6484	0.33	E01023225	E01023225	237,646	15	15,843	142.53	107.338
Winchester 004B		1561	47	31.59	E01023278	E01023278	10,259,086	651	15,759	2.30	6572.124
Winchester 004C		1469	72	20.9	E01023279	E01023279	10,049,130	590	17,032	2.54	6840.796
Winchester 004D		1638	2910	0.53	E01023280	E01023280	4,296,737	254	16,916	6.06	2623.161
Winchester 004E		1653	98	15.19	E01023281	E01023281	12,536,962	791	15,850	1.88	7584.369
						Unallocated	592,068	62	9,550		
Winchester 005A	St Barnabas Ward & St Paul Ward	1649	60	24.81	E01023247	E01023247	10,350,454	568	18,223	2.61	6276.807
Winchester 005B		1199	35	31.95	E01023249	E01023249	7,236,972	443	16,336	2.51	6035.840
Winchester 005C		1718	37	39.33	E01023250	E01023250	8,930,499	668	13,369	2.15	5198.195
Winchester 005D		1260	26	47.5	E01023268	E01023268	9,166,124	486	18,860	2.52	7274.702
Winchester 005E		2471	169	12.23	E01023269	E01023269	8,926,385	502	17,782	4.13	3612.459
Winchester 005F		1645	25	65.99	E01023270	E01023270	7,063,987	463	15,257	3.57	4294.217
						Unallocated	1,461,364	140	10,438		
Winchester 006A	St Bartholomew Ward & St John and All Sants Ward	1288	35	36.82	E01023251	E01023251	5,608,745	484	11,588	2.64	4354.616
Winchester 006B		1456	59	25.67	E01023255	E01023255	8,188,353	678	12,077	2.23	5623.869
Winchester 006C		1457	64	22.84	E01023256	E01023256	5,375,009	491	10,947	2.97	3689.093
Winchester 006D		1515	33	46.57	E01023257	E01023257	8,593,476	605	14,204	2.57	5672.261
Winchester 006E		1529	184	8.17	E01023258	E01023258	7,156,349	515	13,896	2.92	4680.411
						Unallocated	151,543	15	10,103		
Winchester 007A	St Bartholomew Ward, St Paul Ward & St Michael Ward	1832	23	57.65	E01023252	E01023252	9,878,332	779	12,681	1.67	5392.103
Winchester 007B		1807	43	32.62	E01023254	E01023254	10,225,818	709	14,423	1.99	5659.003
Winchester 007C		1637	59	24.45	E01023263	E01023263	10,579,671	587	18,023	2.48	6462.841
Winchester 007D		1565	93	16.63	E01023264	E01023264	10,634,908	587	18,117	2.62	6795.468
Winchester 007E		1674	194	7.79	E01023265	E01023265	12,945,967	789	16,408	1.91	7733.553
Winchester 007F		1474	28	42.54	E01023267	E01023267	8,272,989	549	15,069	2.15	5612.611
						Unallocated	846,971	84	10,083		
Winchester 008A	St Michael Ward & St Luke Ward	1269	19	67.6	E01023260	E01023260	5,377,507	450	11,950	2.84	4237.594
Winchester 008B		1506	32	48.67	E01023261	E01023261	7,396,992	627	11,797	2.52	4911.681
Winchester 008C		1257	26	49.92	E01023262	E01023262	6,346,909	497	12,770	2.66	5049.251
Winchester 008D		1727	48	30.98	E01023266	E01023266	10,766,448	522	20,625	2.88	6234.191
						Unallocated	119,768	10	11,977		
Winchester 009A	St Luke Ward, Oliver's Battery and Badger Farm Ward & Compton and Otterbourne ward	1965	4408	0.42	E01023229	E01023229	12,314,999	552	22,310	3.37	6267.175
Winchester 009B		1339	27	46.81	E01023242	E01023242	6,274,867	494	12,702	2.56	4686.234
Winchester 009C		1333	33	37.03	E01023243	E01023243	5,010,734	538	9,314	2.28	3758.990
Winchester 009D		1516	109	14.06	E01023244	E01023244	12,321,742	651	18,927	2.36	8127.798
Winchester 009E		1353	84	16.91	E01023259	E01023259	9,987,731	549	18,193	2.57	7381.915
						Unallocated	197,644	17	11,626		
Winchester 010A	Compton and Otterbourne Ward, Colden Common and Twyford Ward & Owslebury and Curdridge	1593	1272	1.14	E01023226	E01023226	12,094,758	610	19,828	2.39	7592.441
Winchester 010B		1848	410	3.94	E01023227	E01023227	9,974,578	702	14,209	2.31	5397.499
Winchester 010C		2098	280	7.36	E01023228	E01023228	12,091,338	745	16,230	2.77	5763.269
Winchester 010D		2240	465	4	E01023230	E01023230	16,302,484	749	21,766	2.49	7277.895
Winchester 010E		1458	3691	0.38	E01023246	E01023246	139,156	6	23,193	233.50	95.443
						Unallocated	771,339	64	12,052		
Winchester 011A	Droxford, Soberton & Hambledon Ward, Upper Meon Valley Ward & Swanmore and Newton Ward	2071	4091	0.47	E01023235	E01023276	9,246,630	510	18,131	3.75	4464.814
Winchester 011B		1496	775	1.81	E01023275	E01023277, E01023275	7,512,976	411	18,280	3.75	5022.043
Winchester 011C		1624	174	8.45	E01023276						
Winchester 011D		1183	1486	0.79	E01023277	merged					
Winchester 011E		1978	5579	0.33	E01023282						
						Unallocated	525,117	39	13,465		
Winchester 012A	Bishop Waltham Ward & Shedfield Ward	2212	202	9.51	E01023220	E01023220	11,067,687	789	14,028	2.43	5003.475
Winchester 012B		1690	354	4.59	E01023221	E01023221	9,108,643	684	13,317	2.37	5389.730
Winchester 012C		1532	1169	1.3	E01023222	E01023222	8,597,742	480	17,912	3.17	5612.103
Winchester 012D		1554	254	5.85	E01023223	E01023223	7,681,353	568	13,524	2.61	4942.956
Winchester 012E		1400	108	12.62	E01023272	E01023272	7,388,030	483	15,296	2.81	5277.164
Winchester 012F		1424	239	5.87	E01023273	E01023273	9,168,205	520	17,631	2.70	6438.346
						Unallocated	871,358	100	8,714		
Winchester 013A	Owslebury and Curdridge Ward, Shedfield Ward, Whiteley Ward & Wickham Ward	2358	2199	0.98	E01023245	E01023245	12,282,107	606	20,268	3.55	5208.697
Winchester 013B		1143	676	1.7	E01023271	E01023271	5,791,240	327	17,710	3.52	5066.702
Winchester 013C		3151	595	3.69	E01023283	E01023283	14,981,400	1,138	13,165	1.93	4754.491
Winchester 013D		2897	972	1.21	E01023284	E01023284	12,996,657	849	15,308	1.39	4486.247
Winchester 013E		1579	562	2.57	E01023285	E01023285	7,127,399	545	13,078	2.64	4513.869
						Unallocated	1,922,700	138	13,933		
Winchester 014A	Denmead Ward & Boarhunt and Southwick Ward	1649	3065	0.62	E01023224	E01023224	1,344,613	97	13,862	19.70	815.411
Winchester 014B		1735	793	1.93	E01023231	E01023231	10,519,902	568	18,521	2.69	6063.344
Winchester 014C		1900	752	2.06	E01023232	E01023232	9,806,848	560	17,512	2.77	5161.499
Winchester 014D		1577	67	22.9	E01023233	E01023233	8,772,284	611	14,357	2.52	5562.640
Winchester 014E		1661	35	44.99	E01023234	E01023234	8,130,525	633	12,844	2.48	4894.958
						Unallocated	509,752	42	12,137		
						Unallocated	3,136,575	300	10,455		
									16173.468	Mean	5336.789
									3302.464	Std Dev	1591.439
								> V High Alarm	22778.40	V High Alarm	8519.67
								HA>x<VHA	19475.93	High Alarm	6928.23
								< Low Alarm	12871.00	Low Alarm	3745.35
									9568.54	V Low Alarm	2153.91

Table 4: Assessment of domestic gas demand at LLSOA resolution

The review of LLSOA data identified potential locations for additional district energy network (DEN) installations. The method of analysis was simply to assign LLSOAs to wards and enable better visualisation of gas demand distribution in the District. This method was able to identify locations where natural gas demand per head of population was low and areas where gas demand per meter was high.

The primary benefit of this method was to identify areas that are not well served by mains gas or where demand density is higher than normal. These locations may offer potential for small district heating system that could be fuelled by bio-mass.

It can be readily seen that the following areas are not served with a comprehensive mains gas supply. Data to convert LLSOA areas to specific post codes was not available to the authors of this study. Therefore, LLSOA names have been listed with the associated wards. These are::

1. LLSOA Winchester 001A (part of Wonston & Micheldever ward) – 532 houses are not connected to mains natural gas.
2. LLSOA Winchester 004A (part of Cheriton & Bishops Sutton Ward) – 806 houses are not connected to mains natural gas.
3. LLSOA Winchester 010E (part of Owslebury and Curdridge ward) - 532 houses are not connected to mains natural gas.
4. LLSOA Winchester 011C (part of Swanmore and Newton ward) – 591 houses are not connected to mains natural gas.
5. LLSOA Winchester 011E (part of Upper Meon Valley ward) – 720 houses are not connected to mains natural gas.
6. LLSOA Winchester 014A (part of Boarhunt and Southwick ward) - 600 houses are not connected to mains natural gas.

An assumption has been made that the mean population per household is approximately 2.75. This was calculated by excluding outlying data and calculating the mean with the remaining figures for people per gas meter in each area. This constant was then used to estimate the number of households that are currently running on solid fuel or oil that could benefit from a district energy network or heat pump installations. We applied a similar method to determine the heat load per household at 14,651kWh pa. With this method we have estimated that 3,190 homes could benefit from a low carbon or renewable source of heat and reduce demand from non-renewable sources by 46GWh pa. This is a potential opportunity, if switched to a bio fuel from oil, of 15.5kT CO_2e reduction.

It is also possible to compare with the total demand for natural gas in a given area and thus ascertain the source of anomalies. It can be seen that there are no exceptionally high domestic demands for natural gas in the Lower Levels of Winchester 005 (St Barnabas ward & St Paul ward). On that basis it may be reasonable to assume the high gas demand observed from the MSLOA data is related to the municipal commercial buildings in that area.

5.4 Electricity demand review (MLSOA data set)

Middle Layer Super Output Area data from DECC exclude data for interval metered electricity supplies. Therefore all industrial/commercial electricity supplies with capacity above 110kVA will be excluded. For that reason analysis of this data was not thought helpful for this study.

The more inclusive data set from National Air Emissions Inventory data was selected as the preferred dataset for electricity demand analysis. This approach enables an assessment of electricity demand by 1km square which includes the larger, interval metered supplies.

5.5 Electricity demand review (LSOA data set)

Analysis of Electricity demand using the LSOA data set was not undertaken as part of this report. This data is a higher resolution version of the MLSOA dataset that only applies to domestic supplies. For that reason it was decided that little value would be gained from reviewing this detail in the context of main objectives to be delivered by this study.

6 Other indicators

Section 5 gave a clear indication of the demand for heat and power within the District and the location of that demand. The following section provides an analysis of the GHG emissions this demand creates. Data was available to enable GHG emissions to be identified at a resolution of individual kilometre squares (see Figures 7 and 8).

The review of MLSOA and LLSOA data for energy use was insufficient to establish the distribution of demand within Winchester District with a high degree of certainty and resolution. A key feature of this study was to establish whether it would be possible to site renewable energy conversion engines (heat or power) close to sources of demand. Integrating renewable or low carbon energy installations near existing sites (or 1km squares) with similar power or heat demands may be an effective method to reduce infrastructure costs associated with these installations.

Further analysis at a higher level of resolution was undertaken with a view to resolving the most significant locations for energy intensity. The National Air Emissions Inventory data set for 2009 is recognised as the source data for many other National Indicators. This was a logical source for the more detailed analysis of demand.

An assessment of fuel poverty and the Index of multiple deprivations was undertaken. It was anticipated that this would detect areas with building of low thermal performance, low incomes (increased residence at home) and high cost fuels. The focus for this report was cost and demand, level of oil fired heating (expensive to run) or high unemployment (prolonged weekday heating periods).

It is recognised that there have been a number of relatively recent developments that would remain undetected by the national data. An example is the building of the new Tri-Service Food Wing at Worthy Down military base. Large quantities of food waste are produced in this training facility. All of the food produced for training purposes is currently composted which could be diverted as a feedstock to a central hub AD plant. It is also noted that increased utilisation of accommodation for personnel, and equipment use (ovens, refrigeration and extract fans) will have increased CO_{2e} emissions to some extent in the District since 2009.

6.1 Greenhouse Gas Emissions from Winchester District

A number of indicators and statistics are published for GHG emissions in the area. The main ones are:

- Local Authority carbon dioxide Figures that provide estimates on CO_2 emissions from each LA in the UK from the domestic, commercial and industrial and transport sectors but exclude large point sources of emissions.
- Carbon dioxide emissions within the scope of influence of local authorities (previously NI 186) which is a sub-set of the total CO_2 emission dataset and only includes emissions

that are deemed (by DECC) to be influenceable by the local authority which also includes point sources.

- The National Atmospheric Emissions Inventory Database which contains data on all greenhouse gas emissions by area (including methane and Nitrous Oxide).
- Emissions by 1 km squares compiled from the UK's National Atmospheric Emissions Inventory Database.

Our data search was limited to methane and CO_2 emissions as this selection accounts for 96% of the GHG emissions in the District.

There are a well-known number of discrepancies between the data sets [17] however the underlying source of data is the NAEI database but the differences are small (less than 5%). Where possible this is the data used in this study.

For Winchester (2009) the LA emissions are recorded as 1,083 kilo tonnes of CO_2, the old NI 186 emissions as 868.5 kilo tonnes and the NAEI figures as 1,078 kilo tonnes (including point sources).

However it is also important to note that CO_2 only accounts for 85% of the greenhouse gas emissions in the UK. Methane is the other main contributor and when considering GHG reductions methane must be considered. In 2009 the NAEI database recorded methane emissions from Winchester at 5,071 tonnes. Methane is a potent GHG and is 25[18] times more effective as a GHG than CO_2. Thus 5,071 tonnes of methane is equivalent to approximately 126,000 tonnes of CO_2 (or about 11%) of the District's emissions.

The 2011 GHG emissions conversion factors have been applied to the energy data presented above. These are summarised, in as much as they relate to this report, and are presented in Table 5 below:

2011 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting			
Form of energy delivery	Factor		
Coal - Industry & Commercial	0.39824	kg/kWh	
Coal - Domestic	0.41303	kg/kWh	
Manufactured fuel - Industry	0.41127	kg/kWh	Coke
Manufactured fuel - Domestic	0.41127	kg/kWh	
Petroleum products - Industry & Commercial	0.34740	kg/kWh	Gas Oil
Petroleum products - Domestic	0.33255	kg/kWh	Fuel Oil
Petroleum products - Rail	0.34740	kg/kWh	
Natural Gas - Industry & Commercial	0.22419	kg/kWh	
Natural Gas - Domestic	0.22419	kg/kWh	
Electricity - Industry & Commercial	0.59368	kg/kWh	'Consumed' rate
Electricity - Domestic	0.59368	kg/kWh	'Consumed' rate
Biomethane	0.09755	kg/kWh	
Energy from renewables & waste - Total	0.09755	kg/kWh	
Factor for reporting CH_4 emissions as CO_2e	21		

Table 5: CO_{2e} factors for converting demand data to emissions profiles

[17] See http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/uk_emissions/2009_laco2/2009_laco2.aspx for a detailed discussion on local authority area emissions datasets
[18] IPCC (2007)

As an initial step to demonstrate consistency of data sources these factors have been applied to the energy demand data presented in Figure 5 in section 5.1 of this report. The result is presented in Figure 8 as a version of the sub national data set. This compares well with the data from NAEI which is presented in Figure 9 with slight variations in category names and bundles.

Therefore this study has also assessed the impact of renewable technology on methane emissions within the District. The sources of methane emissions in Winchester are presented in Figure 10

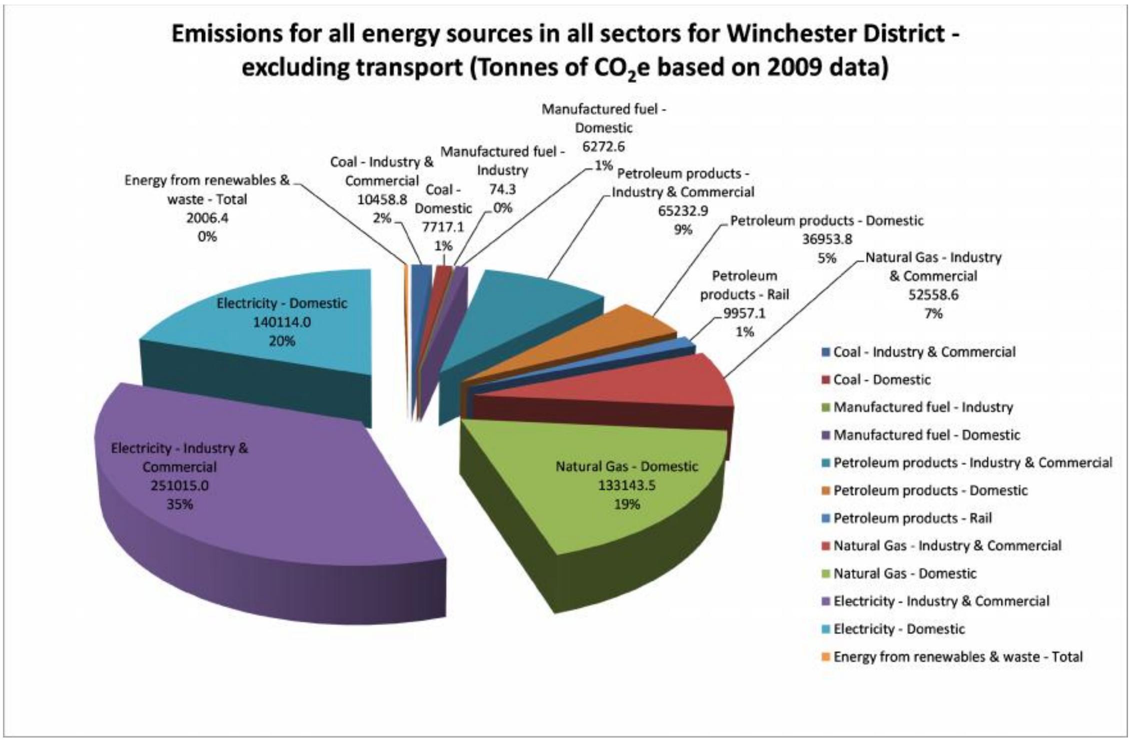


Figure 8: Overview of the CO_{2e} emissions for Winchester District based on Sub National data

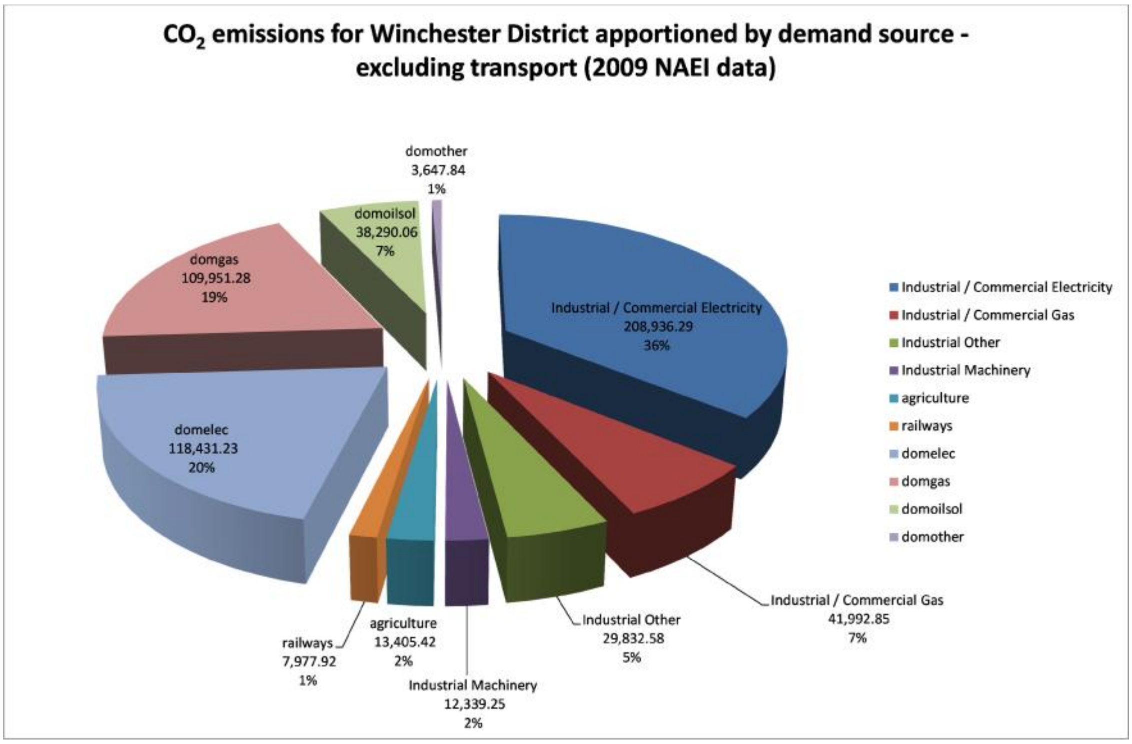


Figure 9: CO2 emissions for Winchester District based on NAEI data

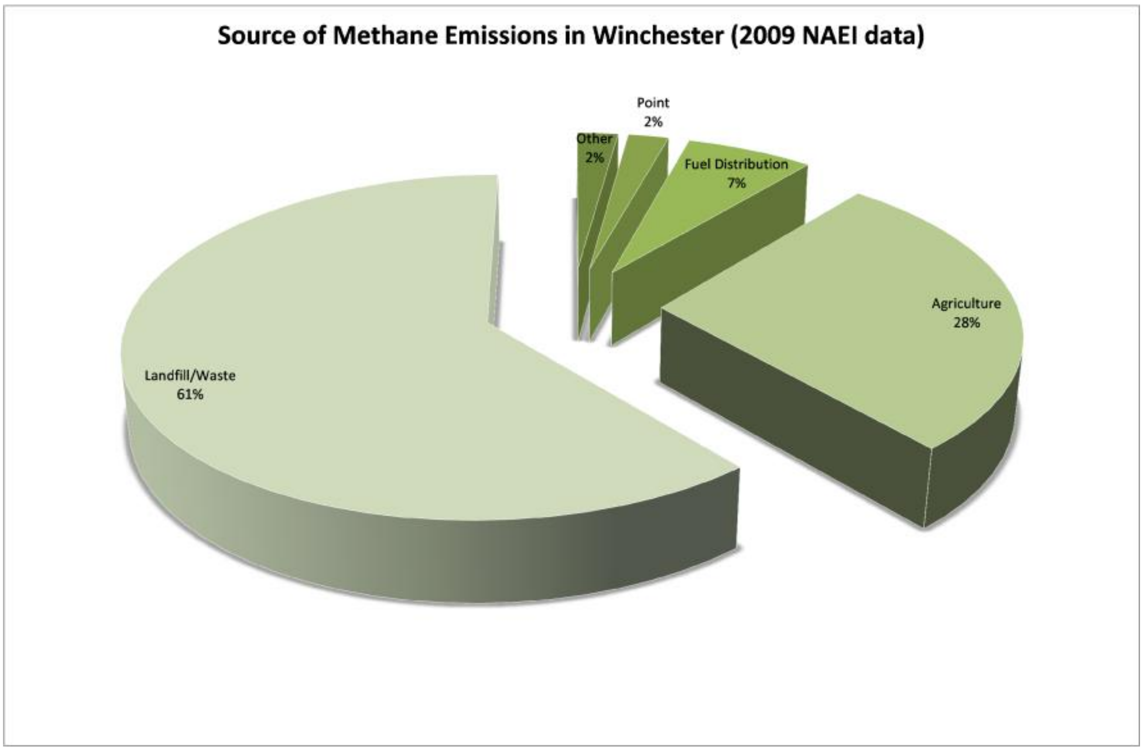


Figure 10: Source of methane (CH_4) emissions in Winchester

Figure 10 clearly shows that emissions from landfill and waste is the largest contributor to methane emissions[19] (equivalent to 77,600 tonnes of CO_2), agricultural accounts for a further 35,100 $CO_{2e.}$

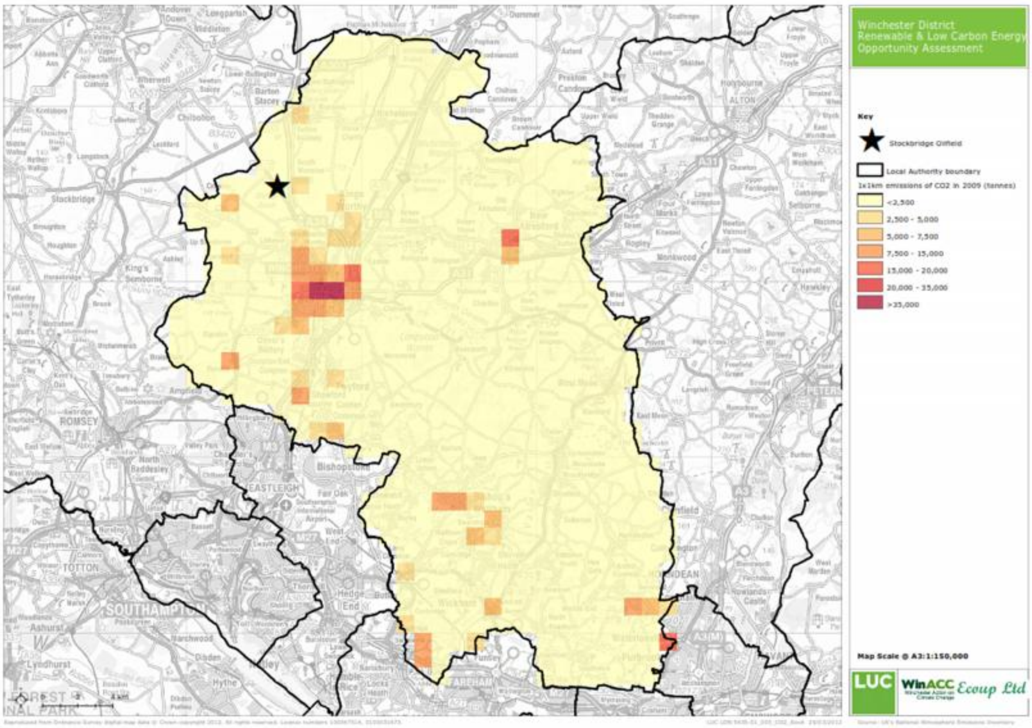
Figure 9 shows the largest contribution to CO_2 emissions arises from Commercial & Industrial demand for electricity. This assessment supports the need for large scale renewable or low carbon electricity generation. It can also be clearly seen that CO_2 emissions as a consequence of commercial and industrial heat demand from natural gas are at a much lower level. Emissions from domestic heat and power demand are much more closely matched. It can also be seen that the demand for domestic heating oil and industrial other (solid fuels, oils, process gases and non-fuel emissions) represent a significant proportion of the total.

A total of 208 ktonnes CO_{2e} emissions are accounted for by Industrial/Commercial electricity demand in Winchester District, based on 2009 data. This data reconciles well with the NI186 data produced by DECC and used in WinACC's management of the Climate Change Programme. If this entire supply could be met by generation from renewable or low carbon sources the Climate Change Programme target could be achieved. This scale of generating demand would be satisfied (or offset) with an average 40 MW_e of continuous generation from renewable sources. This study has assessed the top ten $1km^2$s for total CO_{2e} emissions to consider whether it is likely that on-site generating capacity from renewable sources could satisfy 50% of that demand.

The most likely solutions for generating from renewable sources at sites of high electrical demand were considered to be from Photovoltaic arrays or CHP (running on biomass or biofuels). On that basis roof areas within the sample of ten one kilometre squares were measured (approximately) for dimension and orientation. The proximity of large roofs to potential heating loads was considered. Initial assessment of local topography and proximity to domestic dwellings indicated that these sites were not favourable for deployment of wind

[19] These emissions are largely from the natural anaerobic digestion of landfill waste, and animal manures and enteric methane emission from livestock. Baggot et al, (2005) estimate about 80% of agricultural emissions are from enteric emissions.

turbines. The 1km square data for CO_2 emissions has been plotted on a map of Winchester



District (

Figure 11) to enable a quick review of the focal points for action. This plot is based on the NAEI data that has been used a source of reference for this study.

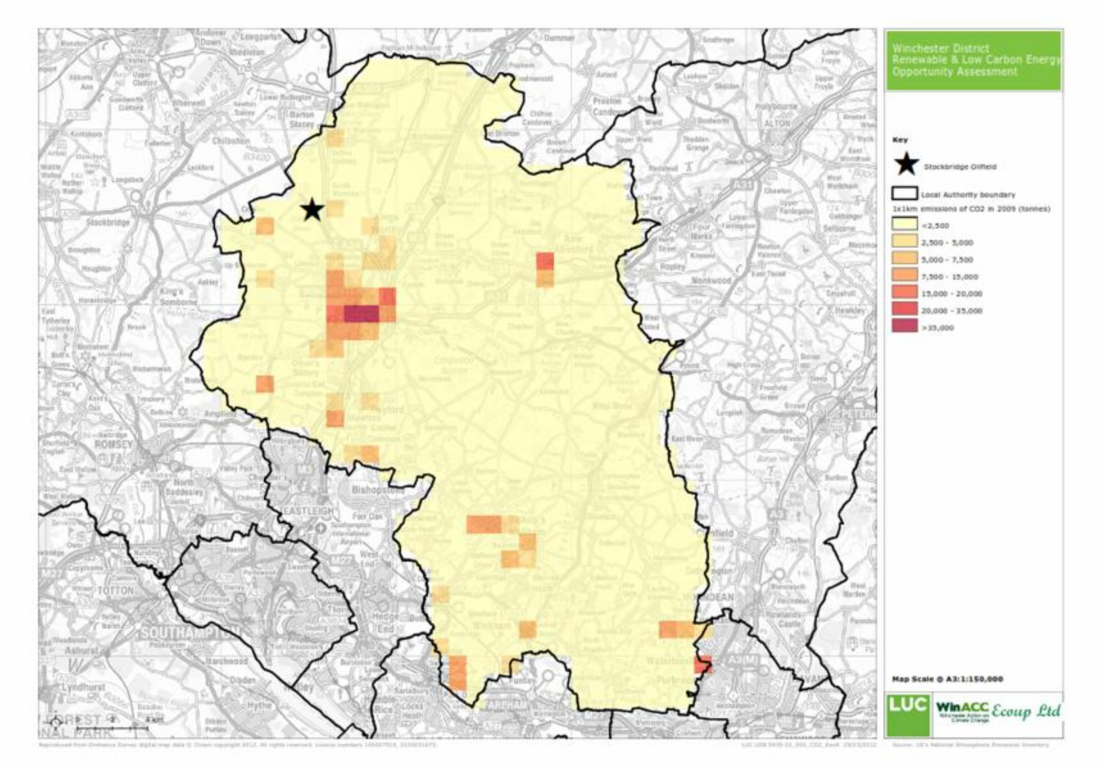


Figure 11: Map of CO_2 emissions for Winchester District at $1km^2$ resolution

The location of the top ten 1km squares was identified as an initial sift for potential onsite generation of renewable or low carbon energy solutions. The results from this search are presented in Table 6 and Table 7.

CO_{2e} emissions rankings	Location description	Mapping references	Notes on CO_{2e} emissions rankings in common categories & a sample of potential loads in this area (based on nearest postcode)
1	North & West of Peninsula Square: Hospital, Prison & University, City of Winchester		Highest level of commercial / industrial demand for natural gas and power (based on LSOA and 1km square emissions data). Also highest for domestic gas and 2nd highest for domestic electricity
		OS X (Eastings) 447499	Macklin House Romsey Road, WINCHESTER, SO22 5HG
		OS Y (Northings) 129500	University of Winchester, Sparkford Road campus
		Nearest Post Code SO22 5HG	Royal Hampshire County Hospital
	51.062879,-1.323545	Lat (WGS84) N51:03:46 (51.062879)	HM Prison Winchester
		Long (WGS84) W1:19:25 (-1.323559)	St Pauls Medical Practice, Alison Way
		LR SU474295	Winchester Sports & Spine, Alison Way
		mX -147337	Westgate School, Cheriton Road
		mY 6599167	King Alfred's College & West Downs Student Village
			HCC office complex
			Peninsula Square
			Stuart Crescent, The Valley & The Battery, Stanmore
2	Centred on Friars Gate, City of Winchester		2nd Highest level of commercial / industrial demand for natural gas and power (based on LSOA and 1km square emissions data). Also 2nd highest domestic gas and highest domestic electricity use.
		OS X (Eastings) 448499	Hampshire & I O W Practitioner & Patient Services Authority, Coitbury House, Friarsgate, WINCHESTER SO23 8EE
		OS Y (Northings) 129500	Sainsburys Supermarket
		Nearest Post Code SO23 8EE	Iceland Food
	51.062796,-1.309276	Lat (WGS84) N51:03:46 (51.062796)	Winchester School of Art, Park Avenue
		Long (WGS84) W1:18:33 (-1.309290)	St Bedes School, Park Avenue
		LR SU484295	River Park Leisure Centre, King Alfred Terrace
		mX -145749	Winchester Guildhall
		mY 6599152	The Royal Hotel, St Peters Street
			Winnall Primary School, Garbet Road
			Pilgrims School, College Street
3	Wellington Gate, Silverthorne Way, Waterlooville (industrial estate)		5th highest commercial / industrial power 7th highest industrial / commercial demand for natural gas in a 1km square. Also highest for CO_2 emissions from other industrial sources (solid fuels, oils, process gases and non fuel emissions)
		OS X (Eastings) 467500	Cobra Installations, Unit C, Wellington Gate Silverthorne Way, WATERLOOVILLE, PO7 7XY
		OS Y (Northings) 109500	Hi Tech Mouldings Ltd, Tyak House, 4 Silverthorne Way, WATERLOOVILLE, PO7 7XY
		Nearest Post Code PO7 7XY	Serco, Unit A, Wellington Gate Silverthorne Way, WATERLOOVILLE, PO7 7XY
	50.881059,-1.041885	Lat (WGS84) N50:52:52 (50.881059)	Unit B, Wellington Gate Silverthorne Way, WATERLOOVILLE, PO7 7XY
		Long (WGS84) W1:02:31 (-1.041885)	Virgin Media, Unit C, Wellington Gate Silverthorne Way, WATERLOOVILLE, PO7 7XY
		LR SU675095	Business Park Including Horizon Leisure centre, Waterberry Drive, Waterlooville, Hampshire, PO7 7UW
		mX -115982	
		mY 6567110	
4	Winnall Industrial Estate & Junction 9 of M3		3rd highest commercial / industrial power 3rd highest industrial / commercial demand for natural gas in a 1km square. Also 2nd highest for CO_2 emissions from other industrial sources (solid fuels, oils, process gases and non fuel emissions)
		OS X (Eastings) 449500	Tesco Superstore, Easton Lane, Winchester, Hampshire, SO23 7RS
		OS Y (Northings) 130500	Hants & IoW Constabulary, Moorside Road
		Nearest Post Code SO23 7UD	Winchester Trade Park
	51.071702,-1.294870	Lat (WGS84) N51:04:18 (51.071702)	Winnall Primary School, Garbet Road
		Long (WGS84) W1:17:42 (-1.294870)	Mooreside Road Industrial Estate
		LR SU495305	Winchester Delivery Office , Winnall Manor Road, Winchester, Hampshire, SO23 0AA
		mX -144144	
		mY 6600725	
5	1km Square centred approximately on Bath Place; North West of Royal Hampshire county Hospital; Chilbolton Avenue at approximately 250m North of Sarum Road.		3rd Highest demand for domestic heating oil (equates to 944 Tonnes CO_{2e} pa)
		OS X (Eastings) 446500	Tegfield House, 24 Chilbolton Avenue, WINCHESTER, SO22 5HD
		OS Y (Northings) 129500	BMI Sarum Road Hospital, Sarum Road, Winchester, Hampshire, SO22 5HA (48 Beds)
		Nearest Post Code SO22 5HD	Kings School, Romsey Rd Winchester SO22 5PN (including swimming pool)
	51.062961,-1.337814	Lat (WGS84) N51:03:47 (51.062961)	Hampshire Trading Standards, Monarch Way Winchester SO22 5PW
		Long (WGS84) W1:20:16 (-1.337814)	
		LR SU465295	
		mX -148924	
		mY 6599181	

Table 6: Part 1 of the top ten areas for CO_{2e} emissions (ranking 1 to 5)

CO_{2e} emissions rankings	Location description	Mapping references	Notes on CO_{2e} emissions rankings in common categories & a sample of potential loads in this area (based on nearest postcode)
6	1km square centred approximately on Perins School and the Watercress line, Alresford		9th highest commercial / industrial power 8th highest industrial / commercial demand for natural gas in a 1km square. Also 3rd highest for CO2 emissions from other industrial sources (solid fuels, oils, process gases and non fuel emissions)
		OS X (Eastings) 458500	Perins School, Pound Hill Alresford, Hampshire SO24 9BS
		OS Y (Northings) 132500	E Williams Plating, 3 The Dean New Alresford, Hampshire SO24 9BQ
		Nearest Post Code SO24 9BS	Alder & Alan, The Huxley Centre Unit 3, The Dean, New Alresford, Winchester, Hampshire. SO24 9BQ
	51.088839,-1.166105	Lat (WGS84) N51:05:20 (51.088839)	IQPFS, The Dean, Alresford, Hampshire SO24 9BQ
		Long (WGS84) W1:09:58 (-1.166105)	
		LR SU585325	
		mX -129810	
		mY 6603754	
7	Peter Symonds College		10th Highest level of commercial / industrial power & 5th highest for commercial / industrial demand for natural gas (based on LSOA and 1km square emissions data) Also 8th highest for domestic electricity and 5th highest for domestic gas.
		OS X (Eastings) 447500	Peter Symonds College, Owens Road, Winchester, Hampshire. SO22 6RX
		OS Y (Northings) 130500	Lanterns Nursery School and Children Centre, Bereweeke Road, Winchester. SO22 6AJ
		Nearest Post Code SO22 6AJ	The Westgate School, Cheriton Road, Winchester. SO22 5AZ
	51.07187,-1.323414	Lat (WGS84) N51:04:19 (51.071870)	
		Long (WGS84) W1:19:24 (-1.323414)	
		LR SU475305	
		mX -147321	
		mY 6600755	
8	Mixed industrial and residential loads that straddle Railway & M27 East of Junction 9		7th highest commercial / industrial power 6th highest industrial / commercial demand for natural gas in a 1km square. Also 5th highest for CO_2 emissions from Industrial off road machinery.
		OS X (Eastings) 453500	ITV Meridian Fusion 3 1200 Parkway Whiteley Hampshire PO15 7AD
		OS Y (Northings) 108500	
		Nearest Post Code PO15 7JD	
	50.873531,-1.241014	Lat (WGS84) N50:52:25 (50.873531)	
		Long (WGS84) W1:14:28 (-1.241014)	
		LR SU535085	
		mX -138149	
		mY 6565785	
9	Bishops Waltham town centre		10th highest Industrial / commercial demand for natural gas. 10th highest demand for domestic gas. Industrial / commercial power demand is relatively high (compared with natural gas) but outside top 10 rankings. No other clear cause of high overall ran
		OS X (Eastings) 455500	
		OS Y (Northings) 117500	
		Nearest Post Code SO32 1AL	
	50.954266,-1.211226	Lat (WGS84) N50:57:15 (50.954266)	
		Long (WGS84) W1:12:40 (-1.211226)	
		LR SU555175	
		mX -134833	
		mY 6580002	
10	Stanmore Lane area. 1 km square due south of area ranked 5th for $CO_{2}e$ emissions		3rd highest domestic electricity use and 4th highest domestic gas use. Also 10th highest for industrial / commercial other (solid fuels, oils, process gases and non fuel emissions); perhaps St Lukes Church is heated with oil for a few hours per week.
		OS X (Eastings) 446500	St Lukes Church, Mildmay St, Winchester SO22 4BX
		OS Y (Northings) 128500	Hampshire Trading Standards, Monarch Way Winchester SO22 5PW
		Nearest Post Code SO22 4DB	
	51.053969,-1.337942	Lat (WGS84) N51:03:14 (51.053969)	
		Long (WGS84) W1:20:17 (-1.337942)	
		LR SU465285	
		mX -148939	
		mY 6597593	

Table 7: Part 2 of the top ten areas for CO_{2e} emissions (ranking 6 to 10)

Reviewing areas with highest GHG emissions acts as a cross reference to verify project priorities in the context of this study. This data will confirm which projects might have the most positive impact in reducing CO_2 equivalent emissions. This data is inclusive of electricity demand covered by half hourly interval metered supplies.

The 1km square data for CH_4 emissions has been plotted on a map of Winchester District to enable a quick review of the focal points for action. This plot is based on the NAEI data that has been used a source of reference for this study.

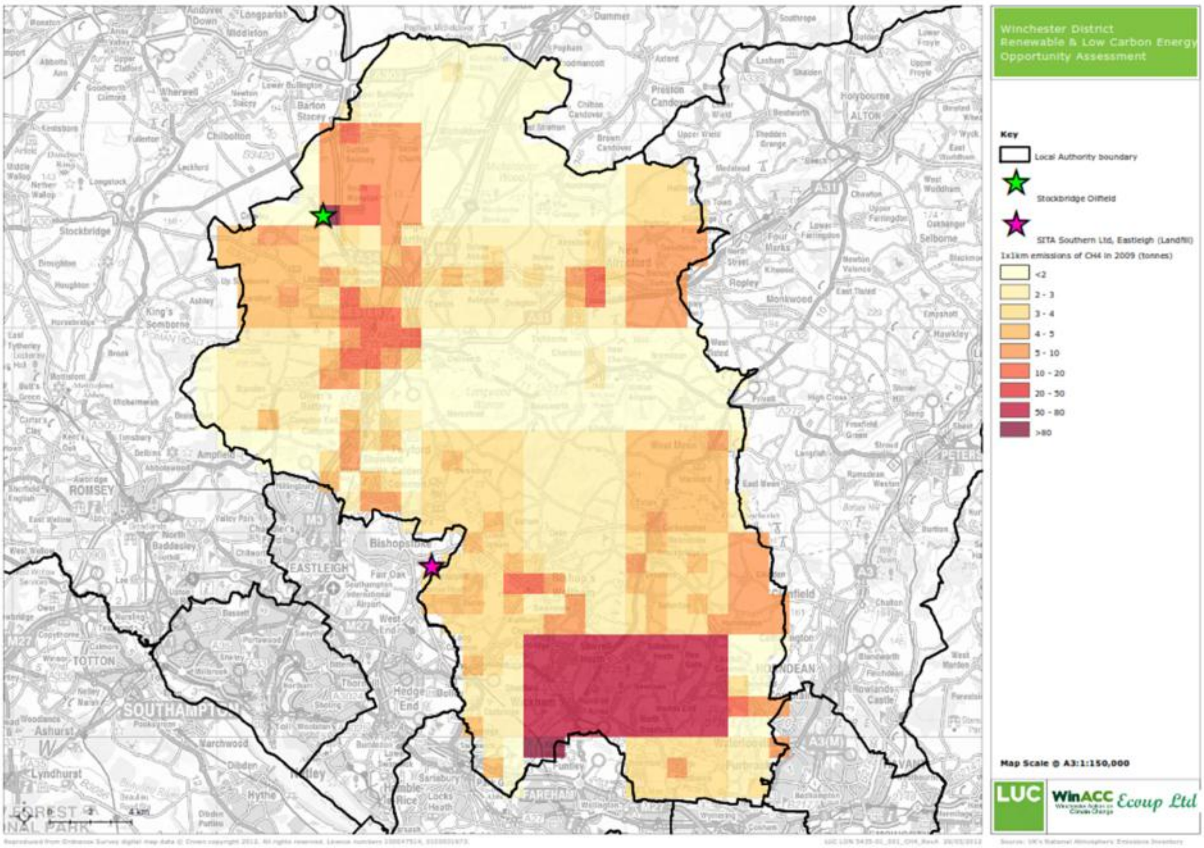


Figure 12: Map of CH_4 emissions for Winchester District at $1km^2$ resolution

Figure 12 clearly identifies the scale of the landfill opportunity within Winchester District. The data is presented as total CH_4 emissions for each $1km^2$ but the most significant contribution in the red area is that from closed landfill sites. Additional point loads are marked as a star with the blue star indicating Eastleigh landfill site and the yellow star marking Stockbridge Oilfield; emissions are very high from these two point sources. Other areas of dense emissions are accounted for by emissions from agricultural waste and indicate potential sites for AD.

6.2 Fuel poverty data review by ward

Fuel poverty statistics estimate the number of households that need to spend more than 10 per cent of their income on fuel to maintain a satisfactory heating regime, as well as meeting their other fuel needs (lighting and appliances, cooking and water heating).

A high level assessment of each location with a relatively high population of fuel poor households was undertaken to evaluate suitability for building district energy networks (DEN). A minority of the fuel poor areas are adjacent to the sites being considered by Hampshire County Council for municipal CHP installations and district energy networks. These locations may present an opportunity / justifiable business case for extending the range of the DENs under consideration based on a potential benefit for the Climate Change Programme.

The purpose of this review is to identify other factors that might be considered to influence the case for renewable or low carbon energy solutions. The count of fuel poor households can be used to inform the scale of opportunity for implementation of a community heating programme. A ward with a high count of fuel poor households but only a small percentage of the total households in fuel poverty may present a good opportunity for a DEN funded by community share issue or other funds. Such a scheme might have the central plant located in a community building (school or hall) with a central boiler system fuelled on biomass (solid, gas or liquid). If a number of these 'mini' or community DENs were possible, the method could make a sensible contribution to the Climate Change Programme target.

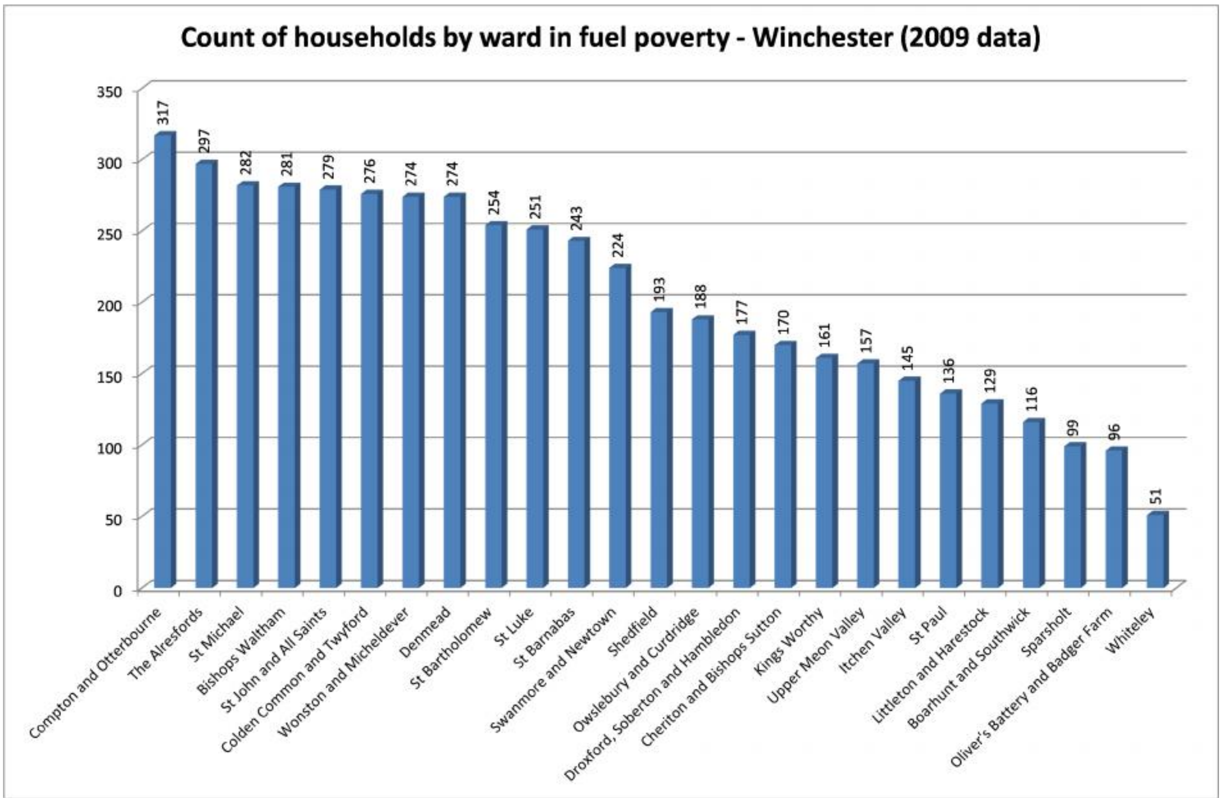


Figure 13: Count of fuel poor households per ward (2009 data)

The motivation for financiers or members of the community to invest would need to pass the same scrutiny of any other green investment. The motivation for customers to change their source of heating would probably be driven by cost. The key to the success of such a project would be the right population density of customers at the start of the project or a single large heat load with a few local residents adding to the portfolio. It would be very important to ensure that the distribution mains were sized for the anticipated network capacity rather than the initial adopters.

The count of fuel poor households per ward in Figure 13 was compared with the proportion per of fuel poor households per ward in Figure 14. This highlighted St Bartholomew ward and St John & All Saints wards as areas that could have potential as areas with a high domestic heating load; 27,634 households at 14,651 kWh each pa. Inclusion of these wards to the proposed DEN (running on biofuel) would have the potential to reduce CO_{2e} emissions by 4.3 kilo tonnes pa. Initial concept footprint for the East Winchester DEN show that only part of the St John and All Saints ward are included.

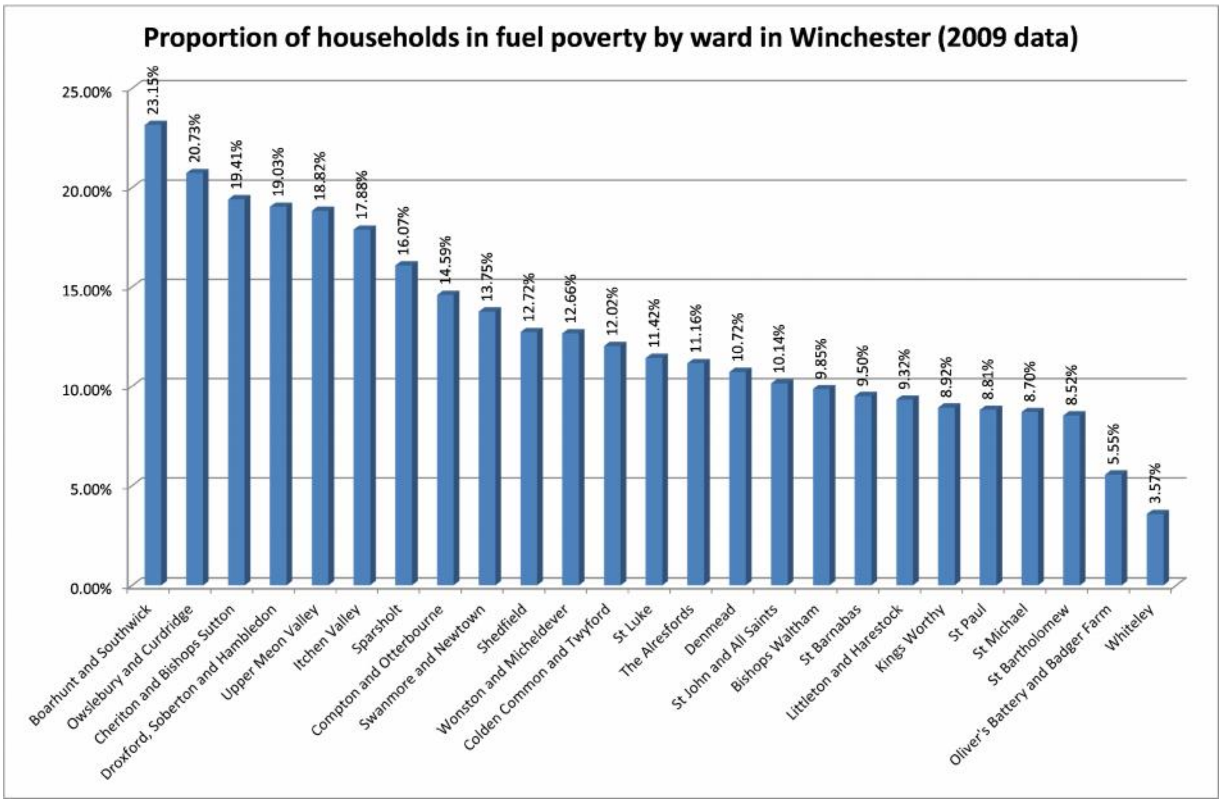


Figure 14: Fuel poor households as a percentage of total by ward (2009 data)

This method was less effective at highlighting areas that are not served by the mains gas network. This is because at ward level there is often a mix of Output Areas that are connected along with those that are not. Areas that are served exclusively by biomass, coal, LPG and oil for heating seem to be in the minority within Winchester District. Converting these areas to heating with alternative sources of fuel (biofuel, GSHP etc) on an individual or community based scale would reduce GHG emissions.

Increasing the scale of such an undertaking to adopt district heating networks with a central plant will increase the complexity and initial capital investment required. However, if appropriate communities can be identified, this type of approach could qualify for the existing (commercial systems) RHI. A heating network that serves more than one domestic property is considered to be a commercial system.

The five areas where the mains natural gas supply is poor or not available should be considered in detail for local DENs. In total these areas contain 3,782 households but it is not clear how many of these are currently heated with oil.

Winchester 011E, 011C and 001A represent 1,844 without mains natural gas supply and may be candidates for a DEN with biomass as a fuel source. We have again applied a limit of 50%

engagement in such a scheme based on technical limitations and an average heat demand of 14,651kWh pa per household Table 4 in section 5.3). This equates to a potential demand of 13.5GWh pa that could be met by 100% renewable fuel sources from three community DENs with a total capacity of around 4 MW. This would deliver approximately 3 kilo tonnes pa of CO_{2e} emissions.

Reflecting on the data in Table 8 highlighted that the majority of fuel poverty in Winchester District does not align with excessive demand for natural gas. The data demonstrates that demand for natural gas in the areas with highest proportion of fuel poor households is fairly typical for the District. It is not possible to know from the data whether these households are heating to a reasonable level of comfort but demand for gas per meter is not excessive. It seems likely that many in these areas will benefit from the introduction of the GREEN DEAL later in 2012. Improving the thermal performance of these properties may be a constructive method to reduce fuel poverty but it is beyond the scope of this study.

#	LSOA Code	LSOA Name	STwardname	All Households	Fuel Poor Households	Percent Fuel Poor	Average mains gas demand per meter point (kWh)	Availability of mains gas supply
1	E01023245	Winchester 013A	Owslebury and Curdridge	907	188	20.7%	20267.50	Good
2	E01023235	Winchester 011A	Droxford, Soberton and Hambledon	930	177	19.0%	18130.60	Good
3	E01023225	Winchester 004A	Cheriton and Bishops Sutton	876	170	19.4%	15843.10	Poor
4	E01023284	Winchester 013D	Wickham	1,080	163	15.1%	15308.20	Good
5	E01023282	Winchester 011E	Upper Meon Valley	834	157	18.8%	0.00	None
6	E01023236	Winchester 002A	Itchen Valley	811	145	17.9%	24813.30	Good
7	E01023224	Winchester 014A	Boarhunt and Southwick	501	116	23.2%	13862.00	Poor
8	E01023229	Winchester 009A	Compton and Otterbourne	806	116	14.4%	22309.80	Good
9	E01023246	Winchester 010E	Compton and Otterbourne	602	109	18.1%	23192.70	Poor
10	E01023228	Winchester 010C	Colden Common and Twyford	912	108	11.8%	16230.00	Good
11	E01023286	Winchester 001A	Wonston and Micheldever	571	102	17.9%	0.00	None
12	E01023274	Winchester 003E	Sparsholt	616	99	16.1%	22882.00	Not good
13	E01023280	Winchester 004D	The Alresfords	599	99	16.5%	16916.30	Not good
14	E01023226	Winchester 010A	Colden Common and Twyford	664	97	14.6%	19827.50	Good
15	E01023285	Winchester 013E	Wickham	660	95	14.4%	13077.80	Good
16	E01023277	Winchester 011D	Swanmore and Newtown	516	94	18.2%	18279.70	Good
17	E01023230	Winchester 010D	Compton and Otterbourne	764	92	12.0%	21765.70	Good
18	E01023232	Winchester 014C	Denmead	593	91	15.3%	17512.20	Good
19	E01023281	Winchester 004E	The Alresfords	775	91	11.7%	15849.50	Good
20	E01023288	Winchester 001C	Wonston and Micheldever	563	91	16.2%	16976.20	Not good
			Totals	14,580	2,400			

Table 8: Top 20 fuel poor LSOAs in Winchester showing mains gas supply availability

Winchester 011C has a relatively low level of fuel poverty but no mains gas supply. This may imply an opportunity for a reasonable capacity DEN serving 560 houses. We might assume a limit of 50% engagement in such a scheme based on technical limitations and an average heat demand of 14,651kWh pa per household (as per LLSOA analysis in section 5.3). A system of this capacity would avoid the combustion of oil or LPG in the order of 4.1GWh pa and approximately 1kTonne of CO_{2e}. If the system were to supply 1.5 MW of capacity for 280 households, the average heat available per household would be just 5.3kW which relates to houses in the order of 75m^2 based on 70W/m^2. The reality in this area is that houses may be larger and less energy efficient and therefore the system capacity may need to be twice or three times the size indicated here if peak loads are to be satisfied.

It may be considered optimistic that each of these systems would achieve a 50% take up rate in the community. In reality it is more likely that nearer 25% of the available households might adopt the DEN scheme. If a household has the option of connecting to mains gas it would be cheaper for the householder to invest in a new condensing boiler than the necessary hardware for a DEN connection, supply pipework, valves and heat exchanger. It is also an unfamiliar approach in the UK and for domestic applications.

The data indicates that there are two types of community that could benefit from a DEN. The rural communities that are currently heated with electricity or oil and those on low income in more densely populated areas adjacent to proposed DENs. This study has also identified the area of Winnall that is adjacent to a large proposed DEN but could be considered as the basis of a new system that serves an industrial/retail area and domestic customers.

6.3 Index of Multiple Deprivation

The study has considered many factors that may influence perceptions about alternatives to accepted norms for heating buildings in the UK. The Index of Multiple Deprivation may provide an indicator of areas where building occupancy (and by implication heating periods) may be longer than average. On that basis, these areas might benefit more from community CHP with district heating projects. This data set is more likely to highlight influences additional to building fabric thermal efficiency and fuel price relative to income.

This study assumes that areas with a high ranking in the Index of Multiple Deprivation (IMD) will be more likely to have higher domestic building utilisation and therefore higher fuel based load for heat and DHW. On that basis the potential to connect to a local DEN may have additional social and economic benefit that although beyond the scope of this report may prove to be valuable in the business case.

Most areas in Winchester District are not featured among the most deprived wards in England.

	Location name	Post Code	Ward	Estimated LLSOA	Ranking (out of 32,482)
1	Battery Hill & The Valley, Stanmore.	SO22 4DN	St Luke Ward	Winchester 009A	9,069
2	Imber Road, Winnal	SO23 0NY	St John & All Saints Ward	Winchester 006D	9,611
3	Stuart Crescent & Cromwell Road, Stanmore	SO22 4AE	St Lukes Ward	Winchester 008D	13,340
4	Trussell Crescent & Fromond Rd, Weeke	SO22 6EF	St Barnabas Ward	Winchester 003E	15,120
5	Sussex St to Princes Bldgs,	SO23 8AS	St Michael Ward	Winchester 007D	15,965

Table 9: Five most deprived OAs in Winchester by the Multiple Deprivation Index

Table 9 lists a number of sites within the City of Winchester that could be served by either of the two DENs under consideration. Extending the district energy network to include these sites would impose additional financial and technical strains on the project but may be justified in terms of CO_{2e} emissions benefits. The distance from either end of the Stanmore estate to the nearest DEN hub would be approximately 500m and therefore represents a viable extension. Connection points that might be considered are:

Zone 1a

1. Hampshire Trading Standards, Monarch Way, SO23 OAA – feeding to Battery Hill / Thurmond Crescent
2. University of Winchester, Sparkford Road Campus – feeding to Cromwell Road & Stuart Crescent

Zone 1b

3. The City of Winchester Fire station – feeding Winnall Primary School area

Connecting Winnall to the DEN Zone 1b would not be without complications. There is a small river to cross and a network of small roads and houses to negotiate. An alternative may be to install a third network in the Winnall Business Park and feed the school and local dwellings from there. This option might consider the Post Office, Tesco or the Primary School as a potential location for the heat (and power) engine.

7 Technologies – in the context of the District of Winchester

The previous two sections have given detailed insight to the District's demand for energy and its GHG emissions. And this has to be done at a detailed (at a sub-ward and kilometre square resolution). The following section describes the feedstocks available within the District and the technologies that can be used to either convert them into an intermediate fuel or directly into power and/or heat.

The DECC Renewable & Low Carbon Energy Methodology (DECC/SQW (2010) was used as the basis to quantify potential for renewable and low carbon energy sources in Winchester District. Where sufficient primary source data was not available secondary sources were used. In those instances the data was available for Hampshire and therefore the following details were used to scale the opportunity in Winchester.

Land area information for Winchester District	661	km^2
Land area information for Hampshire (County)	3,679	km^2
Proportion of Hants in Winchester district	18.0%	
Number of Dwellings in Winchester District	49,549	Dwellings
Number of Dwellings in Hampshire (County)	760,570	Dwellings
Proportion of Hants in Winchester district	6.5%	
Population (2012 forecast) in Winchester District	117,488	People
Population (2012 forecast) in Hampshire (County)	1,304,844	People
Proportion of Hants in Winchester district	9.0%	

Table 10: Scale comparison from Hampshire to Winchester District

7.1 The National Context

The UK Government has European and National legally binding targets to generate 15% of its energy needs from renewable sources by 2020. DECC, the Committee on Climate Change and numerous other organisations have gathered evidence on the potential deployment and costs of renewable energy technologies to 2020. As DECC states in its UK Renewable Energy Roadmap (DECC 2011)

> *"This has allowed us to understand how, and with which mix of technologies, the market can deliver 15% of our energy consumption from renewable sources by 2020".*

DECC analysis indicates that approximately 90% of the generation necessary to meet the 15% target can be delivered from a subset of 8 technologies (set out in Figure 2 below). These technologies are particularly significant "due to their cost effectiveness, potential level of deployment, and importance to the UK's 2050 energy mix".

Figure 2: Technology breakdown (TWh) for central view of deployment in 2020

	Central range for 2020 (TWh)
Onshore wind	24-32
Offshore wind	33-58
Biomass electricity	32-50
Marine	1
Biomass heat (non-domestic)	36-50
Air-source and Ground-source heat pumps (non-domestic)	16-22
Renewable transport	Up to 48TWh
Others (including hydro, geothermal, solar and domestic heat)	14
Estimated 15% target	234

Table 11: DECCs view of renewable energy sources 2020 (2011)

DECC (and others e.g. Mott 2010, AEA (2011) Arup (2011), E&Y 2011) have also examined the potential cost effectiveness of alternative technologies. Their findings are neatly summarised in the following two graphs.

Figure 5: Projected levelised cost ranges for electricity technologies in 2020

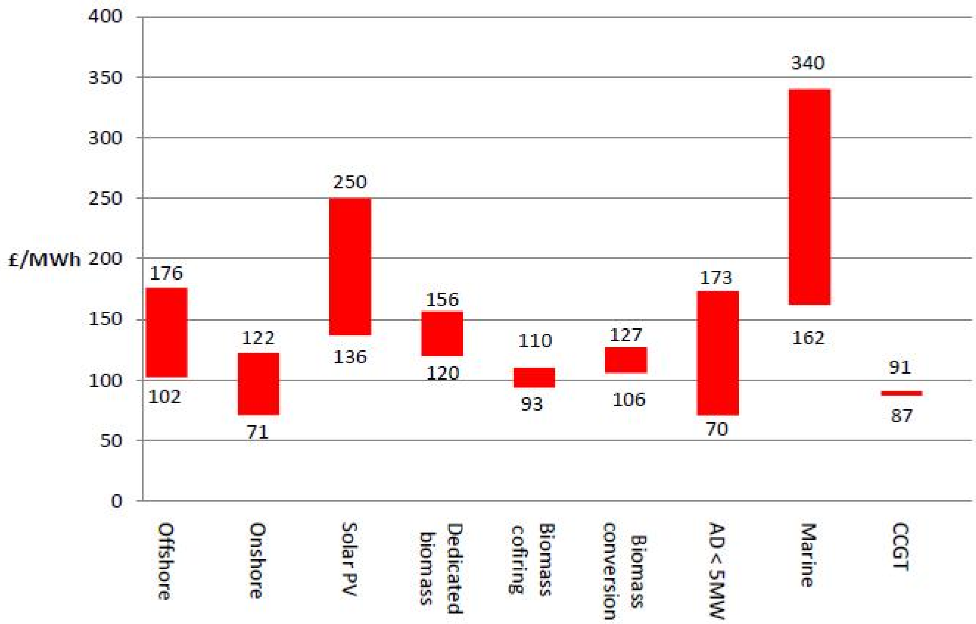


Figure 15 Range of costs per MWh for renewable electricity technologies. Source DECC (2011)

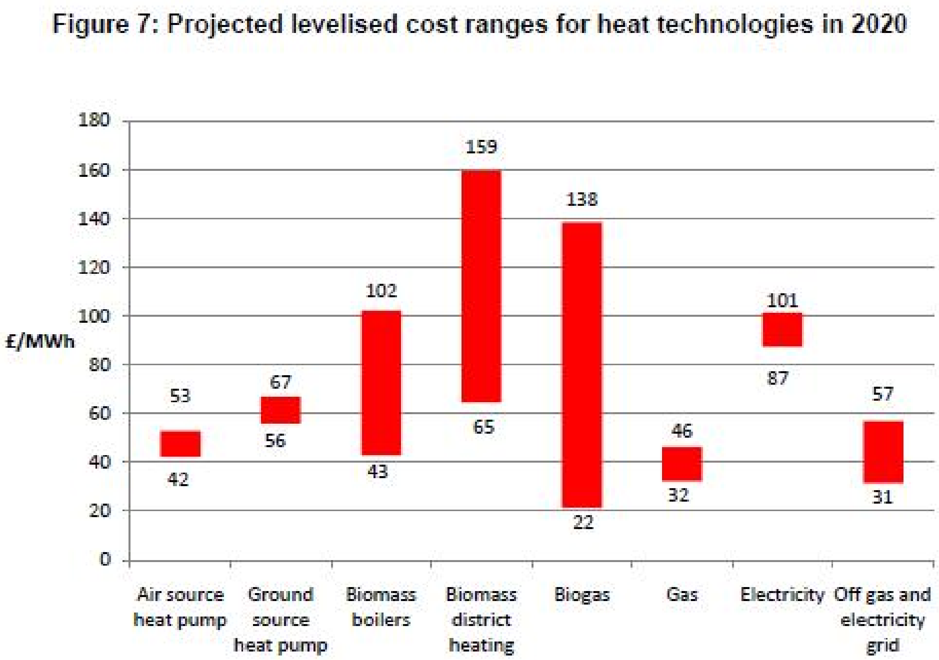


Figure 16 Range of costs per MWh for renewable heat technologies 2020

Whilst DECC has taken a national perspective it is highly likely that the same technologies, and for the same reasons, will be the ones available for deployment in Winchester. Indeed it's also very likely that it is these eight technologies that will attract Government support and financial incentives. It is for this reason that this report is limited to a sub-set of these eight.

It is clear that off-shore wind and marine technology will have no role to play in Winchester and renewable transport is outside the scope of this report. Based on this we only consider the following as suitable renewable energy technologies for the District – wind, biomass, heat pumps and solar[20].

The following section provides a brief description of each technology.

7.2 Wind power

Large scale air currents (wind) across the globe are generated by temperature gradients caused by the unequal heating of the Earth by solar radiation and pressure differentials caused by drag between the atmosphere and the Earth's rotation.

Predictability and intermittency is the fundamental issue with any wind driven source. It is difficult to predict when the wind will blow (or, more importantly, when it won't) and even if this problem was solved there are still periods of zero wind in the UK. There are also large short term (in periods of hours) fluctuations in wind energy availability.

[20] A lack of hydro and geothermal potential in the District has already been documented in reports such as LUC 2010.)

However as Milborrow (2009:25), CAT (2010) and MacKay (2009) point out these problems are not insurmountable.

Overall on-shore wind installation is a relatively cheap source of alternative energy. Although wind farms cover large areas, the land beneath them can be used for farming (unlike large scale PV) and connection to the grid is not a substantive issue. Off-shore farms require substantial investments in an off-shore transmission grid. However this is offset by greater wind strength, predictability and reliability.

Again, a disadvantage of wind power is that it generates electricity rather than the more popularly required heat, however this is not considered a major problem.

Wind is one of the more favoured alternatives. RAE see between 8 -15% of the UK's energy needs being provided by wind. MacKay is even more optimistic with up to 45% being wind generated (although 10% is the more representative figure in his scenarios). UKERC sees between 2-11% being provided by wind generated electricity.

CAT suggests over 60% of the UK's needs can be meet by wind, although given the issues of intermittency, this seems close to an almost 'heroic' assumption.

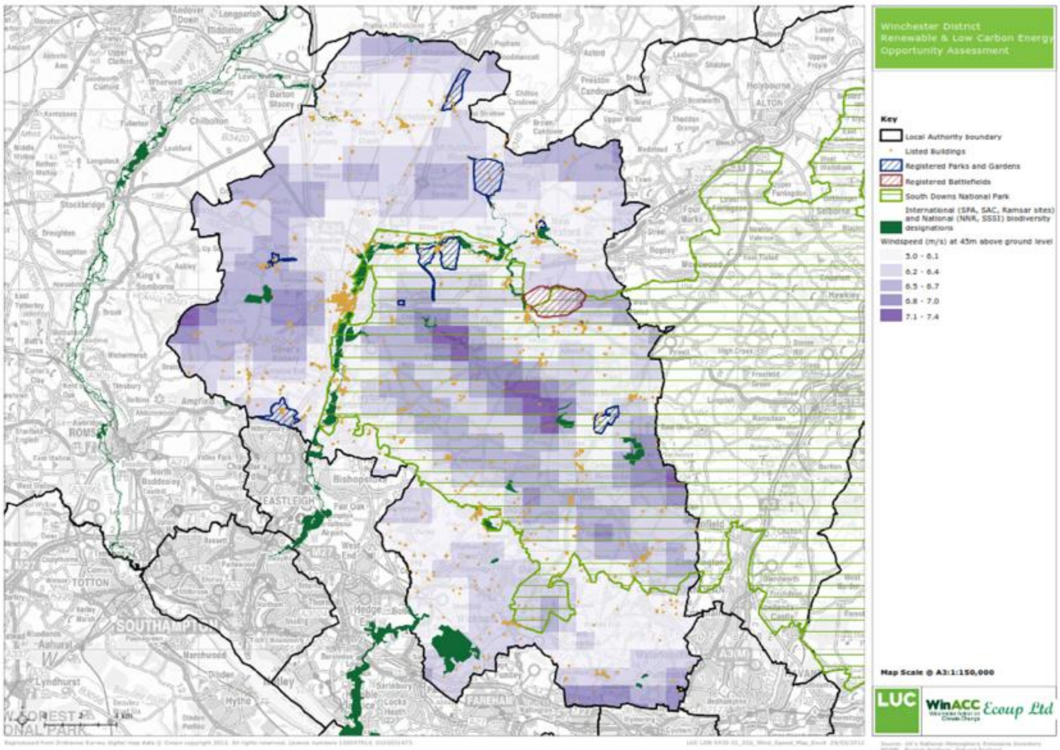


Figure 17: Map of Wind potential for Winchester District at 1km^2 resolution

Figure 17 presents an overview of the wind power potential in Winchester District. It can be seen that many of the areas with the highest potential for wind power generation are confined within the designated areas; out of bounds for this type of development. Eight of the locations within the designated areas have been evaluated for generating potential. These were selected on the basis that the wind potential was within the acceptable band and there are existing loads within 2km of the proposed site.

The costs could not be established in detail but reference has been made to the report on UK electricity generation cost update commissioned by DECC (Mott Macdonald, June 2010).

Three turbines were selected for the purpose of calculating and demonstrating performance at each location. These turbines were selected as machines typical of their type and without detailed comparison of other similar sized machines. It is beyond the scope of this study to make a particular recommendation on turbines in terms of value for money, RAM or environmental performance. The turbines used to present the figures are:

- Vestas V-112 3 MW; hub height 98m; rotor diameter 112m
- Enercon E82 82m 2300kW; hub height 98 m; rotor diameter 82m
- GE 1.5XLE 82.5m 1.5 MW; hub height 80m; rotor diameter 82.5m
- Enercon E33 33.4m 330kW; hub height 45m; rotor diameter 33.4m

The figures that have been used are based on manufacturers' performance charts in published brochures. The study did not include scope to develop independently verified data for these machines. The wind performance data has been based on the Rayleigh Distribution; wind speed standard deviation is assumed to be 52% of mean wind speed.

7.2.1. Large scale machines in clusters

Previous regional studies have engaged with a wide range of stakeholders to establish the boundaries and scope for commercial scale wind farm development. Those stakeholders have been supportive of such studies and reached agreement on the following basic criteria for site evaluation:

- there is no capacity for commercial scale wind energy developments within nature conservation designation – i.e. SPAs, SACs, Ramsar sites, SSSIs, National Nature reserves etc.
- there is no capacity for commercial wind energy developments within designated landscapes but that further local level assessments should be undertaken at a later date.
- there is no capacity for wind turbines within a buffer of 2km adjacent to designated landscapes to reflect the importance of the setting of these areas.

The DECC method presents options for using 9 MW/km^2 or maintaining a distance of 5 rotor diameters between turbines. They have assumed a uniform turbine size of 2.5 MW with dimensions of tip height 135m, rotor diameter 100m and hub height 85m. In this report our assumption is that the dimensions between turbines provides a higher density of installation and therefore should be adopted as the standard at this stage; until more detailed modelling of noise and wind characteristics can be undertaken.

Table 14 presents an overview of the wind power potential for sites that were identified in Figure 17. Background fill with yellow colour coding has been used to highlight those options that the study identified as most attractive for each location. The other colours (blue, orange and green) have been used to highlight areas that appear to provide the best prospect for the District. All the potential sites in each of these three areas have been highlighted by a common colour. The two sites at Portsdown were calculated as one location and therefore there is only one entry for that area.

	Location details	Make and model of turbine	Installed peak capacity (MW)	Ideal potential Annual Yield per turbine (kWh pa)	84% availability Annual Yield per turbine (kWh pa)	CO_{2e} Emissions saved per turbine (kg)	Number of turbines	Total CO_{2e} emissions saved per wind farm (kg)	Approximate budget cost (£M)
Location name	**Mount Down, South East of Sparsholt**	Vestas V112 3MW	15.00	10,188,126	8,558,026	5,080,729	5	25,403,644	25.52
Point Coordinates	440541,128585	Enercon E82; 2300kW	13.80	6,565,989	5,515,431	3,274,401	6	19,646,406	23.47
WGS84 location	51.055184,-1.422947	GE 1.5XLE 82.5m; 1.5MW	9.00	5,666,726	4,760,050	2,825,946	6	16,955,678	15.31
Nearest Post Code	SO21 2PA	Enercon E33; 330kW	3.96	1,038,270	872,147	517,776	12	6,213,313	7.35
Location name	**South of Freefolk Wood, Winchester**	Vestas V112 3MW	15.00	9,158,597	7,693,221	4,567,312	5	22,836,559	25.52
Point Coordinates	450000,144000	Enercon E82; 2300kW	13.80	5,835,867	4,902,128	2,910,296	6	17,461,773	23.47
WGS84 location	51.193059,-1.285794	GE 1.5XLE 82.5m; 1.5MW	9.00	5,166,131	4,339,550	2,576,304	6	15,457,824	15.31
Nearest Post Code	SO21 3BA	Enercon E33; 330kW	3.30	930,259	781,418	463,912	10	4,639,120	6.12
Location name	**Itchen Stokes Down**	Vestas V112 3MW	15.00	9,158,597	7,693,221	4,567,312	5	22,836,559	25.52
Point Coordinates	454879,135417	Enercon E82; 2300kW	13.80	5,835,867	4,902,128	2,910,296	6	17,461,773	23.47
WGS84 location	51.115424,-1.217358	GE 1.5XLE 82.5m; 1.5MW	9.00	5,166,131	4,339,550	2,576,304	6	15,457,824	15.31
Nearest Post Code	SO24 9UB	Enercon E33; 330kW	3.30	930,259	781,418	463,912	10	4,639,120	6.12
Location name	**Worthy Down, Winchester**	Vestas V112 3MW	12.00	9,158,597	7,693,221	4,567,312	4	18,269,247	20.41
Point Coordinates	445080,134437	Enercon E82; 2300kW	11.50	5,835,867	4,902,128	2,910,296	5	14,551,478	19.56
WGS84 location	51.107465,-1.357462	GE 1.5XLE 82.5m; 1.5MW	7.50	5,166,131	4,339,550	2,576,304	5	12,881,520	12.76
Nearest Post Code	SO21 2RJ	Enercon E33; 330kW	2.64	930,259	781,418	463,912	8	3,711,296	4.90
Location name	**Lone Farm, Woodmancott**	Vestas V112 3MW	12.00	8,894,237	7,471,159	4,435,477	4	17,741,910	20.41
Point Coordinates	456570,141985	Enercon E82; 2300kW	11.50	5,651,542	4,747,295	2,818,374	5	14,091,871	19.56
WGS84 location	51.174313,-1.192173	GE 1.5XLE 82.5m; 1.5MW	7.50	5,034,501	4,228,980	2,510,661	5	12,553,305	12.76
Nearest Post Code	RG25 2AX	Enercon E33; 330kW	2.64	902,727	758,290	450,182	8	3,601,454	4.90
Location name	**Portsdown Hill, West of Fort Southwick**	Vestas V112 3MW	9.00	10,188,126	8,558,026	5,080,729	3	15,242,186	15.31
Point Coordinates	462219,107016	Enercon E82; 2300kW	6.90	6,565,989	5,515,431	3,274,401	3	9,823,203	11.74
WGS84 location	50.859317,-1.117364	GE 1.5XLE 82.5m; 1.5MW	4.50	5,666,726	4,760,050	2,825,946	3	8,477,839	7.65
Nearest Post Code	PO6 4LW	Enercon E33; 330kW	1.98	1,038,270	872,147	517,776	6	3,106,657	3.67
Location name	**South Sarum, Pittdown Plantation, Winchester**	Vestas V112 3MW	9.00	10,188,126	8,558,026	5,080,729	3	15,242,186	15.31
Point Coordinates	444544,128940	Enercon E82; 2300kW	9.20	6,565,989	5,515,431	3,274,401	4	13,097,604	15.65
WGS84 location	51.05808,-1.365793	GE 1.5XLE 82.5m; 1.5MW	6.00	5,666,726	4,760,050	2,825,946	4	11,303,786	10.21
Nearest Post Code	SO22 5QT	Enercon E33; 330kW	1.98	1,038,270	872,147	517,776	6	3,106,657	3.67
Location name	**Heath Green, nr Upper Wield**	Vestas V112 3MW	9.00	9,933,307	8,343,977	4,953,653	3	14,860,958	15.31
Point Coordinates	463000,137000	Enercon E82; 2300kW	9.20	6,384,249	5,362,769	3,183,769	4	12,735,074	15.65
WGS84 location	51.128823,-1.101077	GE 1.5XLE 82.5m; 1.5MW	6.00	5,543,861	4,656,843	2,764,674	4	11,058,698	10.21
Nearest Post Code	GU34 5NG	Enercon E33; 330kW	1.98	1,011,471	849,636	504,412	6	3,026,470	3.67
Location name	**Micheldever Train Station, Winchester**	Vestas V112 3MW	9.00	9,418,542	7,911,575	4,696,944	3	14,090,832	15.31
Point Coordinates	452084,143182	Enercon E82; 2300kW	9.20	6,019,188	5,056,118	3,001,716	4	12,006,863	15.65
WGS84 location	51.185501,-1.256164	GE 1.5XLE 82.5m; 1.5MW	6.00	5,293,563	4,446,593	2,639,853	4	10,559,413	10.21
Nearest Post Code	SO21 3BD	Enercon E33; 330kW	1.98	957,466	804,271	477,480	6	2,864,878	3.67
Location name	**Sarum Farm Radio Masts, Ray's Roost, North of Sarum Rd, Winchester**	Vestas V112 3MW	6.00	10,188,126	8,558,026	5,080,729	2	10,161,458	10.21
Point Coordinates	444751,129465	Enercon E82; 2300kW	6.90	6,565,989	5,515,431	3,274,401	3	9,823,203	11.74
WGS84 location	51.062785,-1.362761	GE 1.5XLE 82.5m; 1.5MW	4.50	5,666,726	4,760,050	2,825,946	3	8,477,839	7.65
Nearest Post Code	SO22 5QL	Enercon E33; 330kW	1.65	1,038,270	872,147	517,776	5	2,588,881	3.06
Location name	**Warren Wood, Crawley, Winchester,**	Vestas V112 3MW	9.00	8,894,237	7,471,159	4,435,477	3	13,306,432	15.31
Point Coordinates	443030,136030	Enercon E82; 2300kW	9.20	5,651,542	4,747,295	2,818,374	4	11,273,497	15.65
WGS84 location	51.121946,-1.386552	GE 1.5XLE 82.5m; 1.5MW	6.00	5,034,501	4,228,980	2,510,661	4	10,042,644	10.21
Nearest Post Code	SO21 3NT	Enercon E33; 330kW	1.98	902,727	758,290	450,182	6	2,701,091	3.67
Location name	**Courtney's Copse, Lone Farm, Martyr Worthy**	Vestas V112 3MW	6.00	8,894,237	7,471,159	4,435,477	2	8,870,955	10.21
Point Coordinates	453201,134757	Enercon E82; 2300kW	6.90	5,651,542	4,747,295	2,818,374	3	8,455,123	11.74
WGS84 location	51.109647,-1.241426	GE 1.5XLE 82.5m; 1.5MW	4.50	5,034,501	4,228,980	2,510,661	3	7,531,983	7.65
Nearest Post Code	SO24 9UB	Enercon E33; 330kW	1.32	902,727	758,290	450,182	4	1,800,727	2.45
Location name	**Moor Court Hill, Sparsholt, Winchester**	Vestas V112 3MW	6.00	8,894,237	7,471,159	4,435,477	2	8,870,955	10.21
Point Coordinates	442809,131604	Enercon E82; 2300kW	6.90	5,651,542	4,747,295	2,818,374	3	8,455,123	11.74
WGS84 location	51.082174,-1.390233	GE 1.5XLE 82.5m; 1.5MW	4.50	5,034,501	4,228,980	2,510,661	3	7,531,983	7.65
Nearest Post Code	SO21 2NE	Enercon E33; 330kW	1.32	902,727	758,290	450,182	4	1,800,727	2.45
Location name	**Bridgets Farm, Martyr Worthy**	Vestas V112 3MW	3.00	8,629,876	7,249,096	4,303,643	1	4,303,643	5.10
Point Coordinates	452439,134190	Enercon E82; 2300kW	4.60	5,467,217	4,592,462	2,726,453	2	5,452,906	7.82
WGS84 location	51.104619,-1.252392	GE 1.5XLE 82.5m; 1.5MW	3.00	4,902,870	4,118,411	2,445,018	2	4,890,036	5.10
Nearest Post Code	SO21 1BX	Enercon E33; 330kW	0.99	875,194	735,163	436,452	3	1,309,355	1.84

Figure 18: Summary of Wind power potential for Winchester District

7.2.1.a Heath Green (Average wind speed 6.9m/s)

The best wind resource in this area is just across the Winchester District boundary on the Hattingley Road at Pullingers Farm (7.1m/s). However, in addition to the fact that Pullingers Farm is not within Winchester District, the area of interest also lies adjacent to some large domestic dwellings.

It is likely that the wind speed in the location to the South and South West of Heath Green is worthy of further investigation based on its proximity to the high wind speeds at Pullingers Farm and the local topography. The wind speed data suggests a lower average for this location but it is not possible to be precise and therefore further detailed measurements may be worthwhile.

An area of approximately 75km^2 to the West and South of Heath Green could accommodate three 3 MW wind turbines or four of the smaller commercial machines. If scale is considered to be an issue in the planning and consultation phase this could be a sensible location for the smaller scale installations.

It is recommended that further dialogue is undertaken with stakeholders in the neighbouring District because this site has far greater potential if there is local community support. The steep topography in this area may present difficulties for agricultural exploitation but the Southerly facing aspect could by ideal for enhancing the conversion of wind power from the prevailing direction.

7.2.1.b Woodmancott (Average wind speed 6.5m/s)

The area along Winchester District boundary at Woodmancott just to the South of Manor Farm can be defined by an area of 1 km^2 which is an appropriate location for four 3 MW wind turbines. These turbines would each deliver approximately 7.5 GWh pa. The four turbines would collectively reduce CO_{2e} emissions in Winchester District by 17.7 Kilo tonnes per annum.

7.2.1.c Micheldever Station (Average wind speed 6.7m/s)

The site proposed at this location is a strip of land running parallel with the boundary to Black Wood and running approximately 1 km in length. This should be sufficient space for three 3 MW turbines. Services in this area are excellent with grid connections to the rail network providing good infrastructure and load options. Three 3 MW turbines in this location would each produce 7.9 GHW per annum. The three turbines would collectively reduce CO_{2e} emissions in Winchester District by 14 Kilo tonnes per annum.

7.2.1.d South East of Freefolk Wood (Average wind speed 6.6m/s)

The area of interest is to the South East of Freefolk Wood. It is bounded on the North by the Winchester District boundary and to the South by the A303. It is contained between the two grid reference points (450000,144000) and (451495,144000) and encloses an area of approximately 1.5km^2.

The findings of this study indicate that there could be merit in considering this site along with the two lower and adjacent sites to form a larger wind power installation. The business case or the number of turbines may be limited by the available national grid infrastructure. Detailed analysis of grid connection implications were not possible within the scope of this report.

It is estimated that five large 3 MW turbines could be accommodated in this area while remaining within DECC guidance for spacing and distance from rail and road networks. These turbines would each deliver approximately 7.7 GWh pa. The five turbines would collectively reduce CO_{2e} emissions in Winchester District by 22.8 Kilo tonnes per annum.

7.2.1.e Worthy Down (Average wind speed 6.61m/s)

This site has particular appeal because of its proximity to the A272 and the A34. Both of these roads will produce a significant background noise and therefore there is likely to be less of a protest about any low level noise from the Turbine. The area is also occupied by very few households and is therefore unencumbered by the planning restrictions.

There are two small areas of raised ground in the locality of Worthy Down.

The first is South West of Worthy Grove in the form of a ridge with a bearing of 210° and an elevation of 120m. The top of the ridge is approximately 250m wide and defines an area of 0.25 km^2 which may limit the location to two turbines. The primary limitation is the direction of the ridge being aligned with the dominant wind direction which would result in the performance of the second turbine being influenced by operation of the first. Detailed analysis of this aspect of turbine performance is beyond the scope of this study but should be addressed by a detailed feasibility for this site.

The second location is to the South East of Worthy Grove. The form of this second plateau and orientation suggests that a further two turbines could be installed at this location. This location has the disadvantage of being located to the North East of some trees which may impair the turbine performance to some extent.

The two locations proposed are on opposite sides of the strip of land enclosed by the A34 and A272. They have been considered as a single wind farm for the purpose of this study. Four 3MW turbines in this location would each produce 7.7 GWh pa and collectively reduce CO_{2e} emissions in Winchester District by 18.2 Kilo tonnes per annum.

7.2.1.f Bridget's Farm (Average wind speed 6.4m/s)

Bridget's Farm was selected as a location to evaluate based on elevation above landscape and buildings to the South West and proximity to the M3. The significance of the M3 is from a high level of background noise generated from road traffic. When comparing the noise created by a large scale wind turbine to background noise it could be helpful to contrast with road noise from local roads. The site under consideration at Bridget's Farm is less than 2km from the M3.

The OS map indicates that the site in question has remains of a Roman Villa. This may result in additional costs for the project in archaeological surveys to establish the most appropriate position of turbines on this ridge. However, the ridge runs at approximately 200m wide for a distance of 500m before reaching the marked villa site. On that basis it may be possible to position three smaller turbines without significant disturbance to the site of the villa.

This study has assumed that the scale of plant required to install a single large turbine at the SW end of the ridge might be difficult to gain planning permission due to the Roman Villa remains. If this were acceptable from an archaeological perspective, a single large turbine would make more sense from a business case and would reduce CO_{2e} emissions.

A single 3MW turbine in this location would deliver approximately 7.2 GWh pa and reduce CO_{2e} emissions in Winchester District by 4.3 Kilo tonnes per annum.

The alternative option that may be more acceptable and protect the archaeology at the site of the ruins would be three 330 kW turbines. Each of these turbines would produce 735 MWh pa. These three turbines would collectively reduce CO_{2e} emissions in Winchester District by 1.3 Kilo tonnes per annum.

7.2.1.g Courtney's Copse, Lone Farm (Average wind speed 6.5m/s)

The plateau to the South side of Courtney's Copse is a continuation of the ridge from Bridget's Farm. The wind speed data for this 1km square is a slight improvement on the leading edge of the ridge at Bridget's Farm. The M3 is 2km away and therefore background road noise will remain a consideration when evaluating the environmental impact of wind turbines at this location.

Two 3 MW turbines in this location generating 7.5GWh pa each would reduce CO_{2e} emissions in Winchester District by 8.9 Kilo tonnes per annum.

7.2.1.h Itchen Stoke Down (Average wind speed 6.6m/s)

The site at Itchen Stoke (454879,135417) is a further 10m higher than the plateau at Courtney's Copse and presents a larger area of land. This study has estimated that an area of 1½km^2 could be used to locate five 3 MW turbines in this area. Wind speed at 45m above ground level is also slightly improved however background noise will be lower because of reduced proximity to the M3. There are no dwellings within 500m of the proposed site.

The findings of this study indicate that there could be merit in considering this site along with the two lower and adjacent sites to form a larger wind power installation. The business case or the number of turbines may be limited by the available national grid infrastructure. Detailed analysis of grid connection implications was beyond the scope of this report.

Five 3MW turbines in this location would each generate 7.7 GWh pa. Their collective output would reduce CO_{2e} emissions for Winchester District by 22.8 Kilo tonnes per annum.

7.2.1.i Ray's Roost, Sarum (Average wind speed 7m/s)

Ray's Roost is another local high point from a topographical perspective and the site considered by this study is slightly larger than 0.5 km^2. On that basis it is assessed as viable for two of the 3MW turbines but may be able to accommodate three of the slightly smaller machines.

This study identified two potential limitations at this site:

- In the first instance it is already occupied by a number of radio masts. The operators of these stations may object to potential interference that may arise from turbines in close proximity to the existing radio station.
- Crab Wood is ancient woodland that includes a nature reserve. It is adjacent to the proposed site and this may raise concerns relating to migrating species of interest from scientific or biodiversity perspectives.

A balanced review of the options determined that wind power generated at this site was one of the more acceptable alternatives. It is in close proximity to some of the most energy intensive areas of Winchester District and from that perspective is a good location. Two 3 MW turbines in this location would each produce 8.6 GWh pa. These two turbines would collectively reduce CO_{2e} emissions in Winchester District by 10.1 Kilo tonnes per annum.

7.2.1.j Enmill Farm, South Sarum (Average wind speed 7m/s)

This area stretches from Pittdown Plantation (442462,128915) to the track to the north of Vale Farm (444544,128940). Much of this land is currently used for livestock farming (pigs) that would not be disturbed by the installation of wind turbines. However, the issues (and benefits) raised relating to the site at Ray's Roost would also apply for this site. These refer to the adjacent nature reserve and radio installation.

This study has measured the area of interest to be a strip of approximately 1 km East West and 500m North South running at approximately 100m South of Sarum Road. Assuming 500m separation between large turbines it is estimated that three or four turbines could be situated along this strip. To be consistent with other locations, the productivity figures are based on slightly fewer of the larger turbines and approximately twice the number for the smaller machines.

The 1 km square data used in this analysis is centred at the Pittdown Plantation end of this strip. Three of the larger 3MW turbines in this location would each produce 8.6 GWh pa. These three turbines would collectively reduce CO_{2e} emissions in Winchester District by 15.2 Kilo tonnes per annum.

7.2.1.k Moore Court Hill, Sparsholt College (Average wind speed 6.5m/s)

Moore Court Hill is a local high point immediately to the South of Sparsholt College. This study has identified an area of 0.5 km^2 on this land that may be appropriate for two turbines. This location would offer the additional opportunity to connect the electricity generated to the college and thus deliver a direct benefit to the local community.

Being to the South and South West of the college, the two proposed large wind turbines may cause problems with flicker for certain periods of the day. This would be more pronounced during the winter months when the sun is at a lower elevation. On that basis further more detailed study of the adjacent buildings should be undertaken before selecting the turbines that would be most appropriate for this site.

For the purpose of this study we have assumed that the impact of flicker would be reduced by selecting the smaller turbines in this application. With a reduced rotor diameter it would be possible to install more of these machines in the area available without encroaching on the separation zone (500m) surrounding adjacent dwellings. We have assumed that four EN33 turbines could be installed but also observe that it may be more cost effective to install a single 3 MW machine.

Four 330 kW turbines would each produce 758 MWh pa. The collective output from these four turbines would reduce CO_{2e} emissions in Winchester District by 1.8 Kilo tonnes per annum.

7.2.1.l Warren Wood, Crawley (Average wind speed 6.5m/s)

This is in the area to the south of Warren Wood and Crawley Down. The area being considered occupies approximately 1 km^2 and should be capable of hosting three or four commercial scale turbines. This location is close to a significant source of power demand at Arqiva at Crawley Court. Another site that was also considered is at Windmill Hill which is just to the South West of Crawley Court.

Wind speed in this area is less attractive but other factors make this worthy of further consideration. The wind speed adjacent to Warren Wood is indicated by the NOABL data set as 6.5m/s and the speed at Windmill Hill is slightly lower at 6.4m/s. In reality both of these sites represent a similar prospect and further detailed site measurements would be necessary to determine the best site for the turbines. There is a reasonable distribution of wooded areas adjacent to the higher ground in these two locations, however the Warren Wood site will suffer some additional turbulence from the Crawley Court site.

Each 3MW turbine installed in this area would yield around 7.5 GWh pa. The collective benefit of three turbines would be a reduction by 13.3 Kilo tonnes of CO_{2e} emissions for Winchester District.

7.2.1.m Mount Down (Average wind speed 7m/s)

This location is situated on the western extremity of Winchester District in the Farley Mount Country Park. It is one of the areas of highest wind potential within the District that are outwith the nationally designated areas. However it is situated on the approaches to a landing strip at Farley Farm on Bailey's Down.

The area with the best wind potential is adjacent to the landing strip at Farley Down but is only relatively small in area; sufficient for two large wind turbines. On that basis the slightly poorer location of Mount Down has been selected in terms of wind speed data for the purpose of this study. However, if this location was selected for further development it would make sense to include the Farley Down site and we have therefore included that area when estimating numbers of machines.

The size of this plot has been estimated as 2.5 km^2 and therefore sufficient for 10 large wind turbines. However, connection to the national grid may restrict the number of large (3MW) turbines that could be installed at this location since peak output from this number of turbines would be approaching the limit of the 33kVA network. The location is fairly isolated and therefore connection to large commercial or domestic load centres is unlikely, IBM at Hursley Park is 4 km to the South East.

An installation of this scale at an unspoilt location may also raise strong local resistance. As a local country park, it is well known as a recreational area. Frequent users of the open space may object to any form of industrialisation in this space. There are a number of monuments and sites of historical interest in this area that may also have a bearing on the density of turbine distribution.

Giving consideration to the potential challenges of a large scale installation at this site we have assumed that only 60% of the maximum capacity would be installed. Therefore our analysis of this site has been based on five or six large wind turbines each generating 8.6 GWh pa. The collective energy produced from five turbines would equate to a CO_2 emissions saving of 25.4 kilo tonnes.

7.2.1.n Portsdown Hill (Average wind speed 7m/s)

Following the ridge between Fort Nelson and Fort Southwick it is estimated that there would be sufficient spacing for three large turbines at this site. It is recognised that this area has significance for operations of the MoD, however the landscape has already been industrialised with forts and research stations and therefore may be better suited than some more rural locations in the District. The wind speed data for this location may not be a true reflection of the wind power potential. The coordinates used (462000,107000) defines a $1km^2$ which is centred on the ridge only a few metres from the highest point. The ridge falls steeply to the South and North and therefore the average wind speed may be influenced by large areas that are sheltered from the wind. Based on the topography and the lack of any obstructions to the South or North it is likely that turbines in this location will perform better than any other sites considered by this study.

It is likely that two 3MW turbines could be installed on the strip of land between Porchester Lane (462100,107100) and Fort Southwick (462600,107050). The locations defined by the coordinates would be approximately 100m North of Portsdown Hill Road and Porchester Lane. This should be sufficient distance from the road for planning purposes. If installed at the coordinates indicated the distance would be more than five rotor diameters for the largest turbines being considered.

The third turbine in this area would need to be on the West side of the adjacent research establishment towards the Nelson's Monument (461400,107100).

We have assumed that the average wind speed is the same for all three turbines to simplify the estimating process. The energy performance of these locations based on the average wind speed of 7m/s (NOABL data for 1km square) is 4.7 GWh pa per 1.5MW turbine up to 8.6 GWh pa for a 3MW machine. This would equate to a CO_2 emissions saving of between 8.5 kilo tonnes and 15.2 kilo tonnes of CO_{2e} emissions reduction for three large commercial scale wind turbines.

7.2.2. Smaller turbines

The purpose of this study was to establish the potential opportunity that might be delivered from renewable or low carbon energy sources within Winchester District. The power output of a wind turbine is directly proportional to the swept area and to the third power of the wind speed. Smaller wind turbines are typically mounted closer to the ground (or buildings) which brings the working area nearer to the boundary layer. Frictional losses and turbulence near the ground will normally result in a reduced wind speed than can be found at 100m above ground level. For this reason it is clearly not possible for small wind turbines to make the best use of the wind resource available.

In contrast to larger turbines, those that are smaller than 500 kW may be more acceptable in terms of visual amenity and noise. However, many smaller turbines will rotate at higher speeds and therefore the noise will be produced at a higher pitch which may cause concerns to some.

The primary benefit of smaller wind turbines is that they require far less capital investment in the machine and infrastructure to support their connection to the grid. An industrial scale grid connection at 11 kV would be more than adequate for connection of a few turbines in the range up to 500 kW. On that basis many farms can consider these smaller installations as a one off project.

This report has included figures for a farm/community scale 330 kW wind turbine for all the sites that were evaluated. The price per MW for installation has been assumed at the high ranking (£1,855/kW installed) as defined by Mott MacDonald since it is anticipated that these machines will be installed in small numbers at each location.

Estimated quantities for the maximum number of these turbines that could be installed at each site are for illustration only. If more than three of these smaller machines were to be installed at a single site the business case is likely to support a single large turbine. A single large turbine would also be less disruptive to the land in question. However, an exception to this point may be in locations where the mast height of 50m was the main reason for rejecting wind power installations near a small residential community.

Smaller turbines (less than 500 kW) were found to present a sensible alternative at locations where there are flicker or access limitations. On that basis they could form a useful contribution at the following locations:

- Moore Court Hill, Sparsholt (College)
- Bridget's Farm, Martyr Worthy
- Heath Green, Nr Upper Wield

7.2.3. Practical examples – community wind farms

Westmill Coop was formed in 2004 to progress with a planned development of a small wind farm in Oxfordshire. This was the culmination of many years' background work to establish the concept into a workable form. The proposal was developed to the stage of a share issue in November 2005 and which remained open until February 2006. From that point it took just two years for the machines to be installed, connected to the grid and start generating. The wind farm includes five 1.3 MW turbines with 49m hub height and 66 metre swept area.

The Baywind cooperative was formed in 1997 and has been involved with two wind farms for many years. The first was Harlock Hill, near Ulverston in Cumbria with five 0.5MW turbines. The second interest is in Haverigg II where they own one of the turbines. http://www.baywind.co.uk/baywind_aboutus.asp.

7.3 Biomass

This is the capture of sunlight through photosynthesis leading to plant growth. Therefore the availability of biomass fundamentally relies on:

1) The amount of sunlight.

2) The amount of land/sea available to grow biomass. However there are substantial sources of waste biomass ranging from animal manures and waste food to land fill.

Biomass can be used in a wide range of conversion technologies, including (for dry material) dedicated combustion, co-firing with fossil fuels, and waste combustion, and (for wet material) anaerobic digestion to produce a flammable biogas. High oil content crops such as oilseed rape and sunflower can be converted into bio-liquids which can replace both diesel and heating oils. Other sugar rich crops (maize, sugar beet) can be fermented to produce bio-ethanol however this use is almost exclusively restricted to use in the transport sector.

All of these feedstocks can be used to produce heat and electricity together in a combined heat and power (CHP) plant, or to produce just power or heat.

A number of advanced technologies are also under development, including gasification and pyrolysis however these are not considered as viable short term opportunities. (DECC 2011)

Biomass can be converted to useful energy in a number of ways.

It can be burnt as a direct source of heat; to produce combined heat and power. It can be anaerobically digested to produce bio-methane (which can then be burnt or liquefied) or transesterified into bio-liquid fuel (ethanol and bio-diesel).

This fuel can then either be directly burnt (to produce heat or for conversion into electricity) or further processed to produce bio-fuels in liquid, solid or gaseous forms. These can then be converted into heat, electricity and almost uniquely into liquid fuels that can drive internal combustion and heat engines.

There are numerous processes to produce bio-fuels ranging from bio-digestion of corn (or other vegetable based oils) to produce ethanol and bio-diesel, and of organic waste (sewage) to produce methane. The conversion of landfill gas into energy and the combustion of municipal waste is also considered to be a biomass conversion process.

There are a number of issues:

- Land use and substitutability. At the heart of biomass production is the land required for its growth. MacKay (2009) calculates photosynthesis to be no more than 1% efficient and produces less than 1 W/m^2. Therefore large areas of land may be required to provide significant quantities of biomass. In addition, the diversion of valuable farm land to produce bio-fuels may have adverse effects on food production that in a world that still has mass hunger is a serious concern. However the production of biomass fuels from waste materials is something that MacKay ignores. As our analysis shows there is a significant opportunity in Winchester to produce bio-methane from waste feedstocks.

- Sustainability. To be truly carbon neutral there needs to be a strict balance between the biomass consumed and the biomass grown. Cutting into biomass reserves (e.g. forests) to provide energy actually increases atmospheric CO_2. Replanting must occur at, or above, the same rate as consumption. In addition combustion of municipal waste and use of landfill gases involves complex flows. Over long time periods even forests will require the application of fertilisers to replace minerals and soils removed during the harvesting of biomass.
- Timing. The need for balance between growth and use requires that biomass energy conversion technology can only grow at the same rate as the underlying biomass. Even short-rotation crops work on 10-12 year cycles and therefore biomass as a primary energy source requires a significant planning period before it can make a substantial contribution. Whilst this requires a lead time of typically three to ten years (to produce the first crop harvest), the use of waste from existing agricultural processes largely avoids this issue.

However the use of waste – animal manures, organic municipal waste and wood waste, may go some way in ameliorating the land use issues.

The RAE (2010) believes that up to 20% of the UK's energy needs could be supplied by bio-mass (as opposed to MacKay's range of 7-12% and UKERC's 0-38%). DECC (2011) sees biomass playing an important role both in the short term (2020) and longer term. DECC (DECC 2011) estimates that some 30-50% of the UK's renewable energy needs will be met via biomass fuelled technologies over the next eight years.

AEA (AEA 2011:18) take an even more optimistic view and state;

> *"The modelling of bioenergy supply suggests that by 2020, bioenergy supplied to the UK could be about … 20% of current primary energy demand in the UK. This estimate is based on a price of £10/GJ for biomass feedstocks, assuming that all easy and medium constraints identified for UK feedstocks have been overcome, and a 'business as usual scenario' for international supply (with a 'reference' global demand for bioenergy). By 2030, mainly due to the development of energy crops globally, supply could rise substantially to between 4,800 and 6,700 PJ, or between a half and three quarters of current primary energy demand in the UK".*

Therefore biomass is likely to be a (or the) major source of renewable energy within the Winchester District and our analysis supports this view.

Biomass covers a wide range of fuel types, feedstock and conversion methods which are summarised below. These are based on DECC (DECC 2010) methodology however updated to reflect recent developments in conversion technologies such as anaerobic digestion.

DECC Primary Fuel Type	Fuel Feedstock	Fuel Conversion Method	Fuel product
Plant Biomass	Managed Woodland	Combustion	Bio-solid
	Energy Crops	Anaerobic Digestion or Fermentation or Pyrolysis	Bio-gas or bio-liquid
	Waste Wood	Combustion	Bio-solid
	Agricultural Arisings	Combustion or Anaerobic Digestion	Bio-solid (for combustion) or bio-gas
Animal Biomass	Wet Organic Waste	Anaerobic Digestion	Bio-gas
	Poultry Litter	Anaerobic Digestion or combustion	Bio-gas
Municipal Solid Waste (MSW)	Domestic waste e.g food and organic matter. Generally a combination of plant and animal biomass, Oil derived products (Plastics), Wood and paper products.	Combustion, Anaerobic Digestion or Landfill Gas Collection and combustion	Bio-gas
Commercial & Industrial Waste	Non-domestic waste e.g. food from catering, food processing and retailing. Generally a combination of plant and animal biomass, Oil derived products (Plastics/Tyres), Wood and paper products	Combustion or Anaerobic Digestion Landfill Gas Collection	Bio-gas

Table 12: DECC Recommended Structure for Renewable Energy Assessment

DECC also considers co-firing of biomass with fossil fuels as a potential use. However this is confined to co-firing in large scale oil and coal fired power stations. As the Winchester District has no large scale power station this has not been assessed.

As shown in Table 12 biomass feedstocks can be sourced directly from plant or animals, or indirectly from the organic components of municipal, commercial and industrial waste (which is nothing more than discarded plant or animal biomass). These feedstocks can then be processed into bio-fuels via processes such as anaerobic digestion, fermentation and pyrolysis. In addition, biomass can be directly combusted to produce heat without any interim fuel processing. However all bio-fuel is eventually burnt either to produce heat or electricity[21].

Whilst direct combustion has, to date, been the more common form of conversion, AD is likely to play a far larger role in the future as is the production of bio-fuels by fermentation and transesterification. The production of liquid and gas bio-fuels provides a distinct advantage over direct incineration as these forms of fuel can be more easily transported closely to sources of demand (particularly in the respect of demand for heat).

Throughout this section this three stage process is considered:

- The level of feedstock available in the Winchester District is assessed.
- The amount of fuel this will produce (and its form i.e. Bio-gas, bio-liquid or bio-solid) and the production process e.g. anaerobic digestion, fermentation or pyrolysis is calculated.

[21] The use of bio-fuels to drive fuel cells is becoming possible. However this technology is insufficiently developed to be of immediate deployment.

- The energy this fuel can generate either via a combined heat and power process or a heat or power process only is determined.

From energy production the reduction in CO_2 emissions is derived. In addition several technologies (AD and landfill gas capture) prevent furtive emissions of methane. Methane is a potent greenhouse gas with a global warming potential (GWP) far in excess of carbon dioxide. IPCC (2009) calculates that over a 20 year period methane has a radiative forcing effect of 72 times that of an equivalent mass of carbon dioxide per year. Over a 100 year period the effect is less pronounced but still over 27 times. The impact of reduction in methane emissions is also calculated.

The results are shown in Table 13 below.

	Energy Production					Tonnes CO2e Displaced		Reduction in CH4 emission (Tonnes CO_{2e})
	CHP		Power Only	Heat Only	Average Power	Max	Min	
	GWh_e	GWh_{th}	GWh_e	GWh_{th}	MW	T CO_{2e}	T CO_{2e}	
Managed Woodland for Combustion	10.4	19.9	16.6	33.2	4.7	10,170	7,436	
Energy Crops for Combustion	11.4	21.8	18.2	36.3	5.2	11,143	8,148	
Agricultural Arisings for Combustion	38.5	73.9	61.5	123.1	17.6	37,739	27,595	
Agricultural Arising for AD	15.7	30.1	25.1	50.1	7.1	11,351	6,343	
Heating Oil Replacement	7.7	14.8	12.3	24.6	3.5	5,512	5,512	
Wet Organic Waste for AD	11.1	21.4	17.8	35.6	5.1	8,075	4,513	7,289
Poultry Litter for Combustion	16.8	32.3	27	53.9	7.7	16,529	12,086	
Landfill Gas	0.8	1.6	1.3	2.7	3.3	9,629	2,948	44,795
Sewage Gas	0.2	0.3	0.3	0.5	0.7	1,040	605	
Waste Wood for Combustion	6.5	12.5	10.4	20.8	3	6,373	4,660	
Total	119.1	228.6	190.5	380.8	57.9	117561	79846	52084

Table 13: Annual potential for generation of energy from local renewable sources within Winchester District and impact on GHG emissions

Table 13 shows, for each feedstock, the amount of useful energy that could be produced (in GWh[22]) from renewable resources readily available from within the Winchester District. Three distinct modes of energy production are possible. These are:

[22] Strictly speaking the unit is GWh per year.

1. The use of the feedstock fuel in a combined heat and power engine where electricity and heat are co-produced. In locations where there are sufficient base-loads this generally leads to greater reductions in GHG emissions.
2. Use in electricity only production. This generally leads to higher efficiency in electricity production but leads to significant amounts of waste heat and an overall lower efficiency. This production process is likely to be used where there is a low, or no, geographically co-located heat demand and/or where transport of the feedstock is prohibitive and energy needs to be produced near the feedstock growing location
3. Use in heat only production. Here energy is efficiently converted to heat but requires suitable consistent and high base-loads of heat demand that are co-located (or near to) biomass production. However overall energy delivery is highest i.e. converting all renewable biomass sources into a dedicated heat engine delivers more energy output than delivering the same input energy to a CHP plant. However because of higher emission factors for electricity production overall GHG savings will be higher if the energy is used to deliver combined heat and power.

Energy production for each mode is given.

Average power gives an indication of the power generated by the incineration of the biomass feedstock[23].

The final three columns show the reductions in GHG emissions that would be achieved if the energy produced from biomass was used as a substitute for fossil fuel produced energy. Minimum and maximum figures indicated the different reductions as a result of CHP and/or heat only production.

The reduction in GHG emissions is calculated by reference to DECC's (DECC 2011b) emission factors guidelines[24] as shown in Table 5.

This study shows there are deliverable and practical opportunities for Winchester District to save between 79,000 and 102,000 tonnes of CO_{2e} per annum by the use of renewable energy technology. However further savings of 52,000 tonnes can be made in reducing furtive methane emissions as explained below.

Under certain conditions biomass will decay to methane naturally in the environment. This is particularly true of animal manure and municipal waste. For example naturally occurring anaerobic digestion will take place in slurry lagoons on farms and in landfill sites. Furtive emissions from landfill and agricultural waste amounted to a total of 4,105 tonnes[25][26][27] of methane across Winchester in 2009.

Controlled digestion on animal slurries, capture of landfill gas and the subsequent use of the bio-gas produced will significantly reduce the District's overall GHG emissions. The final column

[23] Average power is the continuous power that would be required to deliver the energy generated in one year.
[24] 2011 Guidelines to DEFRA / DECC's GHG Conversion Factors for Company Reporting.
[25] Source, National Air Emissions Database.
[26] 4,105 tonnes of methane emissions is equivalent to 121,825 tonnes of Carbon Dioxide emissions.
[27] This includes 777 tonnes from the Eastleigh landfill site which is only partially in the Winchester District.

in Table 13 shows the impact on emissions (in tonnes CO_{2e}) that could be abated by the use of appropriate technology.

It is clear that capture and use of furtive methane emissions offers the District a significant opportunity to reduce overall emissions.

Other large opportunities include:

- incineration of agricultural arisings,
- AD of animal and plant biomass waste, and
- poultry litter incineration.

Each of the feedstock sources is discussed in greater details in the following sections.

7.4 Managed Woodland

The Forestry Commission FC (2012) identifies four potential sources of fuel from managed woodland. These are:

- **Sawmill residues** which include bark, offcuts and sawdust. AEA (2010) suggest that current uses include animal bedding and panel board manufacture (about 50% of resource) leaving the remainder available for energy use.
- **Forest residues** which comprise brash, stumps and small round wood not suitable for other purposes. Some of this resource is important to forestry operations, maintenance of the environment of the forest and structural stability of soil. AEA (2010) and DTI (2003) suggest no more than 75% of this material will be accessible.
- **Short Rotation Crop Forest**. Short rotation forestry allows more intensive production of wood, with an estimated yield of up to 4.2 oven dried tonnes (odt) per ha per year at present. Harrison (2010) states that fast growing species of trees would be grown on rotations of 8-20 years, depending on the species and the site. The trees would be gown primarily for the production of biomass for energy. However no more than 75% of the material would be available.
- **Aboricultural Arisings.** There is some confusion in the literature over the precise definition of this biomass source. AEA (2010) says these are residues from transport corridors and urban green space. DECC seems to define it as arisings from managed woodland as do NNFCC (Kilpatrick et al 2008) and DTI (2003).

Regardless of precise definitions the Forestry Commission (2012) provides data and forecasts on the amount of biomass annually available from each of these sources.

These reports are provided for the 90,499 ha of Woodland and Forest in the South East England but not for Counties or Local Authority Areas.

DEFRA (2012) provides data on the area of managed woodland in Hampshire (19,160 ha). It was assumed that as Winchester is 18% of Hampshire it will contain 18% of the County's woodlands (3,366 ha). FC forecast for the SE where pro-rated by land area to give managed woodland as shown in Table 13. However Winchester District also contains some 4,800 ha of ancient woodland. If this resource is also used carbon savings could be doubled.

The Biomass Energy Centre provides data on the energy content of various wood feedstocks.

The FC forecasts for feedstock resource were used to derive the potential energy from each source of managed woodland biomass.

Type of product	SE England Resource Oven Dried (Tonnes/Year)	Area of Woodland in Winchester (Ha)	Winchester Feedstock Resource	Derived Yield (Tonnes/Ha)	Availability of Resource	Energy Content (GJ /Tonne)	Energy Produced (GJ)	Energy Produced (GWh)
Sawmill Residue	22,191	3,366	825		50%	16.86	13,911	3.86
SRF	792	3,366	29		75%	14.71	433	0.12
Arboricultural arisings	144,645	3,366	5,379	1.6	50%	12.57	67,603	18.78
Forest Residue and Small Round Wood	123,028	3,366	4,575	1.36	75%	14.71	67,311	18.7
							149,258.20	41.5

Table 14: Energy potential from managed woodlands' biomass by fuel source

Table 14 shows how the energy produced could be used in either a CHP or stand-alone heat and power engines

Managed woodland	Primary Power	Combined Heat and Power		Electricity Only	Heat Only	Combined Heat and Power		Electricity Only	Heat Only
Product type	MW	MW_e	MW_{th}	MW_e	MW_{th}	GWh_e pa	GWh_{th} pa	GWh_e pa	GWh_{th} pa
Sawmill Residue	0.4	0.1	0.2	0.2	0.4	1	1.9	1.5	3.1
SRF	0	0	0	0	0	0	0.1	0	0.1
Arboricultural arisings	2.1	0.5	1	0.9	1.7	4.7	9	7.5	15
Forest Residue and Small Round Wood	2.1	0.5	1	0.9	1.7	4.7	9	7.5	15
	4.6	1.1	2.2	2	3.8	10.4	20	16.5	33.2

Table 15: Delivered energy from managed woodlands' biomass

	CO_{2e} Reductions (Tonnes)			
	Combined Heat and Power			
	Power (Tonnes CO_{2e})	Heat (Tonnes CO_{2e})	Power Only (Tonnes CO_{2e})	Heat Only (Tonnes CO_{2e})
Sawmill Residue	573.5	415.8	917.6	693.0
SRF	17.9	13.0	28.6	21.6
Arboricultural arisings	2787.1	2020.8	4459.4	3368.0
Forest Residue and Small Round Wood	2775.1	2012.1	4440.1	3353.4
	6,154	4,462	9,846	7,436

Table 16: Emissions reduction potential from managed woodlands' biomass

Assuming the heat and power generated from managed woodland biomass is used as a substitute for fossil fuel generated energy, Table 16 shows the amount Winchester District's emissions could be reduced.

However, as with most biomass feedstocks, they are not co-located with significant heat demand therefore will require transport to CHP facilities. Electricity production would require the construction of small scale power plants (sub 1 MW) in or close to woodland which may lead to planning issues. This may limit the feedstock to use in small scale biomass burners (domestic and industrial) and therefore reduce emissions savings to 7,500 tonnes. DECC figures suggest that overall costs for small scale biomass are in the order of 4.3 – 10p KWh which is more expensive than gas but in the same range as electricity (resistive) and oil-fired systems.

7.5 Energy Crops

The DECC Methodology recommends looking at two categories of energy crops in the UK:

- Perennial woody/grassy crops grown on short rotations (one to three years).
- Single stem trees grown on short rotation - Short Rotation Forestry (10-20 years).

However this seems to neglect short rotation coppice (SRC) e.g. willow and hazel which can be grown over a three to five year cycle once established (Biomass Centre 2012).

> *AEA (2011) are of the view that "The energy crops SRC, miscanthus, switchgrass and reed canary grass can all be grown on arable land or temporary pasture land in the UK, which gives a theoretical upper limit on the area of energy crops in the UK."*

AEA (2011) and Land Use Consultants (2010) both consider SRC and miscanthus energy crop production viable in the Winchester District.

The three key determinants of energy production from crops are the:

- land available,
- yield of biomass per Hectare,
- yield of energy from biomass incineration.

Land availability is the subject of some debate. Kilpatrick (2008) bases his estimates on land not required for food or feed production; a view supported by DECC who state "assume that energy crops are planted only on land no longer needed for food production, i.e. all abandoned arable land and pasture". Others take a different view. Bond (2009) suggests all land in ALC categories 3 and 4 (but no pasture land), ADAS (2008) say 10% of agricultural land and Aylott (2008) says 10% of arable land and 20% of improved grassland. Kilpatrick estimates that 5% of arable land and excess temporary grassland and bare fallow land is all available. This a view contradicted by AEA who say "*grassland is excluded, as seems likely post RED [Renewable Energy Directive] implementation."*

For the purpose of this analysis it was assumed that 5% of the District's arable and cereal land is given over to energy crop production. Land use data for the Winchester District is sourced from DEFRA (2012b).

There is more certainty on both biomass and energy yields. AEA quote *"Current average yield is estimated to be 10odt/ha/y for miscanthus and 9 odt/ha/y for SRC willow [from mature stock*]". See ADAS (2008), Aylott (2008) AEA (2011). DECC suggests 10 odt per ha per year yield for short rotation for coppice (SRC) and 15 odt per ha per year for miscanthus but give no sources to verify this.

However these are UK average yields. ADAS (2008) has produced 5km square yield maps for SRC and miscanthus. Analysis of their results suggests miscanthus yield in Winchester will be below average whilst average for SRC willow.

For the purpose of this analysis it was assumed that yields in Winchester will be 9 odt per ha per year for willow and 7 odt per year per ha for miscanthus.

Energy yield estimates seem to be the more certain with most authors agreeing on 17GJ per odt for willow and 16GJ for miscanthus. The Biomass Centre (2012a) report yields of 4.1 MWh per tonne (14.76 GJ per tonne) for willow and 3.9MWh per tonne (14GJ/tonne) for miscanthus based on a number of field trials.

Biomass Centre data has been used in this analysis.

The result of our analysis is presented in the following tables.

Farmland Type in Winchester District	Total Area (Ha)	Proportion Available for Energy Crops	Energy Crop Area (Ha)
Arable	8,908	5%	445
Cereal	17,428	5%	871
Grassland	13,736	0%	0

Table 17: Energy crop land availability

	Planting split	Area (Ha)	Yield	Feedstock Available	Energy Yield	Energy Produced	
		Ha	(Tonnes/Ha)	(Tonnes)	(GJ/Tonne)	GJ	GWh
SRC	75%	988	9	8,888	14.76	131,194	36.4
Miscanthus	25%	329	7	2,304	14.04	32,354	9

Table 18: Energy production from energy crops

Assuming a 75:25 split between SRC and miscanthus (as miscanthus yields are lower) 45.4 GWh will be available from energy crops grown in the District (Table 17 & Table 18).

Energy Crops	Primary Power	Combined Heat and Power		Electricity Only	Heat Only	Combined Heat and Power		Electricity Only	Heat Only
Product type	MW	MW_e	MW_{th}	MW_e	MW_{th}	Gwh_e pa	GWh_{th} pa	Gwh_e pa	GWh_{th} pa
SRC	4.2	1	2	1.7	3.3	9.1	17.5	14.6	29.2
Miscanthus	1	0.3	0.5	0.4	0.8	2.2	4.3	3.6	7.2
	5.2	1.3	2.5	2.1	4.1	11.3	21.8	18.2	36.4

Table 19: Delivered energy potential from crops

As shown in Table 19 Energy Crops could deliver 33.1 GWh from CHP, or 18.2 GWh of electricity or 36.4 GWh of heat.

This could potentially reduce GHG emissions in the District by between 8-11,000 tonnes CO_{2e} (Table 20).

Energy Crops	CO_{2e} Reductions (Tonnes)			
	Combined Heat and Power			
	Power (Tonnes CO_{2e})	Heat (Tonnes CO_{2e})	Power Only (Tonnes CO_{2e})	Heat Only (Tonnes CO_{2e})
SRC	5408.8	3921.6	8654.1	6536.1
Miscanthus	1333.9	967.1	2134.2	1611.9
	6,743	4,889	10,788	8,148

Table 20: Emissions reduction potential from energy crops

As with other biomass systems there is the issue of mismatched demand and supply. Whilst wood based fuels are more energy dense than straw or poultry litter (in terms of GJ $tonne^{-1}$), combustion in CHP facilities will require the movement of some 11,000 tonnes of fuel (35 - 400 lorry loads). Whilst not insurmountable it reduces the attractiveness of the fuel. It is unlikely that small scale (1 MW) power stations could be constructed on energy crop farms therefore its use may be restricted to smaller scale biomass burning (homes and industry) in areas close to the farms. DECC indicate costs for this form of biomass will be in the range 4.3 – 10p KWh which is similar to electrical resistive heating and oil fired systems.

7.6 Agricultural Arisings

Agricultural arisings (aka Dry Agricultural residues) are simply dry waste agricultural products that are suitable for incineration (wet wastes are dealt with in the following section on Anaerobic Digestion). In Winchester there are two sources:

- Straw. DECC methodology suggests all sources of straw (wheat, barley, oil seed rape etc.) are suitable for incineration. However both AEA (2011) and NNFCC confirm that OSR straw is not suitable due to its composition and difficulty in harvesting. OSR straw is therefore excluded.
- Poultry Litter. DECC methodology does not include Poultry Litter incineration but several others (AEA 2011, NNFCC 2009b) have pointed out that it is a potentially large source of renewable energy and is included in this analysis.

Although a waste product, both AEA (2011) and ADAS (2008) have pointed out that straw has several alternative uses such as animal bedding and feed and cannot all be considered for energy use. AEA estimate that 42% of straw is used in this way and therefore will not be available for incineration.

Chicken litter can be sold as high Nitrogen fertilisers but its use seems to be limited (according to AEA and ADAS), although conversations with local Poultry Farmers seem to contradict this.

The main dry agricultural residue available in the UK is straw. Both AEA and ADAS point out that there are also quantities of residue produced during the processing of grains and oils in the

UK. These include wheat milling residues, seed husks (such as pea and bean hulls and oat husks) and other materials and screenings.

These residues were not included in our analysis.

As with energy crops the three key determinants of energy production from dry arisings are the:

- land available (for straw) or numbers of Poultry,
- yield of biomass per Hectare (or per bird for Poultry),
- yield of energy from biomass incineration.

DEFRA[28] data shows that there are 16,917 Hectares of cereal crops in Winchester and 1,091,567 head of poultry. However DECC suggests that only laying birds be included in any assessment. We estimate there to be 480,000 laying birds in Winchester District.

ADAS (2008) indicate that the average harvestable yield of straw in the UK over the past five years is 8.4Mt/y for wheat, 3.2Mt/y for barley and 2.3Mt OSR (total: 13.9Mt/y). However these estimates are significantly different than those from NNFCC (2008) who estimate average straw yields at 3.1 tonnes per Hectare. The lower figure has been used in this analysis.

There are a number of estimates of poultry litter production, the most cited sources are IPCC (2007) and Steffen (1998) who gives a figure of 0.1 kg bird^{-1} day^{-1}. This is in line with estimates given by local poultry farmers.

AEA assume that straw has a calorific value of 18GJ/t and is available at 15% moisture which is consistent with figures from the Biomass Centre and ADAS.

AEA assumes a calorific value for chicken litter on dry weight basis is 19GJ/odt which is similar to DTI (1999) assumptions.

Agricultural arisings						Energy Yield		Energy Potential	
Product type	Resource Availability		Biomass Yield		Tonnes pa	(GJ/Tonne)	Availability	GJ	GWh pa
Straw	16,917	Hectares	3.12	(Tonnes/Ha)	52,806	18	58%	553,897	17.6
Chicken Litter	479,198	Birds	0.1	per bird (kg /day)	17,491	19	73%	242,596	7.7
									25.3

Table 21: Energy potential for dry residues by fuel type

As Table 21 shows, dry agricultural residues represent a significant source of renewable energy with about 26 GWh available as an input to CHP, or power/heat only engines. This is after accounting for 42% of straw production being used in animal feed and bedding. It is also assumed that 27% of poultry in the District are free range and therefore their litter will be unavailable.

[28] For 2009

Dry Residues	Primary Power	Combined Heat and Power		Electricity Only	Heat Only	Combined Heat and Power		Electricity Only	Heat Only
Product type	MW	MW_e	MW_{th}	MW_e	MW_{th}	Gwh_e pa	GWh_{th} pa	Gwh_e pa	GWh_{th} pa
Straw	17.6	4.4	8.4	7	14.1	38.5	73.9	61.5	123.1
Chicken Litter	7.7	1.9	3.7	3.1	6.2	16.8	32.3	27	53.9
	25.3	6.3	12.1	10.1	20.3	55.3	106.2	88.5	177

Table 22: Delivered energy potential from dry residues

Dry residue could deliver an average power of 25.3 MW and deliver between 55.3 – 88.5 GWh of electricity or 106.2-177 GWh of heat. As shown in Table 22 this will lead to substantial reduction in GHG emissions.

Dry Residues	CO_{2e} Reductions (Tonnes)			
	Combined Heat and Power			
	Power (Tonnes CO_{2e})	Heat (Tonnes CO_{2e})	Power Only (Tonnes CO_{2e})	Heat Only (Tonnes CO_{2e})
Straw	22836.0	16557.1	36537.5	27595.2
Chicken Litter	10001.7	7251.7	16002.7	12086.2
	32,838	23,809	52,540	39,681

Table 23: Emissions reduction potential from dry residues

Dry residuals can have a significant impact on emissions (51,000 tonnes in CHP); their combustion will produce significant amounts of particulate matter (i.e. smoke). In addition, both feedstocks are low density and would require transport to CHP facilities. i.e. moving the required mass of straw may require 5,000 lorry movements unless co-located heat demand could be identified. Without CHP emissions savings fall to 49,000 tonnes for on-site electricity production.

In terms of costs, DECC estimate that electricity produced from dry residuals will fall into the range of 12 – 15.6 p Kwh. The nature of the feedstock makes it unsuitable for small scale heat provision (in homes and industry). Therefore its use may be limited to small (1 MW) scale power on-site production or for transport to nearby district heat and/or CHP facilities. DECC estimates that biomass produced heat will be in the range of 4.3 -10p KWh. Whilst this is competitive with oil and electric heating systems it is not with mains based gas. Therefore its use in district heating systems in areas with mains gas will be limited.

7.7 Anaerobic Digestion of plant and animal biomass

AD is a natural process in which microorganisms break down organic matter, in the absence of oxygen, into biogas (a mixture of carbon dioxide (CO2) and methane) and a digestate (a nitrogen-rich fertiliser). The biogas can be used directly in engines for Combined Heat and Power (CHP), burned to produce heat or electricity, or can be cleaned and used in the same way as natural gas or as a vehicle fuel. The digestate can be used as a renewable fertiliser or soil conditioner.

AD is not a new technology, and has been widely applied in the UK for the treatment of sewage sludge for over 100 years. However until quite recently it has not been used here for treating other waste or with purpose-grown crops. Indeed WRAP (2011) reports that there are already 214 AD plants in the UK with a total installed capacity of 170 MW. DECC/DEFRA (2011) is expecting up to 4,000 AD plants to be installed by 2020 and states *"AD is well established in Europe and we see significant potential for increasing uptake in England too. Based on likely waste feedstock resources, AD could deliver between 3–5 Terawatt hours (TWh) of electricity by 2020".*

According to DEFRA (Jan 2009), the UK produces over 100 Mt of organic material per year that could be used to produce biogas which comprises:

- 12-20 million tonnes of food waste (approximately half of which is municipal waste collected by local authorities, the rest being hotel or food manufacturing waste),
- 90 million tonnes of agricultural material such as manure and slurry,
- 1.73 million tonnes of sewage sludge.

There are four main resources that could be exploited for biogas in the UK: animal manures, food and green waste, agricultural arisings and sewage sludge; although landfill gas is also produced by AD and its use is discussed in section 7.9.1.

7.7.1. Animal Manure

Manure consists of animal excreta with the main sources being Cattle, Pigs and Poultry. Sheep manure can be used but difficulty in collecting the waste makes it impractical to use.

The DECC methodology (2010) ignores the use of poultry litter as an AD feedstock whilst others such as AEA (2011) Anderson (2010), Steffan et al (1998), DEFRA (2005) all see it as a valuable AD input. The debate revolves around the Ammonia content of poultry litter which can slow down digestion. However recent experience in the US, Austria and Italy indicates that when mixed with food and straw waste poultry litter is an effective feedstock - Molinuevo (2007).

The critical factors determining AD energy potential are:

- The number of animals in Winchester.
- The amount of digestible biomass they produce and how much can be collected. Digestible biomass is known as the Volatile Solids (VS) content.
- The rate at which this can be converted into methane. This is measured by the bio-degradability factor (B_o)

DEFRA produce detailed statistics on animal numbers in the District. A number of sources provide estimates of VS production and B_o amongst then DEFRA (2005) and IPCC (2007). DEFRA's manure management guide gives good indications of the amount of manure that can be collected. IPCC (2007) also provides data. DECC and AEA suggest that AD is only 75% efficient at converting the B_o potential to methane. The results are shown in Table 24.

		B_o	Volatile Solids					Methane Production		Calorific Value of Methane	Energy Potential	
	Numbers	$m^3 CH_4\ kg^{-1}$ VS	kg day $^{-1}$	Tonnes VS year $^{-1}$	% of Year Housed	% of Housed Manure collectable	AD Conversion Efficiency	(CH_4 /m ^{3} pa)	Tonnes CH_4 pa	(MJ/m ^{3})	GJ	GWh
Dairy Cattle	6,686	0.24	5.1	12,445	59%	66%	75%	872,304	593	37.4	32,624	9
Beef Cattle	11,383	0.17	2.7	11,218	50%	18%	75%	128,731	88	37.4	4,815	1.3
Pigs	12,455	0.45	0.49	2,227	90%	33%	75%	223,279	152	37.4	8,351	2.3
Poultry	479,198	0.32	0.1	17,491	73%	100%	75%	3,064,376	2,084	37.4	114,608	31.8
											160,397	44.6

Table 24: Energy potential from animal waste AD by fuel source

The potential of animal waste AD as a renewable fuel source is clear from Table 23 and Table 24. AD will produce 4.3 million m ^{3} of methane with 75% of this coming from poultry litter. This will provide an input energy of 44.6 GWh.

Animal waste AD	Primary Power	Combined Heat and Power		Electricity Only	Heat Only	Combined Heat and Power		Electricity Only	Heat Only
Product type	MW	MW_e	MW_{th}	MW_e	MW_{th}	Gwh_e pa	GWh_{th} pa	Gwh_e pa	GWh_{th} pa
Dairy Cattle	1	0.3	0.5	0.4	0.8	2.3	4.3	3.6	7.2
Beef Cattle	0.2	0	0.1	0.1	0.1	0.3	0.6	0.5	1.1
Pigs	0.3	0.1	0.1	0.1	0.2	0.6	1.1	0.9	1.9
Poultry	3.6	0.9	1.7	1.5	2.9	8	15.3	12.7	25.5
	5.1	1.3	2.4	2.1	4	11.2	21.3	17.7	35.7

Table 25: Delivered energy potential from animal waste AD

The bio-methane when used in a CHP engine could deliver an average of 3.7 MW (or 32.5 GWh). In a heat only engine the output would exceed 35 GWh.

The anaerobic digestion of animal waste has a considerable impact on GHG emissions. Clearly the bio-methane produced can be used to displace fossil fuelled heat and electricity as is seen in all biomass sourced energy production. This is shown in Table 25.

Gross reductions show the impact of using the bio-methane produced to substitute for electricity and heat produced from fossil fuels. However as DECC (2012) points out, burning bio-methane is not carbon neutral. Bio-methane has an emissions factor of 0.0976 kg kWh $^{-1}$. The effect of this is shown in the net reductions columns.

Animal Waste AD	CO_{2e} Reductions (Tonnes)							
	Gross CO_{2e} Reductions (Tonnes)				Net CO_{2e} Reductions (Tonnes)			
	Combined Heat and Power				Combined Heat and Power			
	Power (Tonnes CO_{2e})	Heat (Tonnes CO_{2e})	Power Only (Tonnes CO_{2e})	Heat Only (Tonnes CO_{2e})	Power (Tonnes CO_{2e})	Heat (Tonnes CO_{2e})	Power Only (Tonnes CO_{2e})	Heat Only (Tonnes CO_{2e})
Product type								
Dairy Cattle	1345.0	975.2	2152.0	1625.3	1123.9	550.7	1798.3	917.9
Beef Cattle	198.5	143.9	317.6	239.9	165.9	81.3	265.4	135.5
Pigs	344.3	249.6	550.8	416.0	287.7	141.0	460.3	234.9
Poultry	4725.0	3425.9	7560.0	5709.8	3948.4	1934.7	6317.4	3224.4
	6,613	4,795	10,580	7,991	5,526	2,708	8,841	4,513

Table 26: Emissions reduction potential from Animal Waste AD

Thus bio-methane produced from animal waste could reduce GHG emissions by between 4,513 tonnes CO_{2e} (if used to provide heat only) and 7,755 tonnes CO_{2e} (if burnt in a CHP).

But there is also a second order effect. Animal waste will, under the right conditions, undergo anaerobic digestion naturally and produce significant furtive methane emissions. According to the IPCC (2007), methane is a potent GHG with a global warming potential 25 times that of carbon dioxide over a 100 year period. However over 20 years, methane is 72 times more potent with one tonne of methane having a GWP of 72 tonnes of carbon dioxide.[29]

According to DEFRA (2005) and IPCC (2007), of the animal slurry stored in slurry lagoons and left in straw beds will naturally undergo anaerobic conversion to methane. It is possible to estimate the amount of methane produced via these effects.

Any animal manure that is removed from the natural environment will not be able to decay in this way and therefore will result in the reduction of furtive methane emissions. This effect is shown in Table 27.

Reduction in furtive emissions								
Methane Substitution	Volatile Solids	Proportion of Manure as slurry	Methane Conversion Factor	Bo	Furtive Methane Emissions	Emissions from bio-methane combustion		
							20 Years	100 Years
	Tonnes Year $^{-1}$			$m^3 CH_4\ kg^{-1}\ VS$	Tonnes		Tonnes CO_{2e}	Tonnes CO_{2e}
Dairy Cattle	12,445	31%	0.39	0.24	361	993	25,007	8,035
Beef Cattle	11,218	6%	0.39	0.17	45	123	3,090	993
Pigs	2,227	30%	0.39	0.45	117	323	8,121	2,609
Poultry	17,491	0%	0					
					Total	1,438	31,871	7,289

Table 27: Reduction in furtive emissions

Here total Volatile Solids (VS) from each animal source is shown. DEFRA (2005) and IPCC (2007) have calculated the proportion of VS stored in conditions that will lead to methane generation under typical manure management regimes. Both DEFRA and IPCC also assessed the percentage of stored slurry that will convert to methane. The B_0 is then used to calculate furtive emissions for stored manure.

AD of the slurry prevents these emissions by conversion of VS into bio-methane which is then burnt to produce heat/electricity. This combustion produces some net GHG emissions which are shown in column 7. The final two columns show the furtive emissions that will be avoided (per year) in terms of CO_{2e}. As can be seen, the effect is significant with the second order effect as large as the first order GHG savings.

[29] The difference is due to the fact the half-life of methane is about 12 years (IPCC 2007)

7.7.2. AD of plant waste

Several sources of feedstock can be used as an input into anaerobic digesters including food and green waste, agricultural arisings and sewage sludge. DECC methodology only considers sewage sludge however others e.g. AEA, NNFCC and WRAP have pointed out the opportunities of using plant waste as an AD feedstock either on a standalone basis or mixed with animal waste. Indeed recently in its AD strategy and action plan, DECC and DEFRA (DECC/DEFRA 2012) also demonstrate that plant waste is a suitable feedstock for AD, particularly when mixed with animal waste. As Molinuevo (2007) and Steffan have pointed out, mixing animal waste (particularly poultry litter) with plant waste can improve AD efficiency.

Waste organic matter	Resources Availability	Bio-mass Yield	Tonnes	Alternative Uses	Total Solids	VS as % of TS	B_o	Methane Production
Product type	Ha	Tonnes Ha^{-1}					$m^3 CH_4\ kg^{-1}$ VS	$CH_4\ m^3$ pa
Silage	13,736	3.12	42,876	75%	17.50%	90%	0.56	945,416
Food & green waste			15,594	50%	10.00%	80%	0.55	343,068
Straw	16,917	3.12	52,806	42%	70.00%	90%	0.4	7,754,565
Sewage Sludge			2,567		100.00%	100%	0.224	574,933

Table 28: Biogas potential from waste organic matter

Table 28 shows the feedstock availability in Winchester for a selection of waste organic matter and its potential for conversion into bio-methane. Silage is produced from the District's grasslands which DEFRA report as covering 13,736 ha. Straw (Wheat and Barley but excluding oil reed rape) is produced (as discussed in the section on agricultural arisings from the District's 16,917 ha of cereal and arable land. Yields are from NNFCC (2008)[30].

Food waste data is from WRAP, ADAS, 2009 and NNFCC on food and green waste availability. Analysis combines food waste from household, commercial and industrial premises and agro-industrial sites. WRAP (as reported in AEA 2011) assume that the UK produces over 20 Mtonnes of waste from these sources:

- Food waste[31]: 18 M tonnes $year^{-1}$ including :
    - Domestic food waste (6.7 Mtonnes $year^{-1}$)
    - Commercial and industrial waste (5.7 M tonnes $year^{-1)}$
    - Food service and restaurants (3 Mtonnes $year^{-1}$) (NNFCC 2010)
- 2.3 M tonnes $year^{-1}$ of green waste, which is mainly grass and soft biodegradables[32]

[30] Little verifiable data could be found on Silage yields and alternative uses. Therefore assumptions here should be treated with caution.

[31] WRAP (2008) reports food waste amounting to around 18-20 million tonnes each year, of which 6.7 million tonnes is discarded from UK households. According to NNFCC (July 2009), the commercial and industrial sector contribute 1.6 Mt from retailers, 4.1 Mt from food manufacturers and 3 Mt from food service and restaurants.

[32] Garden waste is typically around 13-14% of the total MSW; whereas food waste is typically 18% (DEFRA, 2007)

Food waste from households in Hampshire is mainly collected for incineration at the county's three energy from waste sites and is not available for AD.

Therefore it is assumed that domestic food waste is not available. AEA assume that 55% of the remaining waste will be available for collection (mainly from commercial and green waste collections).

AEA report that currently around 12 AD plants are in operation, mainly in England, that use food waste.

It is understood that processing food waste in an AD plant requires additional pre-treatment (pasteurisation) prior to adding to the feedstock. On that basis it may not be sensible to add the food waste to all AD plants in the area. Restricting the commercial food waste collections to those areas with a high concentration of material to supply may be a sensible compromise. It is noted that food manufacturing process plants are a good source of food waste and that the commercial bakery in Eastleigh could be a welcome participant in such a plan. The factory is on the North East side of Eastleigh which places it in reasonable proximity to dairy and poultry farms that could participate in a community waste processing scheme of this kind.

Energy potential of waste organic matter AD (Winchester District)						
Waste organic matter	Methane Production		Calorific Value of Methane	Energy Potential		
Product type	CH_4 m^3 $year^{-1}$	Tonnes CH_4 $Year^{-1}$	MJ m^{-3}	GJ	GWh	MW Primary
Silage	945,416	643	37.4	26,519	7.37	0.8
Food & Green Waste	410,191	279	37.4	8,438	2.34	0.3
Straw	7,754,565	5273	37.4	169,005	46.95	5.4
Sewage Sludge	574,933	391	37.4	21,503	5.97	0.7
				225,463	62.6	7.1

Table 29: Energy potential of plant waste AD (Winchester District)

At 62.6 GWh per year, plant waste AD offers some considerable opportunity for Winchester however the majority of this comes from AD of straw. As seen in the section on agriculture arising, this same mass of straw can produce 153.6 GWh if incinerated. However incineration will not produce high quality digestate that can be used for fertiliser. Also straw is a difficult produce to transport; its conversion into liquefied bio-methane at or near source and subsequent transport of the bio-methane to a CHP plant in City centres (where there is a base-load of heat), may lead to an overall better efficiency. Liquefaction of bio-methane is an area that needs to be examined in greater detail.

Plant waste AD	Primary Power	Combined Heat and Power		Electricity Only	Heat Only	Combined Heat and Power		Electricity Only	Heat Only
Product type	MW	MW_e	MW_{th}	MW_e	MW_{th}	Gwh_e pa	GWh_{th} pa	Gwh_e pa	GWh_{th} pa
Silage	0.8	0.2	0.4	0.3	0.7	1.8	3.5	2.9	5.9
Food & Green waste	0.3	0.1	0.1	0.1	0.2	0.6	1.1	0.9	1.9
Straw	5.4	1.3	2.6	2.1	4.3	11.7	22.5	18.8	37.6
Sewage Sludge	0.7	0.2	0.3	0.3	0.5	1.5	2.9	2.4	4.8
	7.2	1.8	3.4	2.8	5.7	15.6	30	25	50.2

Table 30: Delivered energy potential from plant waste AD

In terms of delivered energy plant waste AD could provide as much as 45.6 GWh as used in CHP or as little as 25 GWh in an electricity only generator. This again underlines the need of trying to match biomass source location to demand location, i.e. straw based farm produced bio-methane electricity will deliver 18.8 GWh; that same bio-methane compressed and transported to a nearby heat demand could deliver 34.2 GWh in a CHP.

Animal Waste AD	CO_{2e} Reductions (Tonnes)							
	Gross CO_{2e} Reductions (Tonnes)				Net CO_{2e} Reductions (Tonnes)			
	Combined Heat and Power				Combined Heat and Power			
	Power (Tonnes CO_{2e})	Heat (Tonnes CO_{2e})	Power Only (Tonnes CO_{2e})	Heat Only (Tonnes CO_{2e})	Power (Tonnes CO_{2e})	Heat (Tonnes CO_{2e})	Power Only (Tonnes CO_{2e})	Heat Only (Tonnes CO_{2e})
Product type								
Silage	1093.3	792.7	1749.3	1321.2	913.6	447.7	1461.8	746.1
Food & Green Waste	347.9	252.2	556.6	420.4	290.7	142.4	465.1	237.4
Straw	6967.7	5051.9	11148.3	8419.8	5822.4	2852.9	9315.8	4754.9
Sewage Sludge	886.5	642.8	1418.4	1071.3	740.8	363.0	1185.3	605.0
	9,295	6,740	14,873	11,233	7,767	3,806	12,428	6,343

Table 31: Emissions reduction potential from plant waste AD

Table 19 shows GHG emissions reduction from Plant waste AD. Again, as in any bio-methane driven technology, total emissions reduction need to be adjusted for the net emissions factor for bio-methane combustion (shown as net reductions).

AD of plant and animal waste offers an opportunity to reduce emissions by 18,000 tonnes. It has a number of advantages over combustion technologies in that:

- It produces valuable digestate which can be used to re-fertilise the biomass used to generate the feedstock i.e. it is a much more closed system.
- There are no emissions of particulate matter (smoke).
- The bio-methane produced can be liquefied on site and transported to centres of heat demand and effectively used in CHP and district heating systems.

The economics of AD are also favourable. DECC estimates that AD produced bio-methane will cost in the range of 2.2 – 13.8p kWh (with natural gas in the range 3.2-4.8p kWh). Thus it is likely to be competitive with mains gas for heat production.

Electricity from AD facilities is expected to cost in the range of 7-17.3p kWh (with fossil fuelled electricity in the range 8.7 - 9.1p kWh). This makes AD one of the most competitive renewable technologies.

7.8 Sewage Gas

AEA estimate that sewage sludge is 4% by dry solids weight and that 18 million tonnes are available across the UK per year. But as Water UK (2010) point out, 66% of sewage sludge is already treated by AD at present, however only “85% of this methane is utilised effectively with the rest being flared”. However DEFRA in its UK Waste Strategy (2007) comment “18% of sewage sludge in England and Wales goes to incineration and the rest goes to farmland (73%), land reclamation (6%), other uses (4%). All methods would benefit from AD of the sludge, except incineration”.

Therefore there is some uncertainty over sewage sludge availability. However as the potential from sewage sludge is so low in Winchester (even assuming 100% availability), any assumptions made here will not have any material impact on overall results.

7.9 Municipal Solid Waste

DECC methodology considers two potential ways of generating energy from solid waste:

- Recovery of energy from solid waste through combustion technologies.
- The use of landfill gas.

As most of Hampshire's (and Winchester's) solid municipal waste is already incinerated at energy from waste sites (Chineham, Marchwood and Portsmouth), this study did not further consider the potential from waste combustion as this is already being done.

In addition Hampshire County Council's integrated waste management strategy[33] has led to the closure of all but one municipal waste landfill site.

However there are a number of closed landfill sites and one operating one (Eastleigh). Whilst the level of organic waste being landfill in Hampshire is now low, historically (up to 2003) most of County's (and by association Winchester's) waste was landfilled. These sites still exist and still produce considerable amount of bio-gas through natural anaerobic digestion of the organic component of the landfill waste.

The landfill (E&W) Regulations 2002 define landfill gas 'as all the gases generated from landfill waste' and consists of methane, carbon dioxide, Oxygen, Nitrogen and Hydrogen Sulphide which accounts for 99.5% of landfill gas volume. The other 0.5% consists of a cocktail of 500 or so trace compounds (volatile organic compounds) which will include metals such as Arsenic, Lead and Mercury (EA2002a).

Our study has identified a number of closed sites. Table 32 and methane emissions map Figure 12 clearly shows their locations.

[33] See http://www3.hants.gov.uk/projectintegra.htm for details.

Location	Operator	Permit Number	Furtive Methane Emissions (2009) Tonnes pa	Status
Tichfield Lane, Wickham (Funtley Landfill)	Land Reclamation Ltd	19840 19939	860	Closed
Botley Road, Shedfield	SITA	19853	465	Closed
Wickham Vineyard Botley Road Shedfield	SITA	19852		Closed
Raglington Farm, Shedfield	SITA	19858	465	Closed
Rear of Raglingtion Farm, Shedfield	SITA	19859		Closed
Sandpit, Wickham, PO17 5AW	SITA	19861	465	Closed
Fair Oak Landfill Site, Eastleigh, Hampshire. SO50 7EA	SITA		777	Open

Table 32: Landfill sites presented with GHG emissions & status

Whilst the Fair Oak site is mainly located in Eastleigh, a small proportion is in Winchester and is therefore included.

The NAEI database indicates that even the closed sites are still significant emitters of methane (3,032 tonnes) and this represents 77,000 tonnes on a CO_2 equivalent basis.

The global warming potential (GWP) of a gas is measured relative to the impact of CO_2. IPCC (2007) rates the GWP of methane as 25 times that of CO_2 over a 100 year period i.e. a tonne of methane released today will have an equivalent global warming effect of 25 times that of 1 tonne of CO_2 release today – measured over a 100 year period. However the GWP of methane over a 20 year period is 72 times that of CO_2.

Thus the impact of the 3,100 tonnes of methane released from landfill today will have as much impact over the next 20 years as 137,000 tonnes of CO_2 released today. Capture of these gases could lead to a significant reduction in Winchester's overall GHG emissions.

Landfill gas can be captured by installing gas management systems at the site. In short, this comprises of sinking a number of boreholes (approximately on a 100 metre grid) across the capped area of the landfill site. The bio-gas is drawn into the boreholes and rises to the surface where it can be piped to:

- A flaring device where the gas can be burnt off to produce less damaging CO2.
- A gas cleaning plant where the bio-gas methane component is isolated and then to
  - A bio-methane fuelled engine to produce heat and/or power.
  - A further processing plant where purer bio-methane can be produced for liquefaction into LNG for onward transport or for injection into the gas main.

However AEA states the main landfill gas (LFG) conversion technology is electricity generation, with no more than 30% efficiency. Combined with the expense of gas processing, this can make an economical unviable option. AEA also points out that the reduction of ROC income through low banding of LFG has further reduced the economic incentive to exploit LFG.

However, as shown in Table 33, landfill gas could generate up to 29.3 GWh per annum. We assume that at the closed sites only 50% of the gas will be collectable due to retrofitting issues. It would be quite possible to collect all the furtive emissions at Eastleigh.

Energy potential from furtive emissions of Landfill Gas						
MH4 emissions potential	Furtive CH_4 Emission	Energy Yield		Energy Potential		
Source	Tonnes	GJ $Tonne^{-1}$	Capture Probability	GJ	GWh	MW Primary
Eastleigh Landfill	777	55	100%	42,735	11.9	1.4
Funtley Landfill	860	55	50%	23,660	6.6	0.8
Bartley Road Landfill	465	55	50%	12,801	3.6	0.4
Raglington Farm Landfill	465	55	50%	12,801	3.6	0.4
Wickham Sandpit	465	55	50%	12,801	3.6	0.4
	3,032				29.3	3.4

Table 33: Energy potential from landfill gas

Depending on the conversion technology used and their efficiencies, this input could deliver between 23.2 and 11.5 GWh (Table 34).

Plant waste AD	Primary Power	Combined Heat and Power		Electricity Only	Heat Only	Combined Heat and Power		Electricity Only	Heat Only
Product type	MW	MW_e	MW_{th}	MW_e	MW_{th}	Gwh_e pa	GWh_{th} pa	Gwh_e pa	GWh_{th} pa
Eastleigh Landfill	1.4	0.3	0.7	0.5	1.1	3	5.7	4.7	9.5
Funtley Landfill	0.8	0.2	0.4	0.3	0.6	1.6	3.2	2.6	5.3
Bartley Road Landfill	0.4	0.1	0.2	0.2	0.3	0.9	1.7	1.4	2.8
Raglington Farm Landfill	0.4	0.1	0.2	0.2	0.3	0.9	1.7	1.4	2.8
Wickham Sandpit	0.4	0.1	0.2	0.2	0.3	0.9	1.7	1.4	2.8
	3.4	0.8	1.7	1.4	2.6	7.3	14	11.5	23.2

Table 34: Delivered energy from landfill sites

Although landfill gas is a viable option at most sites, bio-gas production falls over time and the methane content decreases. As the old sites have been closed for some time, the quality of bio-gas may be low. And as AEA point out "Below about 30% by volume methane, energy recovery becomes problematic, and below about 17% the landfill gas cannot be flared without a pilot fuel. Most landfill gas energy schemes have a life of about 5-10 years".

The AD process within landfill sites generates significant amounts of heat. Core temperatures within capped sites can reach 50°C. It may be possible to use this heat as a source for heat pumps, allowing for a substantial amount of useful heat to be extracted at a good co-efficient of performance levels. This could be considered as a particular opportunity in the closed site near Knowle where a hospital and local community could benefit from elevated supply temperatures for a community ground source heat pump system. This will be discussed later in this report.

Landfill gas Site location	CO_{2e} Reductions (Tonnes)							
	Gross CO_{2e} Reductions (Tonnes)				Net CO_{2e} Reductions (Tonnes)			
	Combined Heat and Power				Combined Heat and Power			
	Power (Tonnes CO_{2e})	Heat (Tonnes CO_{2e})	Power Only (Tonnes CO_{2e})	Heat Only (Tonnes CO_{2e})	Power (Tonnes CO_{2e})	Heat (Tonnes CO_{2e})	Power Only (Tonnes CO_{2e})	Heat Only (Tonnes CO_{2e})
Eastleigh Landfill	1762	3383	2819	2129	1472	2827	2356	1202
Funtley Landfill	975	1873	1561	1179	815	1565	1304	666
Bartley Road Landfill	528	1,013	844	638	441	847	706	360
Raglington Farm Landfill	528	1,013	844	638	441	847	706	360
Wickham Sandpit	528	1,013	844	638	441	847	706	360
	4,321	8,295	6,913	5,221	3,610	6,932	5,777	2,948

Table 35: Emissions reduction from the use of landfill gas

The use of bio-methane from landfill could reduce CO_{2e} emissions by between 8,075[34] – 4,513 tonnes per annum. However this effect is negligible compared to the reduction in furtive methane emissions which would amount to 137,000 tonnes per annum reduction over the next 20 years, even if only 50% of the emission were captured.

7.9.1. Landfill gas harvesting – notes on practical delivery

In simple terms, the harvesting operation involves a process to extract methane from the organic matter using boreholes to vent and capture the methane produced by anaerobic digestion within the site. Drilling the boreholes requires some specialist methods to ensure that risks of exposure to contaminated matter is minimised; many closed landfill sites contain asbestos. There is also the consideration that methane pockets could be disturbed and released suddenly in an uncontrolled manner which would increase the risk of fire.

The process of constructing boreholes in landfill sites has been adopted in a significant number of sites in the UK. The cost of drilling and lining such boreholes is well understood and it would be possible to install such wells at a rate of 140 – 160 m/week based on a typical depth in sand pits of around 20 - 30m. The cost to drill a well of this type would be in the order of £80 - £100 per metre. We have assumed that a typical operation would require wells to be sunk at 50m spacing (40m spacing at the boundary). Drilling and installation of boreholes in a landfill site with dimensions 600m x 600m x 20m might therefore cost approximately £350k.

More invasive and innovative methods are being developed. One such method would 'mine' the area to extract waste material, recycle all that can be recovered in a useful form, and subject the remainder to intense heat (plasma). Heating the organic matter to 850°C in a contained environment liberates most of the methane in a controlled process without significant loss of gas to atmosphere. A plant which adopts the plasma vaporisation approach is being built in Houthalen-Hechteren, Belgium.

Tapping, collection and burning the methane are the primary benefits to be considered. Even if this means that the heat from local methane combustion is not put to useful work. This process

[34] Interestingly the use of bio-methane in CHP results in a lower net overall CO_2 saving than its use in electricity only plants.
This is due to electricity emission factors being much higher than heat (produced from natural gas) emission factors.

will have a significant benefit on the CO_{2e} emissions for the District of Winchester. The detail of what is required to undertake this crude form of methane emissions abatement have not been explored in detail within the scope of this study.

When the infrastructure is in place to collect the methane from these sites there will be a far higher potential to explore the feasibility of using the biogas to fuel heat engines. If appropriate, the heat engines could be situated on site but there may be more advantage in liquefying the gas for use at remote locations that are not served by the mains gas network. Unfortunately, it seems unlikely that the supply will be viable for many more years from the closed landfill sites. However, there is still a case to explore in the Eastleigh site, subject to confirmation on the type of waste that forms the on-going fill at that site.

7.9.2. Commercial & Industrial waste product

As DECC states in their methodology *"The potential for C&IW energy development is harder to assess as there is no central data holding. This would need to be explored through regional intelligence on C&IW producers*."

AEA and LUC both report that the largest source is waste wood from construction and demolition but present no recent data. In a recent report CONFOR (2010) summed this up as *"Estimates of the size of the waste wood market vary quite considerably, indicating that there are considerable uncertainties about the true size of the market because of the lack of accurate information about the quantity of material going into the different waste streams."*

However WRAP (2009), in their report on Wood Waste Market in the UK, state that waste wood production in the SE England is:

SE England Waste Wood	Kilo Tonnes pa
Packaging	162.7
Industrial	64.3
Construction	150.8
Demolition	190.7
Municipal	57.6
Total waste	626.1

Table 36: WRAP wood waste figures for SE England (2009)

They also state that of the 4.6 M tonnes per year that is produced in the UK, 1.2M tonnes go to the panel board industry and a further 0.7 M tonnes to other uses leaving 3.5 M tonnes going to waste. Pro-rating these figures for Winchester (by population) suggest 8,141 tonnes of waste wood is produced in the area per year.

WRAP also state that 36% of waste wood is recycled into other uses (such as panel boards and animal bedding).

Incineration of this wood (assuming it is all collectable) will generate 26 GWh per annum as shown in Table 37.

C&I wood waste for burning	Wood waste in Winchester District	Energy Yield		Energy Produced		Primary Equivalent
	Tonnes pa	GJ/Tonne	% Available	GJ	GWh	MW
Wood Waste	8141	18	64%	93,533	26	3

Table 37: Energy potential from C&I wood waste (Winchester District)

This could deliver between 19 – 20.8 GWh (Table 38).

Commercial & Industrial	Primary Power	Combined Heat and Power		Electricity Only	Heat Only	Combined Heat and Power		Electricity Only	Heat Only
Product type	MW	MW_e	MW_{th}	MW_e	MW_{th}	Gwh_e pa	GWh_{th} pa	Gwh_e pa	GWh_{th} pa
Wood Waste	3.0	0.7	1.4	1.2	2.4	6.5	12.5	10.4	20.8
	3.0	0.7	1.4	1.2	2.4	6.5	12.5	10.4	20.8

Table 38: Delivered energy from C&I wood waste

This would reduce CO_2e emissions by between 4,600 and 6,400 tonnes per annum (Table 39).

Commercial & Industrial	CO_{2e} Reductions (Tonnes)			
	Combined Heat and Power			
Product type	Power (Tonnes CO_{2e})	Heat (Tonnes CO_{2e})	Power Only (Tonnes CO_{2e})	Heat Only (Tonnes CO_{2e})
Wood Waste	3856.1	2795.9	6169.8	4659.8
	3,856	2,796	6,170	4,660

Table 39: Emissions reduction potential for C&I wood waste

Waste wood is relatively energy dense (*c*18 GJ $tonne^{-1}$) and compact and therefore can be transported more efficiently than some other biomass fuels. This makes the fuel suitable for use in CHP and district heating as it can be moved from source to an area of heat demand.

DECC estimate that dedicated biomass electricity will cost between 12 -15.6p kWh and heat in the order of 6.5 -15.9p kWh, whilst waste wood may not be competitive on a stand-alone basis as it could be when used in CHP.

7.10 Bio Fuels

The DECC methodology examines biofuels resources from first generation biofuels crops (wheat, sugar beet for bio-ethanol and oil seed rape for biodiesel) and the two other feedstocks for biodiesel which are tallow and used cooking oil. As bio-ethanol is used exclusively for transport it is outside the scope of this study.

Initially it was thought that bio-diesel use is limited to the transport sector as well. However a recent report from NNFCC (2011) Evaluation of Bioliquid Technologies for Dedicated Heat Generation which *"considered bioliquids which have the potential to be used as heating fuel, ….. e.g. vegetable oil, biodiesel and, to a lesser extent, tallow"* indicates that bio-diesel could be a low carbon replacement for heating oil.

The combustion of heating oil contributes to about 97,000 tonnes of CO_2 (DECC 2011) emissions in the District. Replacing some or all of this oil with bio-diesel would substantially reduce this total.

In the UK bio-diesel is produced from oil seed rape (OSR), tallow and used cooking oil. However large areas of land are required to grow the crops required.

DEFRA (2012) statistics show that OSR yields in the SE England are 4 tonnes per Hectare and, with 5% of the cereal and arable land planted with OSR Winchester, could produce 5,263 tonnes of bio-diesel from this source.

AEA indicate the total quantity of tallow produced in UK is 200,000-290,000 tonnes. We assume 250,000 tonnes in this study and pro-rata this to Winchester by population. They also indicate the main sources of used cooking oil (UCO) are "catering, food factories and households. The latter represents the greatest resource, but would need to be collected separately from households if it is to be used".

This is a view supported by WRAP (2008) who find that the quantities of UCO produced in each of these sectors are:

- Catering: 108,000 tonnes $year^{-1}$
- Food factories: 20,000 tonnes $year^{-1}$
- Households: up to 130,000 tonnes $year^{-1}$

Again pro-rating these data for Winchester by population gives a feedstock availability of 550 tonnes of bio-diesel from Tallow and a further 458 tonnes from UCO.

These assumptions lead to the conclusion that Winchester District could produce 30.7 GWh from bio-fuels as a heating oil replacement.

Energy potential of Biofuel (Winchester District)							
Waste organic matter	Land resource	Yield	Feedstock Production	Energy Yield	Energy Potential		
Product type	Ha	Tonnes/Ha	Tonnes pa	GJ/Tonne	GJ	GWh	MW Primary
Biodiesel from OSR	1316.8	4.0	5262.7	14.6	76835.7	21.3	2.4
Tallow			458.3	34.5	15794.2	4.4	0.5
Used Cooking Oil			458.3	39.3	18012.5	5.0	0.6
						30.7	3.5

Table 40: Energy potential for Bio-fuel heating oil replacement

This type of fuel could deliver between 12.3 – 24.6 GWh. However if used at all bio-fuels would be used in domestic and industrial boilers as a heat only application, and therefore delivering 24.6 GWh as seen in Table 41. CHP and power figures are shown for comparison purposes only.

Bio-fuel	Primary Power	Combined Heat and Power		Electricity Only	Heat Only	Combined Heat and Power		Electricity Only	Heat Only
Product type	MW	MW_e	MW_{th}	MW_e	MW_{th}	Gwh_e pa	GWh_{th} pa	Gwh_e pa	GWh_{th} pa
Biodiesel from OSR	2.4	0.6	1.2	1.0	1.9	5.3	10.2	8.5	17.1
Tallow	0.5	0.1	0.2	0.2	0.4	1.1	2.1	1.8	3.5
Used Cooking Oil	0.6	0.1	0.3	0.2	0.5	1.3	2.4	2.0	4.0
	3.5	0.9	1.7	1.4	2.8	7.7	14.8	12.3	24.6

Table 41: Delivered energy as a bio-fuel for displacement of heating oil

On the same basis, the use of 5% of the District's arable and cereal land and available tallow and UCO could reduce CO_{2e} emissions by 5,500 tonnes per annum.

Bio-fuel	CO_{2e} Reductions (Tonnes)			
	Combined Heat and Power			
Product type	Power (Tonnes CO_{2e})	Heat (Tonnes CO_{2e})	Power Only (Tonnes CO_{2e})	Heat Only (Tonnes CO_{2e})
Biodiesel from OSR	3167.8	2296.8	5068.4	3828.0
Tallow	651.2	472.1	1041.9	786.9
Used Cooking Oil	742.6	538.4	1188.2	897.4
	4,562	3,307	7,298	5,512

Table 42: Emissions reduction potential of bio-fuel as a replacement for heating oil

Bio-diesel will only be used as a heating oil replacement therefore will be a heat only fuel. On this basis it will deliver about 5,500 tonnes of savings. However devoting the same land area to energy crops would save an additional 5,600 tonnes. This suggests that energy crops are a more carbon efficient way of emissions reduction. In addition, with bio-diesel costing 7.6 -12p KWh (as against heating only at 5.8p kWh), it is unlikely to be cost effective without RHI support.

7.11 Solar energy

Ambient fuel is a flow of energy from either the sun (solar energy) and to all intents and purposes is fully renewable.

Solar energy is also the primary source that drives wind and hydrological energy sources, both of which can be captured for conversion into electricity.

7.11.1. Direct Solar Thermal

At its peak, incident solar radiation in the UK is about 1000 W/m^2, however the average is closer to $100W/m^2$ (NASA 2010). Solar thermal panels can convert this energy to low grade heat at about 50% efficiency (about 50 W/m^2) and about 25 times more efficiently than biomass conversion.

There are clear advantages in that the heat is generated close to the point of use, the technology is relatively cheap to build, install and maintain, and it can use marginal or otherwise used land area (e.g. roofs).

However there are clear disadvantages in terms of predictability and load matching. The sun is often not shining when heat is required (in the winter and at night) and it is difficult to predict. However heat storage can overcome short term fluctuations. Fortunately storing heat is far cheaper and easier than storing electricity. There is considerable interest in the use of interseasonal thermal storage solutions and designs are being converted into practical solutions for buildings. However, this study has adopted the approach of load matching based on the national averages for domestic energy use.

Figure 19 indicates that 17% of domestic energy demand is for heating water (DHW). Given that domestic energy use in the District (excluding transport) is 960GWh pa (Figure 6), we might assume that hot water accounts for 163 GWh pa. If this demand could be synchronised to the availability of solar energy, there would be an excellent opportunity; saving 36.6 ktonnes pa of CO_{2e} emissions.

Sadly, the rate of demand is not constant per day or aligned with the availability of solar energy. Large thermal storage can help to some extent, but in reality it may be difficult at a District level to achieve much more than 10% of the domestic hot water demand from solar thermal. The main challenge is that an oversized solar thermal array will stagnate if there is no load for the heat collected and it will then not be productive until the following day (after overnight cooling to condense vapour locks). The DECC methodology indicates that only 25% of domestic dwellings are compatible for solar thermal. On that basis we might draw the conclusion that approximately 2.5% of domestic hot water demand in the District could be met by solar thermal, relating to 913 tonnes of CO_{2e} emissions.

Commercial energy profiles in 24 hour facilities are much more constant. The special case of municipal facilities found in Winchester (hospitals, care homes, HM Prison & swimming baths) offer an exception to this rule. In those facilities it would be possible to install large systems that could fully utilise the available solar thermal energy to displace combustion. The level of heating base load can be easily determined for these facilities from monthly or weekly records of heating demand throughout the year. Analysis of such detailed information for specific sites was beyond the scope of this study.

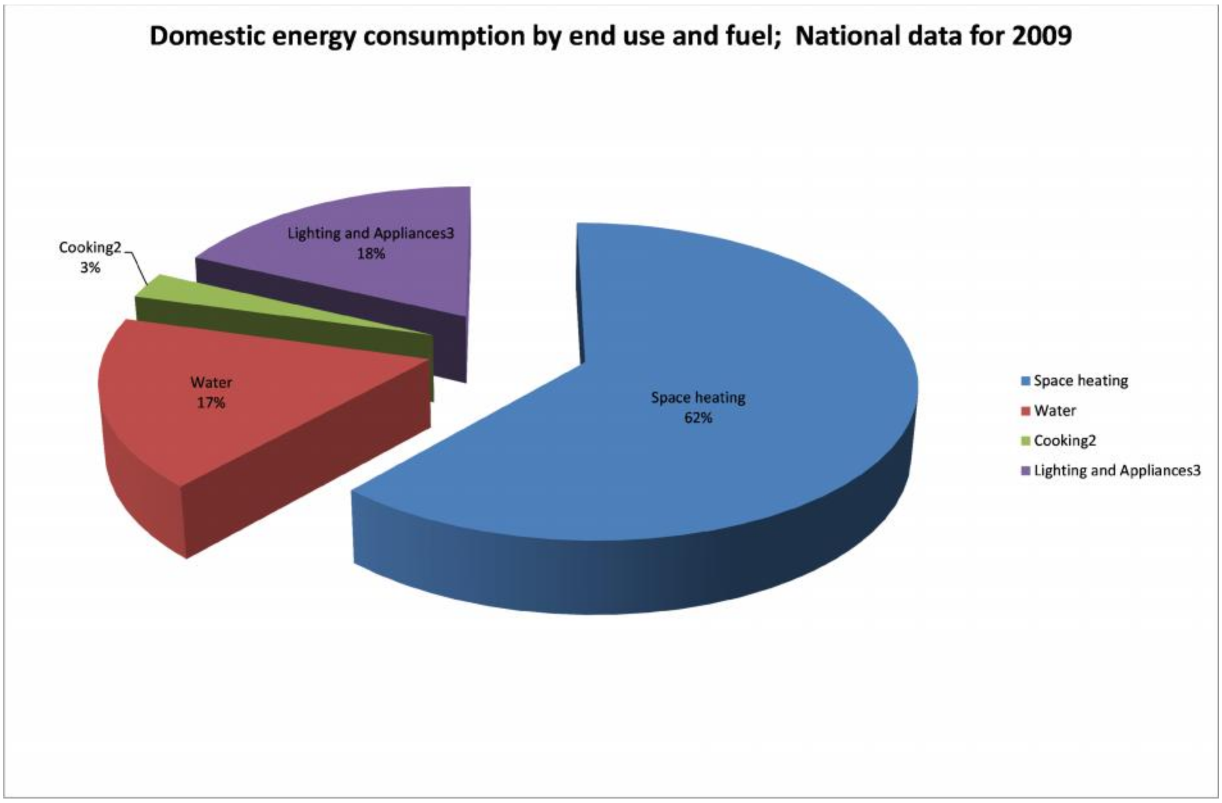


Figure 19: Domestic energy use; National data 2009

Using the NAEI data this study determined commercial heat demand for the two 1km squares that include the hospital and prison. It would be a reasonable assumption that the base load at these facilities is approximately 20% of the annual total for heat and all the ideal roof space is available. The total heat demand from the commercial buildings in the two km squares that cover the hospital and prison is 44 GWh pa. If we assume that 15% is for hot water and this can be used when supplied by solar energy (available at full power for 15% of the time because of 24/7 operations) we would displace fuel demand of 1.8 GWh pa; 395 tonnes of CO_{2e}.

Consider the entire commercial heating load and modifying the logic as for the hospital/prison area because there are relatively few 24/7 operations. Considering Industrial/Commercial use of oil and gas there is a demand for 273.2 GWh pa. If we assume that the DHW part is slightly lower in these buildings (15%) can be met by solar for 30% of the time that would deliver 16.4 GWh pa. However, DECC indicates that only 40% of commercial and 70% of industrial buildings could make use of this resource. Since Winchester is biased towards commercial rather than industrial this study has adopted the lower figure. On that basis 6.6 GWh pa could be delivered from solar for commercial/industrial hot water use; 1.5 kilo Tonne of CO_{2e} emissions.

Solar thermal is not seen as a preferred source of energy by UKERC. Both RAE and MacKay see it playing only a minor role with 1-2% of primary energy input provided by solar thermal conversion. On that basis, supported by the analysis above, it is unlikely to form a significant contribution to the Climate Change Target for Winchester District. However, it should not be dismissed for the specific locations where there is significant base load for hot water; hospital, prison and swimming pools.

In the general case it is considered unlikely that both solar PV and solar thermal will be installed on an available roof space. Also, it is noted that the emissions abatement from these two technologies are broadly similar per unit area. Therefore for the purpose of this study it has been assumed that PV will be installed in the majority of cases since electricity can be more easily delivered to point of demand.

7.11.2. Direct Solar PV

Photovoltaic (PV) materials can be used to convert sunlight into electricity. Efficiencies are lower than for solar thermal (about 10-15%) but are improving over time. However there are fundamental limits to maximum efficiency (about 30% without concentration or 40% with - Azonano 2010).

This study has based the assessment of potential for PV in Winchester District on the land use statistics for 2005. The data is presented in Figure 20 shows the extent of green space in the District and therefore highlights the intensity of energy demand in a relatively small area. This data may prompt further interest in community scale ground mounted PV farms on the south facing hills in the District.

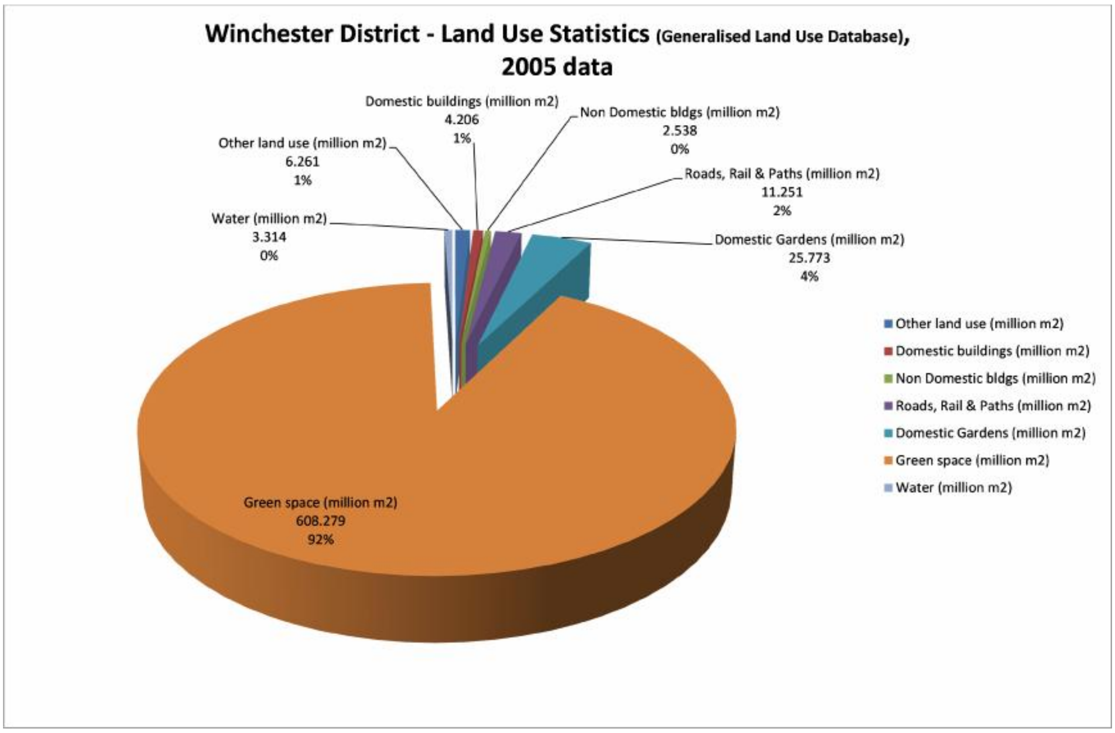


Figure 20: Land use statistics for Winchester District

PV is more expensive than solar thermal but produces electricity which can be transported off-site. Again it suffers similar disadvantages to solar thermal re reliability and predictability. However, costs are falling and in sunnier climates offer a substantial source of primary energy in a highly useable and transportable form.

Both forms of solar energy tend to be high cost (Elliot 2009) with PV particularly so.

Large scale solar PV can also be developed with large solar PC farms covering many hundreds of hectares. However, the combination of high land prices and climate limits opportunities for this in the UK. MacKay suggest that huge farms (of the size of Wales) could be developed in the Northern Sahara to supply some of the UK's needs.

RAE (2010b) suggests solar PV could supply between 3 and 6% of UK energy needs. MacKay's figures are between 2 and 19% with most of this being produced offshore e.g. in North Africa. These are within the ranges suggested by others (CCC, CAT, DECC). UKERC (Strachan et al 2010), however sees no role for solar PV as a primary fuel in the UK.

7.11.3. Large scale community Photovoltaic schemes

It is well documented that the installation of large PV systems is an effective alternative to domestic installations. In terms of cost per watt installed, the prices are approximately half for a 200kWp installation than they would be for a domestic installation. The economies of scale associated with MW scale installations would further enhance the business case.

From Figure 20 it is given that Industrial/Commercial roof space in Winchester District is approximately 2,538,000m^2. DECC methodology indicates potential for installation of solar energy systems to industrial buildings (80%) and commercial buildings (40%). For the purpose of this study it has been assumed that the non-domestic buildings of Winchester District are mostly commercial buildings. It has also been assumed that most of the roof space not already occupied by plant and equipment is of a type that can be devoted to PV.

From a combination of installation experience and industry data sources, a productivity factor of 135kWh/m^2 pa has been established for typical PV installations in Winchester. The potential productivity from PV in the District is therefore calculated as 137GWh pa resulting in a CO_2e emissions reduction of 81 kilo tonnes pa.

7.11.3.a Sarum (radio masts)

Ray's Roost is another local high point from a topographical perspective and the site considered by this study is slightly larger than 0.5 km2. Some details about this site have been discussed in the section on wind power. However, it is also in a strong location from the perspective of solar PV.

The site is already partly industrialised by the installation of radio masts. It is therefore suggested that installation of a large PV installation on this land may be a sensible alternative or complement to wind generation.

It would not be viable to cover the whole area with panels because of shading and access issues. The panels would be mounted on stands fixed into the ground such that the panels had an elevation of 20° with spacing between rows almost equal to the row depth. It may also be necessary to have occasional access routes as columns. As a consequence 40% land coverage has been assumed.

The system would deliver 27GWh pa resulting in 16,700 tonnes of CO_{2e} emissions reduction. The size of this system would total 28.1 MW_p net.

7.11.3.b Heath Green & Hattingley

It is recommended that further dialogue is undertaken with stakeholders in the neighbouring District because this site has far greater potential if there is local community support. The steep topography in this area may present difficulties for agricultural exploitation but the Southerly facing aspect could by ideal for enhancing the conversion of solar power.

A system of the same proportions as the one described for the area of Sarum radio masts could also apply in this location. In reality the system could be much bigger based on the topography but further investigations of grid connection details would be required.

7.11.4. Domestic PV contribution

Most domestic roofs in Winchester District are assumed to be of a pitched form. It is also noted that PV cannot be installed to the edge of the roof space. Therefore approximately half of the building footprint could be used for this purpose.

From Figure 20 it is given that domestic roof space in Winchester District is approximately 4,206,000m^2. DECC methodology indicates potential for installation of solar energy systems to domestic buildings (25%) but geometry adds a further restriction of 50% as stated above. It is assumed that shading issues have already been accounted for in the DECC estimate of potential.

From a combination of installation experience and industry data sources a productivity factor of 135kWh/m^2 pa has been established for typical PV installations in Winchester. The potential productivity from PV in the District is therefore calculated as 74GWh pa resulting in a CO_{2e} emissions reduction of 42,000 tonnes pa.

Assuming that the average household installation is 3kWp this would equate to 24,646 household installations in the District. Economies of scale dictate that the average household installation would cost twice as much as a large community scheme per kWp installed. Combined with the fact that a community scheme can be installed on a roof where the host company will use the electricity generated there seems to be more merit in the large community options.

7.11.5. Practical examples – large Photovoltaic schemes

Ovesco were formed as an IPS in Lewes to install a PV array of around 100kWp on the roof of the roof of a building at the Harvey's brewery. They raised revenue from a share issue that was open for one month in early summer 2011. They raised sufficient funds to undertake the installation and it was commissioned as planned in the same year, prior to changes to the FIT.

Westmill Wind Farm is another example of a co-operative formed for the implementation of community owned renewable energy projects. As the name suggests, this project was initially focused on the installation of wind turbines. However, recent developments at this site have added a large ground mounted PV array which has 5 MWp installed capacity. http://www.westmill.coop/westmill_newsdetails.asp?newsID=48

Arqiva has recently installed a 120kWp installation at Crawley Park. Detailed information about this installation has not been available during the study but may be helpful to advance dialogue around performance from large systems in Winchester.

7.12 Heating of domestic and commercial buildings

It is often the case that conventional central heating systems are designed to run at supply temperatures of 82°C. This design temperature and the desired warm up temperature for a property determine the radiator sizes. On the basis that many systems are designed with oversized radiators to enable short warm up times, it is generally possible to reduce the flow temperature in well maintained central heating systems, periodic system flushing should form part of the PPM regime for heating systems.

The practical minimum temperature is often thought to be 60°C based on the need to minimise the risk from legionella in pipes distributing DHW to outlets. It is not unusual (in a domestic setting) for a system to be run at 50°C when connected to a condensing boiler but periodic pasteurisation at higher temperatures would be advised in these systems. Reducing the operating temperature of a condensing boiler from 82°C to 60°C will deliver an operating efficiency improvement due to waste heat recovery from the flue gas. For the purpose of this study we estimate that such a change in operating conditions would reduce natural gas demand by at least 10%.

For the purpose of this study it is assumed that more than 50% of the installed heating systems fired by natural gas could benefit from running at reduced temperatures. Some will already be operating at 60°C or below and others will not have the condensing heat recovery capability. Although this situation applies equally to commercial as to domestic heating systems, we have assumed that only domestic systems could undertake the change without significant administration. The total domestic gas demand in Winchester results in 133,000 tonnes CO_2 emission pa. Heating of buildings and DHW accounts for more than 96% of that load in the domestic environment (DECC, 2011). A community engagement programme to explain the benefits of lower boiler operating temperatures could be run throughout the District of Winchester. Such an easy win could deliver the potential saving of 6,300 tonnes pa CO_2 emissions pa.

This study has undertaken a thorough review of mapped information and data related to energy intensity at $1km^2$ resolution. Additional searches were undertaken to identify operations with industrial or commercial process equipment that may include potential for waste heat recovery. All of these searches were unable to locate significant sources of high quality heat that is routinely rejected from a process and might therefore be recovered for useful work. On that basis it is considered likely that heat pumps offer significant potential for (ambient) heat recovery in Winchester District.

7.12.1. Heat Pumps

Both the atmosphere and ground have high specific heat capacities. They can, and do, store significant amounts of thermal energy that can be extracted. Heat pumps can extract this heat from either the ground (ground source heat pumps – GSHP) or from the air (ASHP). In addition landfill sites are known to be good sources of heat.

Both are reliant on well proven technology. In essence they are refrigerators running in reverse, that take smaller amounts of electricity to extract heat from the surrounding environment and 'pump' it to where it is required (usually a building). The ratio of heat produced to electricity required is known as the co-efficient of performance (CoP) and is generally in the order of 4-5 i.e. between four to five times as much heat is delivered as electricity used. This is on average lower in an Air Source Heat Pump and the higher performance is more typical of a Ground or Water source system. As well as from this 'free' source of energy, air source heat pumps are easy to install and retro-fit into most buildings.

However, they are relatively expensive to purchase (as compared to gas fired boilers) and require cheap and plentiful sources of electricity. There are also concerns that heat pumps require 3-phase power to achieve maximum efficiencies (DECC 2010).

MacKay and CAT suggest up to 17% of the UK's energy needs could be provided from this source. RAE sees between 6-14%. However UKERC sees little input from this source with a maximum of 2% being provided.

The key operating efficiency criteria with all heat pumps (as with condensing boilers) is to run the delivery temperature at the lowest level possible. Operating any heat pump at these temperatures will degrade the CoP significantly. This operational efficiency trade-off is also true for lower temperatures in the heat source. Therefore Ground Source Heat Pumps perform at a more constant CoP through the heating season.

7.12.1.a Ground Source Heat Pumps (GSHP)

Ground source heat pumps are a well-established and reliable form of heat recovery from renewable sources. Application of this technology has a significant potential to reduce CO_2 emissions and heating costs in areas that are not connected to the mains gas network. It is not unreasonable to anticipate that a well designed and installed system will deliver CoP in excess of 4. Therefore for every 1kWh of electrical energy used by the system 4kWh of heat can be delivered to the householder.

A comprehensive campaign could be implemented to help all households that currently heat with oil or LPG change to GSHP. The approximate cost is per watt installed.

Taking a mid-range example of a 150m^2 domestic dwelling, a GSHP of 11kW would cost in the order of £16k to install a trenched system and £20k to install a borehole system. Taking this concept further to a system that could heat two houses of the same size and the 20kW heat pump installation would cost £22k to install a trenched system and £26k to install a borehole system.

Economies of scale apply so the price for larger systems in commercial applications or connected to a district energy network deliver a better cost per Watt installed capacity. This applies even if the community served is only a few houses because the complexity of a district heat network for a large community would add significant costs. On that basis our sources (commercial) indicate that an installation serving a community of four (4) houses with internal area of 150m^2 each should be possible for £41k (based on a borehole system), however to serve a community with 20 houses or total internal area of 3,000m^2 should be possible for £150k; based on soft dig installations.

The potential reduction in CO_{2e} emissions from wider deployment of GSHP could broadly be assumed as 125% of the figures presented in the ASHP section. The availability of GED GSHP was not identified in this study.

7.12.1.b Air Source Heat Pumps (ASHP)

Air source heat pumps apply the same theory as GSHP but simply draw heat from a less stable environment. The challenge with this form of heating is in the performance delivered when heating is needed most; when it is cold outside! Most systems based on this technology are viable at external ambient temperatures of -15°C and will deliver a CoP of 3 taken as an average throughout the heating season. If operated with high output temperatures or for prolonged periods at cold temperatures the CoP will reduce to less than 2.

ASHP is typically used on smaller applications than GSHP based on the initial capital investment. When considering most applications that are smaller than 150m^2 of heated floor area the ASHP offers a cost effective alternative for most dwellings that are heated with oil or LPG. At the smallest in the range a 5kW system would cost in the order of £8k while an 11kW system would cost around £10k.

On an individual basis ASHP could be deployed in most houses that are currently heated with oil or LPG. This study has been based on more reserved estimates on the basis that many will not make such a change before 2015. Domestic heating oil accounts for almost 37 kilo tonnes of CO_{2e} emissions pa in the Winchester District; approx. 111.1GWh pa. Assuming 85% efficiency of combustion, this equates to 94.4GWh pa of heat input to buildings. Based on an average CoP of 3, this same heat input could be achieved from 31.5GWh pa of electricity via heat pumps; 18.6 kilo tonnes of CO_{2e}. Switching all domestic dwellings that are on oil fired heating to ASHP based systems would save 18.3 kilo tonnes pa.

Considering the commercial application of this technology requires slightly different assumptions. The quantity of oil that is used for heat may be as low as 90% of the total however the conversion rate is likely to be similar to the domestic case. We will neglect insulation losses because, although they may be significant, the scale cannot be quantified with the data available for this study. 187.8GWh pa is supplied for use in commercial and industrial buildings. Adopting the assumptions above we suggest that 77% of this energy is delivered as useful heat; 144.6 GWh pa. This would require an electrical demand of 48.2 GWh pa if delivered using ASHP which would result in 28,600 tonnes of CO_{2e} emissions; a saving of 30,000 tonnes of CO_{2e} emissions. As with all other assumptions it may be more realistic to assume that a 50% adoption rate is the most that could be achieved before 2015 and hence 15,000 tonnes of CO_{2e} emissions could be associated with this change.

The same technology can be applied to improve heating performance where there is an existing mains gas connection. This is an interesting variation and employs some of the waste heat to enhance the efficiency of the ASHP at lower ambient conditions. A typical CoP with these systems is in the range 1.5 – 1.8. When compared to a conventional condensing boiler with a

CoP of 0.9 – 1 under steady state conditions there is a clear economic benefit of this technology. When compared with an electrically driven ASHP (average CoP of 3) there is also a significant advantage with this technology. There is an additional benefit in that the waste heat from the gas engine can be used to provide higher temperature DHW while running the ASHP at lower temperatures for space heating only.

If gas engine driven (GED) ASHP could be applied to all domestic gas fired central heating systems in the Winchester District, demand for mains gas would reduce by more than 30%. This would equate to a saving of 39 kilo tonnes pa. In practical terms, the comprehensive adoption of GED ASHP to the domestic heating market is never likely to be achieved. However, it is an interesting argument for developing a strategy to promote wider deployment of this technology.

A good opportunity exists for using GED ASHP technology in larger commercial and industrial buildings. Demand for natural gas in commercial and industrial buildings in Winchester District is 234GWh pa. Based on the same assumptions as for the domestic case, this demand could be reduced by 30% with a comprehensive deployment of GED ASHP. A deployment of this type is far more achievable but again it would be unrealistic to assume more than 50% uptake for a variety of technical and financial reasons. The opportunity for 50% conversion would be 7.9 kilo tonnes of CO_{2e} emissions reduction using GED ASHP.

7.12.1.c Landfill Source Heat Pumps (LSHP)

Landfill source heat pumps (LSHP) are presented as a special case of the more expensive but operationally more efficient GSHP. The basis behind this concept is simple. Subjecting the thermal collection loop (heat supply to the evaporator) to conditions that are consistently above 6°C will improve the coefficient of performance delivered by the heat pump.

Landfill sites are a special type of anaerobic digester. As a consequence of the process undertaken within the heap of waste there will be heat generated. The result is that some of the mass within the landfill site will achieve local temperatures that are higher than temperatures under local ambient conditions for the same depth of inactive ground. In a process controlled AD plant this temperature might be managed by adjustment of process variables to maintain a feedstock specific stable temperature in the range 25°C to 35°C. In a paper for Journal of Geotechnical & Geoenvironmental Engineering,[35] the temperature profiles within landfill sites in America were reviewed. It is understood that the content of UK landfill sites is likely to differ from that of those in the USA but the principle should still hold true.

The challenge is that Landfill sites are generally considered to be unstable ground and therefore the installation of heat recovery arrays (boreholes) is not without risk. In conventional boreholes the loop is grouted into the well to ensure optimum heat transfer but this practice may not be appropriate in landfill. An alternative may be to allow the leachate level to rise and use this to enhance conductivity but this may compromise methane harvesting and also bring other environmental concerns. Further investigation is required on this topic.

[35] Heat Generation in Municipal Solid Waste Landfills, J. Geotech Geoenviron. Eng. 131, 1330 (2005); Nazli Yesiller, James L Hanson and Wei-Lien Liu

7.12.2. Waste heat recovery

Waste heat is typically any form of thermal energy that has insufficient capacity to add useful work to the process from which it was rejected. The challenge is that this 'waste' heat must by definition be produced as a consequence of a process doing work. It is either rejected because the working environment must maintain a controlled cooler state or the work requires heat input at a higher total energy condition.

It is often the case that waste heat from one process has sufficient energy content to perform useful work as the input to a neighbouring process. The product relationship between the two processes may be independent or related, but the rate at which heat is converted in the secondary process may affect the efficiency/performance of the primary process or vice versa. A simple example of waste heat recovery is found in the condensing boiler designs that are fitted in most UK properties. In these units the heat from combustion that is not transferred to the working fluid in the primary heat exchanger is used to preheat the return flow.

The key feature of waste heat recovery is in the 'contract' between the thermally related processes. The economics of waste heat recovery assume that the cost of putting the waste of one process does not adversely increase the cost of production (disproportionately) in the thermally related process. Therefore, if the 'contract' between processes is to be viable it should focus on the stability of the supply chain that ensures heat is available to meet demand but is also not accumulated to excess at the source of production.

For this reason it is most likely that large scale waste heat recovery will be well suited to an industrial process plant environment. The unfortunate requirement to balance heating and cooling demands may result in risks that one will be available at a rate that is not well matched to the demand for work in a specific aspect of the process. For that reason this is not a universal opportunity but it should be considered further on a case by case basis. Systematic investigation of individual commercial or industrial sites was beyond the scope of this report.

7.13 District Heating Networks

Distributed heat networks have a capacity to minimise waste heat caused by short cycling of boilers or other heat engines in response to an intermittent load. The extent of this efficiency saving depends on the type of connected loads and operational factors that are beyond the scope of this report. The cost of heat is relatively low compared to most household incomes in Winchester District [prosperity report]. When the domestic heating cost (revenue) is compared to the infrastructure (capital) cost of connection with a district heating network it is likely that in most instances the ROI will be unattractive to many households.

One exception to the financial case outlined above arises when the heat supplied to the network comes from waste heat. Another arises when the heat engine is substantially much more efficient than the installed boiler at each household to be connected.

The plant costs of such an installation can be reduced significantly by adopting a model based on heat engines supplied on lease with performance guarantees. These commercial arrangements offer the heat to a client site (or network) at a price per kWh that is in the order of 80 – 90% of the achievable result from installed boiler plant. Such schemes will typically be based on CHP or gas engine driven ASHP.

7.13.1. Large scale 'Combined Heat & Power' option

CHP is a special form of the related processes described in the section on waste heat recovery. District heating networks that operate with a CHP must have capacity to absorb sufficient heat and provide sufficient electrical load to keep the process in balance. To some extent it may be possible to 'dump' surplus electricity from systems that are grid connected but this will have a significant adverse impact on the economics. It would also be possible in most systems to dump surplus heat but prolonged and excessive use of this function will also have an adverse impact on the financial performance.

When it is possible to find a substantial heat sink that is well matched to the period of demand for electricity from a CHP there is a strong case for this type of system. The use of distributed heat networks creates the scale of accumulated thermal load that can provide a stable cooling capacity to satisfy the engine's specified running conditions. However, supplementary heat engines must be available for periods of reduced electrical load to ensure that heat is available when needed.

Need to insert a cost estimate for typical CHP engine - £1000/kWe.

7.13.2. Large scale heat only option

CHP is a special form of the related processes described in the section on waste heat recovery. District heating networks that operate with a heat only function should not be dismissed. It is the finding of this study that from the perspective of CO_{2e} emissions, heat only district energy networks are a significant benefit. However, the relative economic benefits of running a CHP based district heat network are clear when full use is made of the heat and power produced.

7.13.3. Smaller community or facility scale

At a community scale or even multiple houses, there can be advantage in running small scale DENs. These systems are most likely to be for heat only and could utilise Gas engine driven heat pumps and super-efficient boilers. Sophisticated controls could be incorporated to monitor external ambient temperatures and adjust flow and temperature variables to optimise rate of heat delivery. With this approach, it is expected that these systems could run at temperatures in the order of 40-50°C for much of the year (with occasional pasteurisation).

With careful system control and plant design, combined with intelligent mix of GED ASHP and super-efficient boilers, these systems could reduce domestic and commercial building heating costs significantly.

8 Results – summary of costs and potential

The study has identified:

- The availability of renewable fuel resources in the District.
- The technologies that should be used to convert them into the form of energy required.
- The locations of heat and power demand within the District.
- Where renewable energy conversion technologies could be located to give the best match between the fuel available and demand required.

The following section summarises where conversion technologies should be located to meet the demand for heat and power such that 100,000 tonnes or more of GHG emissions are prevented.

8.1 The City of Winchester East DEN – (MLSOA Winchester 007)

The City of Winchester East DEN is an area within the City of Winchester that has the potential for a large district energy network. The authors only had access to aggregated data for electricity and natural gas supplies in this area and therefore the load profiles could not be established. A more detailed assessment of offices, hotels, university buildings and municipal facilities in the area will form part of a more detailed feasibility by others that should establish electrical base loads. It is likely that there will not be a single site with sufficient electrical base load to benefit from an on-site CHP that could supply heat for the whole network. However, there may be potential for a relatively small number of micro CHPs with capacity of circa 30kW - 500kW to be connected to a common heat network. In this configuration the owner of the generating plant would gain cost advantage from on-site electricity supplied from the CHP, while neighbouring buildings could benefit from a relatively cheap, low carbon heat source.

The MLSOA data set can be used to quantify the scale of electricity and heat demand potential in this area compared to electricity demand. Taking the entire electricity demand and assuming a constant average load would indicate a generating capacity of approximately 5.6 MWe. It may be reasonable to assume that the base load is less than 20% of the average and therefore the business case may only exist for a single CHP plant with capacity of 1 MWe if a load existed at this level. It is more likely that a number of sites (ten or more) could join the DEN. In such a co-operative ESCo model, each CHP would discharge surplus heat to the network while delivering electricity to meet the on-site base/critical load. Under this model, each CHP owner/operator would engage their own fuel supply chain and receive payment for heat exported to the network.

The approach suggested here would require an integrated control network to ensure each CHP had sufficient supply of cooling load. The recommended approach would be for the network to be sized based on peak demand but CHP installations to be sized for onsite base load (electrical). It is likely that installations would be more attractive to facilities with a 24/7 operational load (supermarkets and data centres, swimming pool etc) which all exist in this area. It would also be necessary for the excess heat demand in the DEN to be met from supplementary boilers but existing installed capacity is already available to meet that demand.

For such a system to work it would be necessary for a central authority, ESCo or community co-operative to be responsible for the investment in the distributed heat network. The DEN infrastructure owner would be responsible for attracting loads and supplies for the heat in the network and maintaining the operational efficiency of the system. It is unlikely that the network would be comprehensive to the whole area or fully utilised where installed in the early period. On that basis, the design of core infrastructure would need to take account of potential growth in connected load as the system becomes more familiar. As a method of minimising the capital investment until revenue streams are robust, it would be logical to start with a number of concentrated loads and expand the network organically from those hubs.

Installation of the network will be disruptive to traffic and trade in main access routes to the commercial heart of the City centre.

8.2 The City of Winchester West DEN – (MLSOA Winchester 005)

A second district energy network is being considered and is the topic of a further technical appraisal by MACE on behalf of Hampshire County Council. This system will serve the area immediately to the West of the system described in Section 8.1 and will extend out to the Kings School on the Western edge of the City. This network will serve a number of City Council buildings, Hospitals, Schools, HM Prison and University buildings. It may also be designed to include capacity for domestic households along the main routes. In this instance it is likely that the main heat engine will be situated on a site with sufficient base electrical and thermal load to ensure that a large CHP can run economically. The design may also include distributed heat engines at other locations on the network.

The information about scale of this plant was not available at the time of this study. The NAEI data indicates that the annual industrial and commercial energy use in this area is circa 66GWh. As the prison and hospital will form a high proportion and offer a 24/7 service it seems likely that a base load of 33% of average would be reasonable. On that basis a CHP engine with 2.5 MWe capacity could be run continuously, but it may be preferable to run two smaller machines to enable better load matching. It is noted that the heat demand is less significant and therefore a pair of smaller engines will ensure more scope for modulating work done to match demand for heat.

An early briefing note shows that the plan is for multiple boilers in support of a 2 – 3 MWe CHP. The proposed network includes the Kings School on Romsey Road and therefore, as with the other DEN, there will be a significant heat sink available in the form of a swimming pool.

It seems likely that the main engines for this network will be operating with a demand for fuel of around 8 MW continuously. On that basis, any supply of fuel would need to be from the mains gas supply or biofuel in concentrated form such as LNG. If running exclusively on LNG, there would be a need for a 20T fuel delivery every day; this may be considered as an excessive number of fuel deliveries.

8.3 Owslebury AD plant – (MLSOA Winchester 013)

This study has identified the potential to build fifteen or more community based AD plants at hubs around the District. The key to enabling such a programme to develop is the demonstration of how such a scheme could work. Developing a full scale commercial feasibility study for one site would be a realistic first step in such a programme.

This area of Winchester is well served by dairy farms, poultry farms and has close proximity to the commercial food waste from Eastleigh. All of these factors would support further study to determine the best location for a community AD plant in this Middle Layer Super Output Area.

This plant should include an LNG liquefaction plant to demonstrate the potential for fuelling district heating systems with this renewable fuel.

This study established that there are relatively few AD plants that have been implemented in the UK. Reliable cost information was not available for a typical design for the UK market. This report has concluded that the first step in preparing the cost for such a plant would be to establish a reliable source and blend of feedstocks. When the feedstock is understood in more detail it will be possible to create a budget price and an indication of how that price would vary with type, quantity and quality of feedstock.

8.4 Large scale wind turbines – (MLSOA Winchester 001, 002, 003 & 009)

Wind profiles for the North of Winchester District are within the range that could generate a strong return from wind power. There is also a strong case for wind turbines to be installed at the North and West extremities of Compton and Otterbourne ward.

Analysis of all the locations with the highest average wind speeds that are not included in national designated areas highlighted the potential from this energy source. If all the sites assessed were developed it would be possible to reduce CO_{2e} emissions in the District by more than 200 kilo tonnes with wind power alone.

It is unlikely that all the sites identified by this study could or should be developed. The relative merits of each site should be considered by the community along with the preferred route for project implementation. It is likely that commercial developers will need to be involved to enable the majority of investment to be raised and therefore they will also have a say in which fit with their commercial models.

This study has concluded that three sites are most likely to provide the benefits of wind power in terms of CO_{2e} emissions reduction with the lowest cause for objection:

- Portsdown Hill
- Micheldever (three sites; south of Freefolk Wood, Woodmancott & Micheldever train station)
- Itchen Stokes Down (including Courtney's Copse plateau and Bridget's Farm ridge)

Adopting these three projects could deliver a generating capacity of 212 GWh pa from 69 MW of installed generating capacity. Delivery of these projects alone would deliver 126 kilo tonnes pa of CO_{2e} emissions reduction for the District.

A firm view on project lead times can only be established by a formal project plan which is beyond the scope of this study. Reference to other successful community wind power projects would indicate that this is not a short process. However, a pragmatic assessment of lead time to develop and deliver a wind farm project (typically 7 years for a community owned scheme) is likely to delay project delivery beyond 2015. Added to the lengthy technical aspects of such a development, there is a significant risk of local objections prolonging the process. On an optimistic note, if design, consultation and planning met with no objections it may be possible to deliver a wind farm of the scale identified in this report within 2 – 3 years. Commercial developers would be better placed to provide a firm view on project lead times.

8.5 Replacement of heating oil with alternatives – (MLSOA Winchester 001, 003, 004, 010, 011 & 014)

The benefits of moving households from heating oil (or storage heaters) in terms of CO_{2e} emissions reduction have been presented in this report. With the anticipated extension of RHI to include domestic properties, there will be strong financial incentives for those households to switch. However, there will also be a large number of new entrants to the market of delivering these systems. WinACC and Winchester District authorities could provide vital support and information in helping householders in this period of transition.

Many of the biomass options require larger installations for fuel storage to make deliveries more economically attractive. This situation may present an opportunity for mini or community DENs which would attract the commercial RHI and could therefore be implemented sooner. These systems could be run from commercial scale GSHP, local sourced biofuels or in some cases (LLOA Winchester 004A, 014A & 010E) mains gas. The central heat engine for these systems would not necessarily need to be purchased on capital because there are finance deals available that would lease equipment for a period on performance contracts. Indeed the whole system could be installed by a third party ESCo, but the householders would be financially better off in the long term with a community funded scheme; an IPS for the benefit of the community.

Reliable budget cost information for a programme to change existing oil fired boilers to liquid fuels from renewable sources was not available. However, it is known that oil storage tanks and seals would need to be replaced with units of compatible material. It is also known that the supply pipework would need to be cleaned or replaced and the burners adjusted. A budget price for tank replacement is £1,400 and other works £600 per domestic system.

Further consideration of changing from heating oil to solid or gas fuelled systems would depend on a significant number of variables at each site. This study concludes that there is insufficient information available to provide a cost per kW of installed capacity for such a conversion.

Heat pumps do offer a well proven substitute for heating with oil. For all commercial buildings that are not served by a mains gas connection, heat pumps should deliver a strong financial return, as well as delivering significant reductions in CO_{2e} emissions. Ground source heat pumps (GSHP) represent a significant investment but will operate at least 30% higher efficiencies than Air Source Heat Pumps (ASHP).

Conversion of all oil heating LPG (commercial and domestic) in Winchester District to ASHP would reduce more than 48,000 tonnes of CO_{2e} emissions. Adopting GSHP as the heat engine for mini or community DENs could deliver even better reductions in emissions. GSHP based DENs could also offer compelling simple payback periods based on entitlement to RHI and more efficient operation of the plant.

Gas engine driven heat pumps (GED ASHP) can also deliver significant efficiencies for buildings that are connected to the mains gas network. CoP in excess of 1.5 can be achieved with these heat engines which will result in gas demand by more than 40%. These systems are generally larger and therefore more appropriate to commercial buildings or community district heating networks.

8.6 Landfill gas harvesting – (MLSOA Winchester 010)

Fair Oak landfill site near Eastleigh is situated at the border of Winchester District with Eastleigh. It is adjacent to a golf course that may have historically also been part of the landfill site. The data for MH_4 emissions lists this site as a point source and it appears rather less dramatic in Figure 12 than the large area in the south of the District. In reality, the emissions from this site may be far more significant and easier to harvest.

The authors were unable to source reliable information about the scale and content of this landfill site in the period of this study. Within the scope of our search there was no documentary evidence that landfill gas harvesting is already operational at this site or planned for the near future. It has therefore not been possible to prepare meaningful budget estimates for landfill gas recovery from this site. With limited information, our findings remain inconclusive about the practical steps required to convert the GHG emissions from this landfill sites into a useful energy resource.

8.7 Solar PV

Based on the DECC method combined with land use statistics there would appear to be considerable scope for installation of solar PV on buildings in the Winchester District. The total potential using the method indicates less than 216 MWp of installed capacity can be achieved on buildings in the District. This approach should probably be considered as the easiest source of renewable or low carbon energy conversion to install.

In other local authority areas, the opportunity to install large systems has been shown to have a significant advantage for investors and community. Recent experience has shown that uncertainty over rates of the FIT can result in programmes being cancelled at short notice in spite of strong returns; for example, the Hampshire County Council cancellation of their programme. On that basis it seems unlikely that PV will be deployed on mass in Winchester unless led by community investment.

Community ownership of such systems could provide a balanced benefit to host site, local people (investors) and the Climate Change Programme. There are many examples of such schemes in community ownership in the range 120 kWp to 5 MW. At these scales the energy productivity per unit of investment is much higher. Taking an extreme view it would appear that two sites that may be considered inappropriate for wind could provide benefit with solar PV; the key point being to avoid displacing crops or livestock from agricultural land.

The situation remains that uncertainty over the rates to be paid by FIT (reviewed six monthly by DECC) may change the business case of a project between feasibility and commissioning. However, based on current modelling methods, it is clear that community investment in such schemes on buildings where the load can be used without export will provide a better return than cash in the bank! These schemes also create an effective method of engaging communities in dialogue about the wider energy demand reduction opportunities.

The price per Watt installed is subject to extreme shifts in cost of materials. On that basis there is no publically available data that can present a budget price. However, commercial experience has demonstrated that the cost of large systems (>120kWp) is less than half the market rate for domestic installations and therefore it may be reasonable to estimate an installed price of less than £1.90 per watt installed for large systems at the time of writing. The cost per Watt installed for systems in excess of 500kWp are beyond the scope of routine pricing models.

8.8 Solar thermal

DECC methodology was reviewed to find a logical method for determination of solar thermal capability on a District scale. The challenge is that there is no easy method to establish the potential benefits of solar thermal within Winchester District without an understanding of base load demand by building. This is straightforward when assessing individual buildings but a bit more of a challenge on a District scale.

Other sources were also assessed that offer the view that this form of renewable energy could only account for 1-2% of contribution to heat demand. On that basis this study has prioritised on other forms of renewable and low carbon energy source that will have a greater impact on the District Climate Change Programme.

Energy use statistics were used as a guide for hot water demand from a domestic building perspective. Estimates were used to relate this to the commercial/industrial building portfolio. The outcome of that analysis indicates that solar thermal will not make a significant contribution to the Climate Change Programme targets for Winchester District.

9 Discussion

A balanced portfolio of large scale renewable and low carbon energy projects combined will enable Winchester District to meet the Climate Change Programme target for CO_{2e} emissions by 2015. A significant possibility exists in the opportunity to harness energy from furtive methane (CH_4) emissions and wind resources in the District. Implementation of Anaerobic Digestion technology with biogas liquefaction may have the added bonus of providing an opportunity to displace significant demand for heating oil and LPG in areas that have no connected gas grid supply.

Conventional use of biomass will play a role for those applications where space and traffic movements are less of a priority; typically rural communities. There is no shortage of potential for biomass supply from the District, however attention has to be focused on the most effective methods of concentrating, storing and handling the fuel.

There is also considerable scope for the application of heat pumps and better use of low temperature heat emitters in all OAs of the District. Heating buildings with a lower temperature hot water supply in central heating will deliver perfectly acceptable results in all but the most adverse weather conditions. A programme of education to explain the more appropriate control of condensing boiler systems and heat pumps could deliver significant CO_2 savings; reduced heat input for longer periods.

District energy networks are also seen as having strong potential for energy demand reduction. Control and maintenance of a central plant serving many small loads will reduce losses of multiple small boiler systems short cycling to meet peaks in demand. The accumulation effect of multiple loads connected together should result in systems with better turn down ratios in terms of load per connected building. Once again, if modern insulation systems are deployed to distribution pipework, and the flow temperatures are minimised whenever possible, losses will be reduced.

9.1 Easy wins

Our survey has highlighted a number of opportunities that could be implemented with relative ease and rapid return on investment required.

9.1.1. Priority #1

Undertake urgent action to procure a detailed feasibility study of tapping all closed and active landfill sites for landfill Gas; either to collect or flare and thus reduce CO_{2e} emissions.

9.1.2. Priority #2

A community engagement programme to explain the benefits of lower boiler operating temperatures could be run throughout the District of Winchester. This programme could deliver the potential saving of 6.3 kilo tonnes pa CO_2 emissions pa.

9.1.3. Priority #3

Publicity campaign to the commercial and industrial sector about the potential benefits of GED ASHP in terms of CO_{2e} emissions reduction.

9.1.4. Priority #4

Community energy engagement events to be held in all areas that are not served by a mains gas supply to present options for ASHP / GSHP, bio fuel substitution and community scale or mini district energy networks.

9.2 Practical next steps

A sample of the concepts discussed in this study have been proposed as the practical next steps in Winchester District for the renewable and low carbon energy part of the Climate Change Programme. All of the projects proposed will require significant investment and funding of such projects requires a higher level of detailed evaluation for each project than was possible within the scope of this study.

9.2.1. Winchester DEN feasibility assessments

Hampshire County Council, in partnership with a number of key stakeholders within the City of Winchester, has commissioned a detailed study of potential for district energy networks in the City. There are two locations that are under consideration, and deployment in these areas is supported by data that has been reviewed as part of this study.

MLSOA data indicates that Winchester 007 (mostly St Bartholomew and St Michael wards) offers a substantial opportunity to absorb a significant district heating load. At the time of this report, MACE were well progressed with their study to identify particular loads and practical plans for the distribution of heat in this area. The findings of the MACE report were not available during this study because of report timing.

Data for the CO_2 emissions indicates that the 1km squares with the most significant heat load are situated in the areas surrounding and including the Royal Hampshire County Hospital. However, consideration is being given to the stable thermal loads at other buildings that are under the control of HMG, Winchester City Council or Hampshire County Council. This network could be extended to enable heating supply to the areas in Stanmore that are ranked 1st and 3rd in Winchester's listing from the Index of Multiple Deprivation.

Further study should consider the complexities of running renewable fuels into the City of Winchester on a regular basis. It is the findings of this study that LNG could form a significant solution to the need to reduce road miles per kWh of fuel delivered.

9.2.2. Engage with specialist Wind Power development companies

Analysis undertaken as part of this study has indicated that there is significant potential for electricity to be produced from wind energy in Winchester District. The three areas assessed as the most viable options should be the focus of community dialogue, along with the other areas that have been set aside in this report. The potential return on investment is sufficient for these projects to attract commercial investment from wind farm developers.

The potential for community investment should not be ruled out. However, it seems unlikely that a community share issue will be possible at the levels of investment required to deliver all sites identified by this study. It is likely that developers will be open to the concept of including a community owned machine in each wind farm development.

9.2.3. Engage with Dairy and Poultry farming communities for dialogue on the topic of AD

This study has found that the farming communities within Winchester have formed in significant clusters that produce waste material compatible for Anaerobic Digestion. The figures reported in this study are based on documented production rates for particular agricultural, dairy and poultry operations. A more detailed study of the specific quantity and quality of product that could be collected from each site should be undertaken. Engaging the farming community in support of such further study will be the most cost effective and practical method to collect the necessary data and samples.

Additional support in this further study may be available from the NFU AD specialist (Dr Jonathan Scurlock) and the Veterinary laboratories at Bridget's Farm, Martyr Down.

The specific aim of further study would be to identify the optimum location for more than 15 Anaerobic Digestion Plant hubs to ensure that waste product transportation is kept to a minimum. It would also need to establish the optimum blend of waste products from each area that would ensure the most cost effective production of biogas and fertiliser (digestate). The feedstock may include manure, poultry droppings, chopped straw, commercial food waste and bread waste (bakery in Eastleigh).

It is understood that processing food waste in an AD plant requires additional pre-treatment (pasteurisation) prior to adding to the feedstock. On that basis it may not be sensible to add the food waste to all AD plants in the area. Restricting the commercial food waste collections to those areas with a high concentration of material to supply may be a sensible compromise. It is noted that food manufacturing process plants are a good source of food waste and that the commercial bakery in Eastleigh could be a welcome participant in such a plan. The factory is on the North East side of Eastleigh which places it in reasonable proximity to dairy and poultry farms which could participate in a community waste processing scheme of this kind.

9.2.4. Engage with the communities identified as first priority for mini DENs

Consideration should be given to the creation of mini and community scale district energy networks, in addition to further extension of the proposed commercial systems in the City centre. These community DENs may be well suited to the communities identified in section 6.2 as locations with limited or no mains gas supply.

A further study should also be undertaken, perhaps in partnership with Tesco, to investigate potential for a DEN in the Winnall Industrial/Business Park. If sufficient of the industrial/commercial buildings were connected to such a network it would be relatively straight forward to extend into the residential area of Winnall. This area includes the area rated second in Winchester listings from the Index of Multiple Deprivation.

A community DEN feasibility study should be undertaken should be for a combined system to include Winchester 011E and 011C. These are two locations that are not served by the national distribution network for mains gas and therefore will be heating with alternatives that produce higher CO_{2e} emissions. Any such community owned DEN that included heat pump technology or boilers with a renewable energy fuel source (LNG or biomass) would attract payments from the RHI. With RHI payments it may be possible for a community share issue to generate sufficient finance for both areas and thus reduce the number of fuel poor households.

Fuel Poverty ranking (out of 69)	LSOA Code	LSOA Name	STwardname	All Households	Number of domestic gas meters	Fuel Poor Households	Percent Fuel Poor	Average mains gas demand per meter point (kWh)	Availability of mains gas supply
3	E01023225	Winchester 004A	Cheriton and Bishops Sutton	876	15	170	19.4%	15843.10	Poor
5	E01023282	Winchester 011E	Upper Meon Valley	834	-	157	18.8%	0.00	None
7	E01023224	Winchester 014A	Boarhunt and Southwick	501	97	116	23.2%	13862.00	Poor
9	E01023246	Winchester 010E	Compton and Otterbourne	602	6	109	18.1%	23192.70	Poor
11	E01023286	Winchester 001A	Wonston and Micheldever	571	-	102	17.9%	0.00	None
12	E01023274	Winchester 003E	Sparsholt	616	342	99	16.1%	22882.00	Not good
13	E01023280	Winchester 004D	The Alresfords	599	254	99	16.5%	16916.30	Not good
20	E01023288	Winchester 001C	Wonston and Micheldever	563	Unavailable	91	16.2%	16976.20	Not good
47	E01023276	Winchester 011C	Swanmore and Newtown	560	-	58	10.4%	0.00	None

Table 43: Off mains gas supply network by LLSOA

Table 43 also highlights that Winchester 004A (within Cheriton and Bishop Sutton ward) may be a prime candidate for community DEN. This is another area that is largely off the mains gas supply but the number of households in a single area is much higher than in other locations. This area would be local to the proposed landfill gas harvesting and also at least one of the proposed AD plants and so LNG should provide a low cost local fuel option. The population density may result in a lower cost installation for many households. It is likely that this system will require third party finance or for a community share offer that will draw investment from the wider community of Winchester.

9.2.5. Undertake a feasibility study on the prospect for landfill gas and heat recovery at closed sites

This study has identified that CH_4 emissions are significant in the areas around closed landfill sites in Winchester District. The concentration and content of landfill gas within the closed sites are unknown. It is not possible to design the landfill gas harvesting system in any detail until more information is known about the quality of gas that is available within each site. The installation of landfill gas harvesting apparatus in landfill sites is a specialist activity that should be undertaken by experienced well drilling contractors that are familiar with working on landfill sites.

Further study at one of the landfill sites should be undertaken to determine the viability of drilling for landfill gas and heat harvesting. In this first instance the study should focus on one of the closed sites with the highest rates of CH_4 emissions as indicated by the NAEI data.

9.2.6. Undertake a community heating efficiency awareness campaign

Much focus has been drawn throughout Hampshire on the benefits of insulation for householders and commercial property. This will continue as an ongoing project with the Insulate Hampshire brand developing new community schemes to follow on from the demise of CERT funding for the full scheme. The wider discussion and action planning to develop the thermal performance of buildings is covered in other studies and will not be discussed further here.

This study has highlighted the benefits in terms of CO_{2e} emissions that could be achieved by better management of boiler temperature controls; waste heat recovery. The methods adopted and lessons learnt during Insulate Hampshire could be adopted as a starting point for a campaign for more effective heating controls. It would be relatively simple to find similar houses with similar heating systems and run a short trial with data acquisition to demonstrate the significance of key boiler, room thermostat and programmer settings.

For the duration of any trial it would be necessary to install pulse counting data loggers on the gas supply meters and temperature loggers inside the building. It would be advisable to undertake an EPC assessment to ensure that the differences between buildings was understood. Engaging the community in a study of this kind may help to inform a wider group on the simple adjustments that could deliver significant reductions to fuel bills and CO_{2e} emissions.

9.2.7. Switch 'off gas grid council buildings from oil heating to bio fuels

Winchester City Council could help the off gas grid communities to see the benefit of running heating systems on an alternative to heating oil. They could achieve this by implementing changes to the heating systems in municipal buildings that are not served by mains gas. Switching these buildings to a bio fuel system would be an investment that could demonstrate the technology as a reliable heating method.

It is a tough call for individuals to be the early adopter in a community that invests their own capital to switch to unfamiliar technology. Changing from heating oil to a vegetable oil or LNG based alternative system requires significant capital investment. The vegetable oil system would require a new storage tank, pipe cleaning and burner adjustments. It may also require additional insulation of the storage tank and possibly some trace heating of tank and pipework for extreme cold weather. The LNG option would probably require a new boiler as would the biomass fired options.

There is also a risk that in the early days this vegetable oil, biomass or LNG might be more expensive than oil. However, as local sources become available, it will be easier to demonstrate the cost benefits and accelerate the switch to biofuels if the community can see a working system running well.

This study has shown that there are significant GHG emissions advantages in making this change from heating oil to green alternatives. It will not be viable for all households to become connected to the mains gas network or a mini district heating system (DEN). However, with council leadership it may be possible for those communities to become familiar with the advantages of bio fuels and thus improve the rate of change.

9.2.8. Engage with local communities on co-operative large scale solar PV

There is a substantial opportunity for local communities to co-operatively develop large scale (greater than 200 kW_p) PV systems on roofs of commercial and industrial buildings. Deployment of small scale PV on domestic roofs may prove to be inefficient. Installation costs are high and a large number of installations are required to deliver any significant reduction in GHG emissions. Large scale installations are more cost effective (up to half the cost per installed Watt) and a small number (*c.*100) will significantly reduce emissions. With local funding the financial benefits will accrue to the local community rather than to external providers of financing.

10 Conclusions

The UK's energy system, and consequently Winchester's, faces a number of challenges. Energy prices are likely to rise; our system is almost entirely dependent on the combustion of fossil fuel the sources of which are increasing liable to interruption. Fossil fuel combustion accounts for the vast majority of the UK's GHG emissions which we are legally obliged to reduce by international, EU and national law.

To increase the reliability and resilience of the energy system, a partial shift to alternative fuels is required. This also delivers a substantial reduction in our GHG emissions.

The Government is offering substantial financial incentives to investors prepared to invest in renewable energy. This is creating opportunities which should be explored by Winchester District and could deliver significant benefits to the local community in terms of revenue, lower cost of energy to commercial and domestic markets, greater economic competiveness, job creation and cleaner environment. Winchester District is in an excellent position to take advantage of these incentives. However:

- The technological options are many and varied but this should not prevent the Councils in investigating these in greater detail.
- The analysis of MLSOA data has been largely inconclusive but has informed consideration for further study. Use of the 'Ratio of Demand Totals' has highlighted areas with a high concentration of interval metered supplies.

Renewable and low carbon energy resources exist that could be converted to reduce GHG emissions from within Winchester District by more than 100ktonnes pa. By harnessing the renewable and low carbon energy potential within Winchester District this will enable the Climate Change Programme target for reduced GHG emissions to be achieved by 2015. Winchester District has the renewable energy resources available to achieve the entire Climate Change Programme for CO_{2e} emissions reduction exclusively from wind power sources outwith National Designated areas. There are numerous other opportunities to further reduce emissions and these should not be missed.

In addition specific communities within Winchester District could benefit by significant cost savings by switching from existing heating methods to heat supplied by mini, community or larger scale district energy networks.

Community ownership of large scale renewable or low carbon energy systems is a viable option to be considered when seeking to fund these developments.

Current levels of (furtive) methane emissions in the Winchester District are a significant factor that should be addressed as part of the Climate Change Programme. Harvesting and liquefaction of existing methane resources within Winchester District could provide a source of low carbon fuel for CHP and off gas grid communities.

In addition to the above, detailed feasibility studies should be commissioned for three of the sites identified in this study as having the greatest wind energy potential; Portsdown Hill, Micheldever/Freefolk Wood and Martyr Worthy/Itchen Stokes Down.

A number of other points should also be noted:

- Heat pumps (GSHP, ASHP and GED ASHP) could play a more significant role in delivery of low carbon heating solutions for commercial buildings and mini heat networks in Winchester District.
- Based on the DECC method applied to the land use statistics, there is potential to install 142.7 MWp of solar PV on commercial/industrial areas in Winchester. This amounts to 1200 community scale 120kWp systems.
- Solar thermal will play a very small part in actions to deliver the Winchester Climate Change Programme but should be deployed as part of the Winchester West DEN and heating for the municipal swimming pools (Winnall, River Park and Kings School).
- The combination of 2005 land use statistics and the DECC methodology have presented an optimistic view of the potential for PV in Winchester.
- A more pragmatic estimate of potential from PV in the short term is achieved with a focus on the areas of highest non-domestic building density using land use statistics.

11 Recommendations

The recommendations from this investigation are:

1. Further action should be undertaken to engage with stakeholders in Winchester District that could make available resources (in the form of land and/or finance) for the purpose of renewable or low carbon energy conversion.
2. A detailed plan should be created for actions that will lead to the deployment of large scale renewable and low carbon energy conversion projects in the Winchester District.

3. The Climate Change Programme should invite the specific communities identified in this study to engage in dialogue about how community energy projects could save them money and help them to be more informed about which technologies to adopt for the biggest benefits.
4. Options for community ownership of generating assets should be a part of the community engagement activity associated with the Climate Change Programme in Winchester District.
5. The farming community and producers of commercial food waste should be engaged in the potential for Anaerobic Digestion at hubs located near the source of waste.
6. Further consideration should be given to the opportunities of heating with community systems and use of lower temperatures in all central heating systems; heat pumps and condensing boilers will work more efficiently at lower flow temperatures.

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13 Glossary

AD – Anaerobic digestion. A natural process where fats, carbohydrates and proteins are digested by bacteria. A by product is the production of methane. AD can be used to produce bio-methane from animal and plant waste. The bio-methane can then be used as a fuel.

ASHP – Air sourced heat pump. A technology that can extract low temperature energy from the air and use this to heat water to a higher temperature. This water can then be used provide space or water heating. On occasions air can be heated rather than water. See also ground sourced heat pump.

CHP – Combined heat and power is a system that co-produces heat and electricity. Most of the current technologies for large scale electricity generation require large amounts of heat which is often wasted. That heat can be used to provide heat for district energy networks (DEN) and therefore avoid wasting energy.

CH_4 – The chemical formula for methane which is a potent greenhouse gas. Methane is the main constituent of natural gas. Methane is also useful fuel that can be burnt to produce useful sources of energy. Methane produced over geological time scales is a fossil fuel. Methane contemporaneously produced from natural processes is known as bio-methane.

CO_2 – The chemical formula for carbon dioxide which is a greenhouse gas and the main cause of anthropogenic climate change. It is a by-product from the combustion of fossil fuels.

CO_{2e} . CO_{2e} is CO_2 equivalent. Greenhouse gases are a mixture of compounds that induce radiative forcing within the Earth's atmosphere. This leads to an increase in the global temperature. CO_2 is the main actor but other GHGs are also present. Methane (CH_4) and Nitrous Oxide (N_2O) are the main other compounds. Each compound has a different effect on radiative forcing. For comparison purposes each tonne of GHG is converted into the equivalent mass of CO_2. Emissions targets (under the Kyoto Treaty) are cited in terms of CO_{2e}.

DEN – District Energy Network. A heating system that comprises a network of pipes that connects and heat source (such as a large scale boiler) with a heat use (such as a home, office or factory). DENs can be an efficient why of providing heating to small geographic areas particularly when the heat is generated by a combined heat and power unit. See also CHP.

ESco – Energy Services Company. An enterprise that is engaged in service delivery under terms defined by a performance based contract and offers guarantees on delivery of output conditions in an energy conversion process. The provision of this service often includes a fully financed provision of plant, equipment and consumables that are required to achieve the contracted deliverables.

Feedstock - The raw material used in the production of fuel. In the context of this report is is confined to animal and plant bio-mass that is suitable for conversion into a fuel that can then be used to provide useful energy.

FIT – Feed in tariff which is a government scheme to encourage investment in technologies for the renewable generation of electricity. Investors are paid for each unit of renewably sourced electricity they produce. FIT is limited to a number of specific technologies. See also RHI.

GSHP - Ground sourced heat pump. A technology that can extract low temperature energy from the ground and use this to heat water to a higher temperature. This water can then be used provide space or water heating. On occasions air can be heated rather than water. See also air sourced heat pump.

GWh – Giga Watt-hour. A measure of energy equivalent to 1,000 mega Watt-hours (MWh) or 1 million kilo Watt-hours (kWh). One kWh is the standard unit of electricity used in electricity bills.

ha – A Hectare which is a unit of area equivalent to 10,000 square meters.

kW - Kilo Watt. A unit of power (or energy used per second). One kilo Watt is equivalent to 1,000 Watts (W). Using one kilo Watt for one hour is defined as a kilo Watt-hour (kWh).

LLSOA - Low level super output areas. Government collects national statistics at the level of super output areas. These are small geographic areas broadly based on the enumeration districts and contain about 20 -100 households. The lowest level at which energy statistics are published are at LLSOA level which broadly consist of 2-7 SOAs. Each ward contains between 1 and 4 LLSOAs. LLSOA data is further consolidated to a high mid-level (MLSOA data).

LPG – Liquid Petroleum Gas is a liquefied form of natural gas.

MLSOA – See LLSOA

MW – Mega Watt. A unit of power (or energy used per second). One mega Watt is equivalent to 1,000 kilo Watts (kW)

MW_e – A measure of electrical power output. Power can be delivered in several forms. In the context of this report power is delivered in terms of heat and electricity. The subscripts th and e denote which form of power is being discussed. See also MW_{th}

MW_p – A measure of peak power output. Most power generating units are defined in terms of their maxium (or peak) capabilities. Average powers tend to be much lower.

MW_{th} – A measure of thermal power output. Power can be delivered in several forms. In the context of this report power is delivered in terms of heat and electricity. The subscripts th and e denote which form of power is being discussed. See also MW_e.

PV – Photovoltaic. The production of electricity from light.

RHI - Renewable heat incentive which is a government scheme to encourage investment in technologies for the renewable generation of heat. Investors are paid for each unit of renewably sourced heat they produce. RHI is limited to a number of specific technologies. See also FIT.

UCO – Used cooking oil which can be used, once filtered, as a fuel.

WinACC – Winchester Action on Climate Change. A local charity that works with Winchester City Council and its citizens in reducing the area's greenhouse gas emissions.