LOW/ZERO CARBON

RENEWABLE ENERGY FOR UTTLESFORD

SUMMARY

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January 2008

Altechnica

Study undertaken for Uttlesford Futures

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Dr Derek Taylor is Principal of Altechnica - an independent multidisciplinary architectural and renewable energy innovation practice established in 1990 and specialising in the fields of renewable energy technologies and ultra low energy building concepts. He is also a visiting lecturer in *renewable energy + design* at the Open University. He is a chartered architect and holds a Masters Degree from the Royal College of Art in industrial design engineering and a Doctorate from the Open University in renewable energy.

Derek Taylor has been involved with renewable energy technologies and low energy building design since 1972. He has worked on innovative vertical and horizontal axis wind turbines since that time and has invented and patented a number of innovative novel wind energy devices. He is responsible for the wind energy section of the Open University's renewable energy courses and he was a recipient of the 1996 British Wind Energy Association's *Wind Energy Pioneer Award* in recognition of his contributions to wind energy development in the UK.

Dr Taylor has expertise in the design of ultra low energy buildings and has designed one of the most energy efficient houses in the UK - currently under construction in Herefordshire. He has a special interest in the zero energy design of buildings and has been researching Building Integrated Renewable Energy Technologies (in combination with demand reduction) as a means of creating buildings which aim to achieve zero net energy consumption.

Altechnica has carried out a wide range of projects in renewable energy for a variety of organisations including government departments, government agencies, companies, local authorities, universities, housing associations, charities, architects and private clients.

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Renewable Energy in Uttlesford

SUMMARY

1. SUMMARY

Uttlesford Futures commissioned Altechnica to carry out a study of the renewable energy potential within Uttlesford in order to examine the options for reducing the carbon dioxide emissions from energy consumption in the households within Uttlesford.

The current CO_2 emissions estimated to be resulting from domestic energy use in Uttlesford are given in the following table from DEFRA statistic for 2005. Of the 28 k households in Uttlesford around 19 k are currently supplied with gas. The majority of the non gas consumers are located in rural areas (see attached map and that shown in the Figure **2-15** in the section on solar energy).

CO2 Emissions in Utllesford from Domestic Energy Use for 2005

Total Domestic CO2 emissions	$ktCO_2/y$	tCO_2/y
Domestic Elec	91	91,000
Domestic Gas	71	71,000
Domestic oil	28	28,000
Domestic solid fuel	2	2,000
Total CO_2 from Domestic Sector	192	192,000
Population	68.946	

Source DEFRA: *Local and Regional Estimates Carbon Emissions by End User, Detailed Sector Split 2005*

This current study on Renewable Energy in Uttlesford has attempted to look beyond the current economic constraints to explore the potential from the available resource. It also attempts to address the opportunities that this resource provides for Uttlesford.

1.1 Solar Energy

Solar energy can be converted into heat which can be used for heating hot water, space heating, process heat, or for ventilation and cooling through convection. Active solar systems can be used to heat water by means of specially designed collectors. There are around 60,000 solar water-heating systems already in operation in the UK, costing from about £1,500 upwards.

Example of a flat plat solar collector of the kind used for solar water heating or active solar space heating - Filsol

Assuming a comparable proportion of the households to those in Cambridge are suitable for accommodating solar collectors, then between 60 and 70% of households in Uttlesford could employ **solar water heating** systems which would potentially yield approximately **17 to 23 GWh/y** and abate of the order of **4,000 to 5,000 tonnes of CO_2/year** depending on collectors used.

Active solar space heating uses solar collectors similar to those used for solar water heating but the heat is used for space heating. It could potentially meet space heating loads of houses built to super-insulation standards, and with high performance windows. **Large active solar systems** can be combined with community heating schemes. They are relatively common in Scandinavia, and can use inter-seasonal heat stores.

Passive solar design comprises passive solar heating and integrated low energy design taking into account orientation, thermal mass and high insulation standards. Passive solar heating can reduce the space heating requirements of individual houses by up to **1,000 kWh/year**. Special passive solar features such as sun-spaces (unheated), atria and solar roof spaces can improve on this but these features can become energy wasting. Properly designed ***Super Passive Solar Heated Buildings*** can achieve zero energy space heating performance.

Passive solar ventilation and cooling can avoid the need for air conditioning and mechanical cooling - features increasingly common in commercial buildings. Among the techniques available are cooling with atria, solar chimneys and passive stack ventilators.

The use of **natural daylighting** can avoid much of the electricity requirement for lighting in non-domestic and domestic buildings (this represents about 17% of CO_2 emissions from commercial buildings)

Solar photovoltaics (PV) uses specially treated semiconductor materials to convert light into electricity. PV cells are grouped into a panel known as a PV module. Many types of building surfaces and orientations are capable of producing PV-generated electricity. Technical innovations have reduced the cost of this technology though it remains an expensive option when considered only in purely electricity cost terms if other complementary benefits are not considered.

Building-integrated PV (BIPV) consists of cladding on walls or on roofs. PV for roofs can be manufactured as tiles, slates or shingles. In addition it can be incorporated into glazing systems and also for shading devices and canopies. Special modules are available for flat roofs and carports.

PV can be installed in either grid-connected or stand-alone systems. It has become easier to connect PV systems to the grid and government grants are available for this purpose. PV can be used for domestic, commercial and industrial (as part of cladding or shading), public and school buildings. It can also be used to power parking meters, street lamps, and to provide electricity to parking bays for charging electric vehicles (EVs) and the new plug-in hybrid electric vehicles (PHEVs)[1].

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[1] See also the section on wind energy.

With the new developments planned for Uttlesford, there is large potential for domestic application of PV.

Use of **less than a third of 1% of the land area** in Uttlesford for mounting PV modules would generate enough electricity to provide for all of the existing households.

Uttlesford is not in the sunniest part of the UK, however, according to solar radiation data from Cambridge, it is exposed to almost 1,100 kWh/m^2 on south facing slopes at optimum tilt angles in shade free locations - a value slightly greater than that in London. As such Uttlesford is well suited to electricity production from PV.

If Building Integrated PV (BIPV) and/or Building Attached PV (BAPV) arrays (assuming a mix of 4 kWp and 3 kWp systems) were installed on **50% of the households in Uttlesford,** the estimated electricity generated could potentially be approximately **29 to 31 GWh/year** - equivalent to around **21 to 26%** of average household electricity requirements in Uttlesford. This would abate of the order of **17,000 to 18,600 tonnes of CO_2/year**.

If **60% to 70% of the houses in Uttlesford** were able to accommodate BIPV/BAPV systems, the estimated electricity generated could potentially be approximately **35 to 44 GWh/y** (equivalent to **26% to 36%** of average household electricity requirements in Uttlesford) and abate approximately **20,000 to 26,000 tonnes of CO_2/year** depending on technologies employed.

There may be a possible conflict with available space between residential BIPV/BAPV and solar water heating collectors, so this would adjust the potential estimates of both residential solar water heating and solar electricity estimates.

As well as BIPV/BAPV another potentially promising application is to use PV over open spaces used for other purposes including car parks. The potential for generating CO_2 free electricity from **PV-Carport Solar Power Stations** at the On-Airport car parking at Stansted Airport and on ten town centre car parks are estimated.

For the Stansted Airport systems, the estimated annual electricity production could be approximately **23** to **26 GWh/y** - equivalent to **17** to **19%** of the households in Uttlesford - and abate of the order of **13,300** to **14,700 tonnes per year of CO_2 emissions** (or 20,150 to 22,300 tonnes CO_2/y if on the same basis as wind farm CO_2 abatement) or more if used to recharge EVs or PHEVs.

The PV Carports for ten town centre car parks were estimated to be able to generate approximately **1,100** to **1,200 MWh/y** and abate around **640 tonnes/y** to **720 tonnes/y** (or **980** to **1,000 tonnes of CO_2 per year** if on the same basis as wind farms) or more if used to recharge EVs or PHEVs.

Therefore there does appear to be scope to generate useful amounts of CO_2-free solar electricity from suitable open spaces to complement residential BIPV/BAPV (as well as non-domestic BIPV/BAPV) installations and wind energy in Uttlesford.

1.2 Wind Energy

Wind energy is one of the fastest growing energy sectors and at the end of 2006, some 74 GW of wind generating capacity had been installed globally. The UK has the largest land-based and offshore wind energy resource in Europe, with 40% of the European land based potential. The exploitation of wind energy for electricity generation involves minimal impact on land use, as farming can continue around the turbines, and can provide an income for landowners. Windmills were a traditional form of energy technology in Uttlesford and Essex, with evidence of many former windmills, mill mounds as well as a few examples still standing.

Factors influencing the viability of wind energy include:

- the annual mean wind speed at the site
- the wind speed frequency distribution
- topographic features
- the proximity of electric power lines
- the capital cost of turbine & installation
- unit price of electricity required/offset

Until recently, sites with annual mean wind speeds (AMWS) of below 6.5 metres/second were considered uneconomic and most wind farm developers prefer higher mean wind speeds (7 m/s or more). Because of the inland location of Uttlesford the wind speed resource is not as great as in coastal regions, but because of recent improvements in aerodynamic and mechanical efficiency together with the availability of taller towers and lower ‘cut-in wind speeds’, inland sites are becoming more viable. Much of Uttlesford is undulating terrain with hills and valleys so there are fewer suitable wind energy sites compared to plains. Analysis of the UK NOABL database of annual mean wind speeds (AMWS) indicates that there are a considerable number of OS 1-km grid squares with annual mean wind speeds (AMWS-45) of over 6 m/s at a height of 45 m above ground level (AGL) and much of the non-wooded high ground in Uttlesford has promise if modern medium/low wind speed specific wind turbines are employed and mounted on relatively tall towers. Other sites could potentially be exploited through pilot community wind energy projects.

The Uttlesford District could potentially accommodate an installed capacity of over **1200 MW**, generating approximately **2,900 to 3,700 GWh per year - enough electricity for 630,000 to 780,000 homes**. These estimates are for the maximum that may be technically feasible but there is uncertainty as to whether certain of the turbines included in this total would be affected by Stansted Airport being within Uttlesford and possible constraints from air traffic control issues. The latter factor has some influence throughout Uttlesford and is also affected by the turbine heights, so these factors would need to be reviewed according to the individual project characteristics. It may also affect some of the estimates from wind energy given below.

Community wind energy projects also provide scope for rural communities to earn income from wind energy; alternative scenarios include outright ownership, community companies and joint ventures with the local council and Energy Service Companies (ESCOs) or Wind Energy Service Companies (WESCOs).

The towns and certain larger villages in Uttlesford could consider a small group of wind turbines at locations on their periphery to supply carbon-free electricity for all or a large proportion of the houses in their boundaries. Such **Town or Village Wind Energy Schemes** could considerably reduce the carbon footprints of these towns.

In addition there would be potentially scope to plan to use wind energy to reduce the CO_2 emissions and costs of **personal transportation** in the District. This would require vehicle users (domestic and non-domestic private, public and fleet operators) to opt for the new **'plug-in hybrid electric vehicles'** or ***PHEVs***.

To see what numbers of wind turbines would be involved if the energy needs within the Domestic Sector in Uttlesford were to be powered by wind energy, further assessments were carried out to estimate the scale of develop that would be needed to match the current energy needs. Clearly it would make sense to try and reduce the demand and that should be encouraged, but for the assessment, it was assumed that current levels of electricity consumption based on the UK average household electricity demand of 4,700 kWh/y be used.

To provide the electricity demand of the assumed 30,000 households in Uttlesford, it was estimated that it would require **21 to 32 E82 turbines**[2] or **32 to 42 V82 turbines**[3]. These turbines would then abate around **121,000 tonnes of CO_2 per year**. If we were to aim initially to generate electricity equivalent to

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[2] 82 metre diameter Enercon E82 turbines rated at 2050 kW.

[3] 82 metre diameter Vestas V82 turbines rated at 1650 kW.

around **20%** of current electricity demand then this would require **5 to 7 E82 turbines** or **7 to 9 V82 turbines** which would abate around **24,200 tonnes of CO_2 per year**. Generating electricity equivalent to **50%** of current household electricity demand would require **11 to 16 E82 turbines** or **16 to 21 V82 turbines** and would abate around **60,000 tonnes of CO_2 per year**.

The electricity needs (based on UK average demand of 4.7 MWh/y) of the households in the **parish** of Great Dunmow could be supplied by electricity equivalent to output from **2 to 3 E82 turbines** or **3 to 4 V82 turbines** and abate around **7,900 tonnes CO_2/year.** Saffron Walden by **5 to 7 E82 turbines** or **7 to 9 V82 turbines** (and abate **16,800 tonnes CO_2/y**), Stansted Mountfitchet by **2 to 3 E82 turbines** or **3 to 4 V82 turbines** (and abate **6,000 tonnes CO_2/y**), Thaxted by **1 E82 turbines** or **2 V82 turbines** (and abate **2,800 tonnes CO_2/y**).

To see what numbers of turbines would be needed to offset heating demand, an estimate of the numbers of turbines was made assuming the domestic space heat and hot water demand for the households in Uttlesford was met by heat pumps. Whilst heat pumps would not be able to be utilised universally, the estimates give an indication of what might be considered.

To estimate the average household demand the average domestic gas consumption of 21,400 kWh/y (from *DUKES06*) for Uttlesford was used as a guide. Clearly there could be substantial potential for reduction in the space heating demand if an effective thermal performance upgrade programme was carried out, but the current value was used in the assessment. To determine the electricity production required, heat pumps with a coefficient of performance (COP) of 3 were assumed.

On this basis, to provide the space and water heating demand of all of the assumed 30,000 households in Uttlesford, it was estimated that it would require **34 to 49 E82 turbines** or **51 to 62 V82 turbines**. These turbines were estimated to abate almost **137,000 tonnes of CO_2 per year** assuming all of the households were off-setting gas condensing boilers. If 64% were offsetting gas condensing boilers and the 36% were offsetting oil fired boilers, the CO_2 abatement would then be of the order of **159,000 tonnes of CO_2 per year**.

If the wind turbines are used to provide electricity for heat pumps (COP 3) for just the electrically heated (Economy 7) households in Uttlesford, would require **4 to 6 E82 turbines** or **6 to 8 V82 turbines** and abate almost **34,000 tonnes of CO_2 per year**

Using the ***wind energy + heat pump*** option is a potentially useful strategy (using current technologies) for using an indigenous CO_2-free source of energy which, if combined with heat storage, could also provide a useful way to exploit and store energy from the variable winds.

To provide both the estimated electricity needs plus the space and water heating needs, it was estimated that it would require **56 to 80 E82 turbines** or **83 to 106 V82 turbines**. These turbines are estimated to abate almost **258,000 tonnes of CO_2 per year** (assuming heating energy is offset from gas condensing boilers).

Plug-In Hybrid Electric Vehicles (*PHEVs*) are Hybrid Electric Vehicles that have a sufficiently sized battery pack to enable them to operate as emission-free electric-only vehicles (EVs) for a certain range (after being recharged by plugging-in in a similar manner to recharging a mobile phone) enabling them to achieve very high MPG values.

To see what the use of PHEVs might require in terms of wind energy, it was assumed that there would be one PHEV/household and a UK average daily range of 24 miles/day (38.7 km/day). It was assumed that they would have the same energy consumption (7.5 km/kWh) as the *Tesla Roadster* manufactured in East Anglia by Lotus.

To provide the electricity demand for 30,000 PHEVs in Uttlesford, it was estimated that it would require **9 to 13 E82 turbines** or **14 to 17 V82 turbines**. These turbines would then abate around **55,000 tonnes of CO_2 per year** assuming the vehicles offset are internal combustion engine (ICE) powered cars with an emission rate of 130 gCO_2/km. If they were off-setting ICE cars with an emission rate of 185 gCO_2/km, then they would be estimated to be abating over **78,000 tonnes of CO_2 per year**.

It remains to be seen as to whether it is feasible, but using the *wind energy + PHEV* option is a potentially useful strategy for solving a difficult problem by using an indigenous CO_2-free source of energy. In addition PHEVs, could provide a useful way to exploit and store energy (with smart metering) from the variable winds. If there is sufficient uptake of PHEVs, this use of wind energy could also be potentially very economically attractive, given the high cost of petrol.

As a result of these estimates it is also possible to see how many turbines would be needed to provide the estimated **electricity needs plus the space and water heating plus *PHEVs*** in Uttlesford. It was estimated that it would require **64 to 87 E82 turbines** or **96 to 114 V82 turbines**. These numbers of turbines are estimated to abate almost **313,000 tonnes of CO_2 per year** (assuming the heating energy offset is from gas condensing boilers, and the PHEVS are offsetting ICE (internal combustion engine) vehicles with 130g/km).

Unless it is severely constrained because of potential conflicts with aviation and/or radar (because of the proximity of Stansted Airport), Wind Energy in combination with other renewable energy resources has an important potential role to play in Uttlesford with regard to electricity provision and also potentially for the supply of heat and transportation energy from local CO_2-free source. **Table 1-1** shows the numbers of wind turbines for a range of scenarios for Uttlesford household energy needs.

Table 1-1: Wind Energy Scenarios for Uttlesford Household Energy Needs

Numbers of Wind Turbines for Range of Uttlesford Scenarios - Unconstrained by Maximum Height					
	demand	# E82 WTs	# V82 WTs	Energy Generated	CO_2 Abated
Scenario	%	#	#	MWh/y	tCO_2/y
Wind energy generation to provide electricity for present uses	100%	21 to 32	32 to 42	141,000	121,000
	50%	11 to 16	16 to 21	70,500	60,000
	20%	5 to 7	7 to 9	28,200	24,200
Wind energy generation to provide space and hot water heating demand by means of heat pumps (COP = 3)	100%	34 to 49	52 to 62	216,000	137,000
	50%	17 to 25	26 to 31	108,000	68,500
	20%	7 to 10	11 to 13	43,200	27,400
Wind energy generation provide to recharging of one PHEV per household	100%	9 to 13	13 to 17	57,000	55,000
	50%	5 to 7	7 to 9	28,500	27,500
	20%	2 to 3	3 to 4	11,400	11,000

As such wind energy could help Uttlesford to substantially reduce the CO_2 emissions from within the district - subject to any restrictions from air traffic control constraints.

Limiting the maximum height of the turbines to 90 m AGL may potentially be a constraint for wind turbines in certain areas for airport/air traffic reasons. Though this would reduce the output of each turbine and also result in an increased number of turbines to generate the equivalent energy.

To generate an equivalent amount of electricity as the needs for the 30 k households in Uttlesford (assuming UK average of 4.7 MWh/y) below a 90m maximum height constraint would require **32 to 38 E82** turbines or **38 to 45 V82** turbines at **49 m hub height**. To provide an equivalent amount of electricity to operate heat pumps to provide heat for 30 k households would require **49 to 55 E82** turbines and **58 to 65 V82** turbines. Also to provide an equivalent amount of electricity to charge 30 k PHEVs would require **13 to 16 E82** turbines or **15 to 18 V82** turbines. To provide electricity + space & water heating + PHEVs for 30 k households would require **94 to 104 E82** turbines or **110 to 123 V82** turbines operating at 49 m hub height.

Table 1-2 shows the numbers of wind turbines for a range of scenarios for Uttlesford household energy needs assuming constrained by maximum height of 90 metres.

Table 1-2: Wind Energy Scenarios for Uttlesford Assuming turbines constrained to 90 m max height.

Nos of Turbines for Range of Uttlesford Scenarios - Constrained by Max. Height of 90 m AGL (49 m HH)					
Scenario	demand %	# E82 WTs #	# V82 WTs #	Energy Generated MWh/y	CO_2 Abated tCO_2/y
Wind energy generation to provide electricity for present uses	100%	32 to 38	38 to 45	141,000	121,000
	50%	16 to 19	19 to 23	70,500	60,000
	20%	7 to 8	8 to 9	28,200	24,200
Wind energy generation to provide space and hot water heating demand by means of heat pumps (COP = 3)	100%	49 to 55	58 to 65	216,000	137,000
	50%	25 to 28	29 to 33	108,000	68,500
	20%	10 to 11	12 to 13	43,200	27,400
Wind energy generation provide to recharging of one PHEV per household	100%	13 to 16	15 to 18	57,000	55,000
	50%	5 to 7	7 to 9	28,500	27,500
	20%	3 to 4	3 to 4	11,400	11,000

1.3 Ground Coupled and Air Coupled Energy

Geothermal energy is derived from heat generated within the Earth; solar energy stored in the ground (but nearer the surface) is referred to as **Ground-Coupled Energy** although the latter is also often referred to as geothermal. Geothermal energy is not available, but Ground-Coupled Energy is available in Uttlesford - and can provide heat, hot water and cooling energy ('coolth'); can pre-heat and pre-cool ventilation air and can be used to store energy. Low grade heat contained in ambient air can also be exploited to provide space and water heating.

Ground-coupled energy can be exploited in the following ways: -

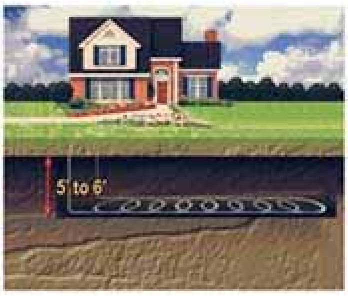
- direct ground-coupling via earth sheltering or using an underground building
- via a ground heat exchanger, bore hole or a water source
- pre-heating or cooling of ventilation air via earth pipes or tubes
- heating &/or cooling by ground water heat pump
- heating &/or cooling via ground collector heat pump

Earth Tubes are widely used in European countries and can cool or pre-heat ventilation air and can be integrated into heat recovery and ventilation (HRV) systems and reduce cooling and heating needs and thus reduce CO_2 emissions.

Ground-coupled 'free cooling' has been successfully employed at the BRE Environment Office in Watford with the aim of avoiding the use of air conditioning; this approach circulates cooling water from an onsite borehole through the building. This approach could be applied in Uttlesford for cooling needs.

Wherever an appropriate body of water exists there will be opportunities to make use of **ground water source heat pumps**.

The temperature of the ground throughout most of Uttlesford is such that Ground Coupled Energy can be exploited via a ground collector and a heat pump (known as a **Ground Source Heat Pump**) to warm buildings in winter and cool them in summer without emitting high levels of CO_2. If electricity to power the heat pump comes from a renewable energy source[4] then it can be an efficient zero CO_2 method of heating and cooling.



GSHPs may be able to compete economically in rural locations where the only conventional form of heating available is that fuelled by oil or electric storage heaters.

Ball park estimates of using GSHPs to provide the space and water heating for the Uttlesford non-gas households indicate that they could abate an aggregated level of CO_2 emissions of the order of **9,000 tonnes/y for 20%**; **22,000 tonnes/y for 50%**, and **32,000 tonnes for 70% of the non gas households**. If it proved to be feasible for all of the non-gas households to use GSHPs, then they could abate around **45,600 tonnes CO_2/y**, i.e. around a **27% reduction of the total[5] Uttlesford domestic space and water heating related CO_2 emissions**.

If electricity from a renewable energy source is used, then GSHPs could abate of the order of **15,000 tonnes CO_2/y for 20%** of the non-gas households**; 22,000 tonnes CO_2/y for 30%**; **38,000 tonnes CO_2/y for 50%**; **53,000 tonnes CO_2/y for 70%** and **around 75,000 tonnes CO_2/y for all non gas households,** i.e. around a **45% reduction of the total Uttlesford domestic space and water heating related CO_2 emissions**.

More recently the performance of heat pumps that extract heat from the ambient air (**Air Source Heat Pumps** or **ASHPs**) has been improved such that it is also possible to consider this form of space and water heating throughout Uttlesford.

The ball park estimates of using ASHPs indicate that they could abate of the order of **7,900 k tonnes/y for 20%** of the non gas households; **19,800 tonnes/y for 50%**, **27,700 tonnes for 70%** and **39,600 tonnesCO_2/y for all of the non gas households**, i.e. around a **23% reduction of the Uttlesford domestic space and water heating related CO_2 emissions**.

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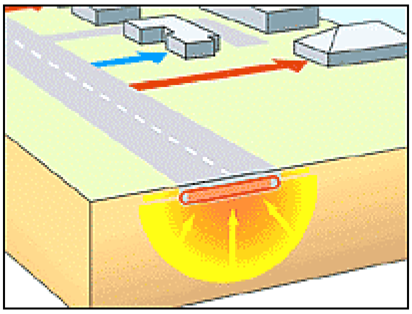
[4] See the section on wind energy.

[5] Total includes both gas households and non-gas households.



Another related approach is known as **Solar-Assisted Ground Coupled Energy** or **Solar Roads**. There are a number of variants but the main principle is to use asphalt/tarmac or paved surfaces as simple unglazed 'solar collectors' in combination with **Ground Coupled Energy Storage**.

Assuming 10% of the road area in Uttlesford were used as Solar Roads, the ball park estimates indicate that around **3,360 (around 12%) of Uttlesford households** could be supplied with space and water heating assuming current average demand (or around 7,000 households or around 26% of Uttlesford households if average space and water demands were reduced to 10 MWh/y by means of energy conservation). Using the Solar Road technology in the main town centre car parks would provide for around 100 to 140 households or 210 to 310 households at 10MWh/y average space and water heating demand. Utilising additional private car parks/terraces/play grounds could enhance the number of households.

The ground can also be used to inter-seasonally store energy (as heat or 'coolth') known as **Ground Coupled Energy Storage** or **Underground Thermal Energy Storage** (UTES) via ATES (**Aquifer Thermal Energy Storage**) or BTES (**Borehole Thermal Energy Storage**). Both open loop ATES and closed loop BTES systems appear to be feasible in Uttlesford and have potential to provide inter-seasonal energy storage to heat and cool large buildings or groups of households. These systems have been successfully employed in various European and North American countries and have been used in a number of UK projects.

If suitable open spaces/roads are available adjacent to buildings that have either a need for heating or cooling or have excess heat then these UTES systems and Solar Road systems have potential and could provide a means of reducing the CO_2 emissions from hard to heat/insulate old/listed buildings. These systems could also facilitate the integration of neighbourhood/large scale renewable energy sources including solar and wind energy and could also improve the viability of district scale combined heat and power systems.

The suitability of ground soil conditions for drilling of bore holes at individual sites in Uttlesford needs to be confirmed, though no major problems are anticipated. The potential energy and CO_2 benefits of Ground-Coupled Energy should be promoted and publicised to building owners, developers, builders and housing associations.

1.4 Biofuels

There are a range of biofuel resources available within Uttlesford and these can be utilised for a variety of applications and employ a range of technologies, some of which are available now and some are imminent.

Wood pellet

Wood pellet fuelled boilers seem to be the most likely candidates for utilising biofuels at a domestic scale initially because of their relatively 'user friendliness', the generally consistent quality of pellets compared to some of the other fuels (particularly wood chips) and resources and the fact that they can be relatively easily substituted for oil and solid fuel based systems. Wood pellet stoves may have some appeal to users (including some with gas based systems) who wish to have a 'fireplace feature' - or to have a backup form of heating in reserve in the event of possible future gas shortages or power cuts - but have recognised that open fires are very inefficient, conventional wood stoves may also not be particularly efficient and they also do not wish to collect firewood or chop logs.

From a capital cost point of view wood pellet boiler based systems are likely to be more competitive than ground source heat pumps that are probably the main other renewable energy competitor for the oil and solid fuel heated houses, but it also depends on the costs of providing the flue/chimney, fuel store and any automatic loading systems.

At the present time there are no sources for wood pellets produced in Uttlesford, though if the mobile wood pelletting technologies employed to pelletise wood chips become viable then there could well be some locally produced pellets from wood chips produced as a by-crop from the various woods within Uttlesford or from arboricultural trimmings from tree surgeons and the like. However it seems probable that wood pellets will mainly be imported into Uttlesford from elsewhere and whilst this may not be a major issue at the present time if the wood pellets are sourced from East Anglia, East Midlands or parts of the South East because of the comparatively higher energy density compared to wood chips (pellets have about three times the energy density (more if the chips are not dry)) but care should be taken to check the sources as many wood pellets are imported form overseas. So if wood pellets do become very popular, there may well be a need to develop some form of robust accreditation, if one is to achieve CO_2 savings by using such fuels.

Wood chips

Wood chips are more suitable for larger houses and other larger properties as they require more care and maintenance compared to wood pellet based systems though there are systems with automatic loaders and hoppers etc which improve their operation.

Wood chips are available from much of East Anglia from a variety of sources ranging from forest thinnings, arboricultural trimmings under-managed woodlands and from tree surgeons. Improvements to the supply chain by a number of organisations such as Anglia Wood Fuels, the Forestry Commission, Renewables East and the Deer Initiative amongst others should improve the take up of wood chips.

According to the land suitability maps produced by DEFRA much of the land available in Uttlesford to grow wood based energy crops based on short rotation coppice is not optimal, so this method of producing wood chips is not likely to become attractive to farmers or land owners in Uttlesford. The appeal of supplying the annual 1.82 million tonnes of wood chip requirements for the 2 MW wood chip boiler being planned as part of an extension to Stansted Airport remains to be seen, but it might stimulate local interest in the production of the fuel.

Whilst the short rotation coppice (SRC) may not be optimal, the use of an updated form of **wood pasture/pollard system** could potentially be viable as it has extensive historical precedence (e.g. Hatfield Forest). Whilst it would not have the yields of SRC and would operate over different cycles it is more of an 'agroforestry' approach which does not displace food production and there is increasing awareness of its wildlife friendly attributes based on low inputs and potentially more robust tolerance to the effects of climate change. Whilst it may not be appealing to farmers at the present time due to the difficulties being experienced by conventional livestock farmers elsewhere in Britain, it is an approach that does have a number of ecological/ biodiversity/ sustainability attributes on longer time scales.

Miscanthus

The conventional woody energy crop that does, according to DEFRA, seem to be suitable for growing within Uttlesford is **Miscanthus** a perennial grass which has attributes more akin to conventional agricultural crops so is likely to be more appealing to farmers and it can (at the present time) produce a higher annual yield (though more productive strains of willows are being researched at a number of sites including some in the East of England).

In principle it would seem to be possible to provide Miscanthus fuel to all of the oil or solid fuel households (at current average space and water heating demands) in Uttlesford from around **2,300 ha** or around **41%** of the Uttlesford Set-aside land (abating around **38,500 tonnes CO_2/y**). If average space and water heating demand was reduced by **30%**, the amount of miscanthus required could potentially be grown on around 29% of Uttlesford Set-aside land (abating around **39,500 tonnes CO_2/year**). Whether it would be sufficiently user friendly for smaller boilers remains to be seen, though at least one UK miscanthus grower is developing miscanthus pellets - however they are not suitable for use in current wood pellet boilers.

Straw

The main form of land use in Uttlesford is the growing of cereals, followed by oil seed rape (OSR). There is thus a considerable amount of **straw** available to provide a potential heating fuel without conflicting with food production. There is considerable research underway to develop straw pellets as fuel particularly in Denmark - and in north America they have been experimenting with grass pellets. Whilst all of these have some substantial promise, they do produce much more ash and clinker than wood pellets and can be corrosive so it is not advisable to use them in wood pellet boilers. However the boilers designed to burn corn or grain can apparently cope with these characteristics and such boilers are available in the UK.

To provide the current average space and water heating needs for all of the oil and solid fuel households in Uttlesford would require straw from approximately **38%** of the current Uttlesford wheat crop land (abating around **38,500 tonnes CO_2/y**). With a 30% reduction in demand for space and water heating the required land area would reduce to around 27% of the current Uttlesford wheat crop area (abating around **39,500 tonnes CO_2/year**). As such there may be surprising scope for the use of locally grown straw pellets for the heating of the oil or solid fuel heated households in Uttlesford - provided adequate guidance about the factors involved are made available. Perhaps a few demonstration installations within the district to monitor the performance and remedy any shortcomings would be worth consideration in some Uttlesford DC properties.

Bio Micro-CHP

Micro-CHP is a technology which is still under development and undergoing field trials, though when driven by gas they have not proved to be as effective in reducing CO_2 emissions as anticipated. However if they are able to be powered by biofuels then they could potentially achieve substantial CO_2 abatement. A range of technologies are under development which can use a variety of biofuel sources. The most likely candidate is a Micro-CHP unit fuelled by rape seed oil based fuels including **Biodiesel** and straight vegetable oils (**SVO**).

If oil seed rape (OSR was grown on **50%** of Uttlesford Set-aside land (together with 50% of the current OSR being grown) and the oil extracted from the OSR and used to fuel Micro-CHP units, they could supply **3,780 households** (assuming average UK electricity demand of 4.7 MWh/y) or **5,920 households** (at 3 MWh/y average electricity demand). In terms of current average heat demand the OSR Micro-CHPs could supply around **2,250** households, or **3,190** households (assuming space and heating demand reduced by **30%**), or around **4,500 households**.

This level of OSR based Micro-CHP would abate of the order of **10,000 tonnes of $C0_2$/year** offsetting electricity plus **9,560 tonnes** of $C0_2$/year (Micro-CHP heat output assumed to be offsetting 90% efficient gas fired boilers). If the OSR straw is also used as a fuel, a further **9,200** tonnes of $C0_2$/year could be abated.

Straw-CHP

As well as having potential in the form of pellet fuels, straw has potential to supply energy in **distributed or district scale combined heat and power stations** of a similar size range to Danish **Straw-CHP stations**, the first of which began operating in 1989.

If the straw from the 50% of the Uttlesford wheat crop area plus straw from the current OSR crop area and OSR grown on 50% of Uttlesford Set-aside was used in Straw Fired CHP stations, this would provide electricity for around **8,170 households** (at 4.7MWh/y per household) or **12,800 households** (at 3 MWh/y average electricity demand) and abate around **16,200 tonnes** CO_2/year. Similarly the heat derived from the Straw-CHP could supply around **4,360 households** (at current space and water heating demand consumption), around **6,400 households** (assuming 30% space and water heating demand reduction) or **8,700 households** or around 60% of the housing stock (assuming 50% space and water heating demand reduction) and abate around **18,500 tonnes CO_2/year.**

Food Waste Anaerobic Digestion

The **kitchen and green wastes** emanating from Uttlesford have potential for converting the biological waste stream into useful renewable energy by processing in an **Anaerobic Digester**. Using the South Shropshire Biowastes Digester as a guide, indicates that **Food Wastes AD** could generate **390,320 kWh/y** of net electricity (and abate around **220 tonnes CO_2/year**) and around **574,520 kWh/y** of net heat output (abating **1,210 tonnes CO_2/year**).

Biomass CHP and Distributed Energy

Both the Straw-CHP and the Food Waste AD based CHP units could form part of a distributed heat and electricity network in combination with more conventional CHP and link up with other renewable energies such as car port solar, neighbourhood/community wind power and group scale ground coupled energy/ground coupled inter-seasonal storage or solar/ground coupled roads.

Such combinations, together with heat mains and heat stores, could also form the basis of a distributed energy network that facilitates the establishment of **'Private Wire'** networks on the lines of that implemented at Woking in Surrey. These types of arrangements can also provide funding mechanisms to expand the use of renewable energy technologies but also to help fund some of the more difficult energy saving measures and infrastructure.

Straw-CHP (and the Food Waste AD based CHP) could provide a possible means of low carbon electricity for non gas communities or they could operate in tandem with gas-CHP stations in a distributed network in the settlements with gas available.

Also, depending on the proximity of the plant to hard to heat houses and listed buildings, such a scheme would assist in reducing the CO_2 emissions from this difficult housing stock group.

1.5 Hydro Energy

As rainfall in eastern England is generally lower than in the west, hydro energy is generally less viable.

For hydro to be viable requires a number of factors to come together. These include a reasonably sized catchment area, appropriate levels of rainfall, a sufficient 'head' to capture useful amounts of energy and sufficient flow rates throughout most of the year.

A number of streams and rivers have their origins in Uttlesford but, from a preliminary analysis and discussions with local water power groups, the Environment Agency, local anglers and Anglia Water amongst others. there do not appear to be sites with sufficient of the above factors to be worth utilising, though there is documentary evidence of a few water mills in Uttlesford and a small micro-hydro project is being developed in Stebbing to provide electricity for a house at a former water mill.

The possibilities of utilising hydro electricity in the water distribution network was also discussed but Anglia Water has apparently reviewed the potential and decided that there was little of merit within Uttlesford.

One aspect with hydro technology that might have some potential given the undulating topography is the use of **pumped storage**. This involves utilising or creating lakes and reservoirs - one located at or near the top of a hill and one located in a valley. When excess energy is available, water is pumped up to the upper lake and when electricity is required the water passes through a hydroelectric turbine and electricity is generated.

In itself such pumped storage schemes may be expensive, but if they are also employed to assist in water storage and water conservation or in biodiversity enhancement it may be a more feasible option.

1.6 Renewable Energy in Uttlesford

Table 1-3 and **Table 1-4** summaries the range of technologies and ball park estimates renewable energy potential for Uttlesford.

Taken together the renewable energy technologies reviewed in this study could show the way in tackling many of the challenges of climate change. Particularly wind, solar, ground coupled energy technologies and certain biofuel technologies can help to reduce the CO_2 emissions for electricity and heat provision and potentially for vehicles.

Table 1-3: Summary Table of Renewable Energy Resources and Ball Park Estimates of potential for Solar Energy & Wind Energy in Uttlesford

		Power	**Output (GWh/y)**			**CO$_2$ Abatement (tonnes/yr)**			**(PHEVs)**
		MW	elect	heat	heat + elect	(elect.)	(heat)	(heat+ Elect)	
Solar heat + electricity potential									
Solar water heating potential									
10% of households				2.9 (ET1) to 3.4 (FP2)			690 to 790	690 to 790	
50% of households				14.9 (ET1) to 17.1 (FP2)			3,450 to 3,950	3,450 to 3,950	
60% of households				17.9 (ET1) to 20.5 (FP2)			4,100 to 4,700	4,100 to 4,700	
70% of households				20.9 (ET1) to 23.9 (FP2)			4,800 to 5,500	4,800 to 5,500	
Solar PV									
Option 1 (1 kWp+500kWp Arrays)									
BIPV+BAPV on 10% of Households			1.29 to 1.39			730 to 790		730 to 790	
BIPV+BAPV on 50% of Households			6.45 to 6.97			3,600 to 3,950		3,600 to 3,950	
BIPV+BAPV on 60% of Households			7.74 to 8.36			4,390 to 4,750		4,390 to 4,750	
BIPV+BAPV on 70% of Households			9 to 9.76			5,130 to 5,540		5,130 to 5,540	
Option 2 (2kWp+1kWp Arrays)									
BIPV+BAPV on 10% of Households			2.58 to 2.78			1,450 to 1,570		1,450 to 1,570	
BIPV+BAPV on 50% of Households			12.9 to 13.94			7,320 to 7,910		7,320 to 7,910	
BIPV+BAPV on 60% of Households			15.48 to 16.73			8,790 to 9,490		8,790 to 9,490	
BIPV+BAPV on 70% of Households			18 to 19.51			10,260 to 11,000		10,260 to 11,000	
Option 3 (3kWp+2kWp Arrays)									
BIPV+BAPV on 10% of Households			4.17 to 4.5			2,450 to 2,640		2,450 to 2,640	
BIPV+BAPV on 50% of Households			20.88 to 22.56			12,280 to 13,260		12,280 to 13,260	
BIPV+BAPV on 60% of Households			25 to 27			14,740 to 15,920		14,740 to 15,920	
BIPV+BAPV on 70% of Households			29.23 to 31.58			17,200 to 18,500		17,200 to 18,500	
Option 4 (4kWp+3kWp Arrays)									
BIPV+BAPV on 10% of Households			5.86 to 6.31			3,440 to 3,710		3,440 to 3,710	
BIPV+BAPV on 50% of Households			29.24 to 31.59			16,250 to 18,610		16,250 to 18,610	
BIPV+BAPV on 60% of Households			35 to 37.9			20,690 to 22,340		20,690 to 22,340	
BIPV+BAPV on 70% of Households			40.9 to 44.22			24,140 to 26,000		24,140 to 26,000	
PV Carports Stansted Airport		33.6	23 to 26			13,300 to 14,700			
PV Carports in 10 Town ctr Car Parks		1.64	1.1 to 1.2			640 to 720			
Wind Energy (no height constraint)									
Wind Energy for Household Electricity	(4.7MWh/y per HH)								
20% of households	7 to 9 V82 WTs	8 to 11.2 MW	28.2			24,200		24200	
20% of households	5 to 7 E82 WTs	10 to 14 MW	28.2			24,200		24200	
50% of households	16 to 21 V82 WTs	25.6 to 33.7 MW	70.5			60,000		60000	
50% of households	11 to 16 E82 WTs	22 to 32 MW	70.5			60,000		60000	
100% of households	32 to 42 V82 WTs	51.3 to 67.4 MW	141			121,000		121000	
100% of households	21 to 32 E82 WTs	43 to 65.6 MW	141			121,000		121000	
Wind Energy for Household Space & Water Heating	via Heat Pumps @ COP 3								
20% of households	11 to 13 V82 WTs	17.6 to 20.8 MW	43.2	129.6			27,400	27400	
20% of households	7 to 10 E82 WTs	14.3 to 20.5 MW	43.2	129.6			27,400	27400	
50% of households	26 to 31 V82 WTs	41.7 to 49.7 MW	108	324			68,500	68500	
50% of households	17 to 25 E82 WTs	34.8 to 51.2 MW	108	324			68,500	68500	
100% of households	52 to 62 V82 WTs	83.4 to 99.5 MW	216	648			131,000	131000	
100% of households	34 to 49 E82 WTs	69.7 to 100.4 MW	216	648			131,000	131000	
Wind Energy for PHEVs	1PHEV per HH (24 m/day)								
20% of households	3 to 4 V82 WTs	4.8 to 6.4 MW	11.4						11,000
20% of households	2 to 3 E82 WTs	4 to 6 MW	11.4						11,000
50% of households	7 to 9 V82 WTs	11.2 to 14.4 MW	28.5						27,500
50% of households	5 to 7 E82 WTs	10.2 to 14.3 MW	28.5						27,500
100% of households	13 to 17 V82 WTs	20.8 to 27.3 MW	57						55,000
100% of households	9 to 13 E82 WTs	18.4 to 26.6 MW	57						55,000

Table 1-4: Summary Table of Renewable Energy Resources and Ball Park Estimates of potential for Ground Coupled Energy & Biofuels in Uttlesford

		Power	**Output (GWh/y)**			**CO_2 Abatement (tonnes/yr)**			**(PHEVs)**
		MW	elect	heat	heat + elect	(elect.)	(heat)	(heat+ Elect)	
Ground Coupled Energy									
GSHPs									
10% of non-gas households		8.9 MWth (3MWe)	7	21			4560		
20% of non-gas households		17.9 MWth (6MWe)	14	42			9120		
50% of non-gas households		44.5 MWth (15MWe)	35	105			22,000		
100% of non-gas households		89 MWth (30MWe)	70	210			45,600	45,600	
10% of Electrically heated households		3.3 MWth (1.1MWe)	2.63	7.9			2,260	2,260	
20% of Electrically heated households		6.6 MWth (2.2MWe)	5.26	15.8			4,520	4,520	
50% of Electrically heated households		16.5 MWth(5.5 MWe)	13.15	39.5			11,300	11,300	
100% of Electrically heated households		33 MWth (11 MWe)	26.3	79			22,600	22,600	
Solar Roads									
12% of households (@21 MWh/y per HH)	10% of UF road area			70.56	70.56				
26% of households (@10 MWh/y per HH)	10% of UF road area			70.56	70.56				
Solar Road Car Parks *(conflict with SolarPV CarPorts)*									
100 to 140 housholds (21MWh/y per HH)	town centre car parks								
100 to 140 housholds (21MWh/y per HH)	town centre car parks								
Biofuels									
Miscanthus in boilers									
All oil + solid fuel heated households at current demand	Grown on 2,300 ha or 41% Setaside							38,500	
All oil + solid fuel heated households demand reduced by 30%	Grown on 29% Setaside land							39,500	
Straw pellets in boilers									
All oil + solid fuel heated households at current demand	Straw from 38% of wheat crop land							38,500	
All oil + solid fuel heated households demand reduced by 30%	Straw from 27% of wheat crop land							39,500	
Bio Micro CHP									
Rape seed oil or RME biodiesel fuelled MicroCHP units									
3780 hses (elec @4.7MWh/HH) + 2,250 hses (Sp&WH)	OSR on 50% of Setaside		17.8	47.3	65	10,000	9,560	19,560	
	(further 9,200 tCO2 abated if OSR straw used)								
5,920 hses (elec@3 MWh/HH) + 3,190 hses (Sp&WH @30% red demand)	(further 9,200 tCO2 abated if OSR straw used)		17.8	47.3	65	10,000	9,560	19,560	
Straw-CHP									
8,170 hses (elec @4.7MWh/HH) + 4,360 hses (Sp&WH)	50% wheat crop + 50%OSR straw +OSR on 50% Setaside		38.4	91.6	130	16,200	18,500	34,700	
12,800 hses (elec @3MWh/HH) + 8,700 hses (SpWH demnd red by 30%)	50% wheat crop + 50%OSR straw +OSR on 50% Setaside		38.4	91.6	130	16,200	18,500	34,700	
12,800 hses (elec @3MWh/HH) + 8,700 hses (SpWH demnd red by 50%)	50% wheat crop + 50%OSR straw +OSR on 50% Setaside		38.4	91.6	130	16,200	18,500	34,700	
Food Wastes Anaerobic Digestion									
Assuming 50% of UF food wastes est. to yield 250 t of biogas									
Elect for 80 Hses @ 4.7 MWh/y + heat for 26 Hses @ current demnd			0.39	0.574	0.964	220	1,210	1,430	
Elect for 130 Hses @ 3 MWh/y + heat for 37 Hses demnd red by 30%									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