LOW/ZERO CARBON

RENEWABLE ENERGY FOR UTTLESFORD

SOLAR ENERGY

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Study undertaken for Uttlesford Futures

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2. SOLAR ENERGY

SUMMARY

Solar energy is the primary source of energy which creates the winds and waves, and drives the hydro cycle which creates the rains, and the photosynthesis process, which is vital to the biological food chain. It is therefore the primary source for all forms of renewable energy apart from tidal and geothermal 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.

Assuming a comparable proportion of the households to those in Cambridge which 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 between **17 and 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 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].

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

[1] See also wind energy section.

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 house 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 and 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 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.

Table S-1 Summarising Solar Energy Technologies and ball par k potential in Uttlesford

	Power	Output (GWh/y)		CO_2 Abatement (tonnes/yr)		
	MW	elect	heat	(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		13,300 to 14,700
PV Carports in 10 Town ctr Car Parks	1.64	1.1 to 1.2		640 to 720		640 to 720

CONTENTS

2. SOLAL ENERGY

Solar Energy Definition

The sun is a gigantic fusion reactor that converts hydrogen into helium, which maintains the sun's surface temperature at approximately 6,000 °C. This process emits short wave radiation[2] into space and is the mechanism by which solar energy reaches the Earth.

Solar energy is the primary source of energy which drives the atmospheric engine which creates the winds (and the waves). It drives the hydro cycle which creates the rains (and thus the streams and rivers). It drives the process of photosynthesis which plants use to grow and to drive the food chain of life. It also drives ocean circulation which help to distribute heat around the planet and moderate the temperature of the Earth. The sun is therefore the primary source of all forms of renewable energy apart from tidal and geothermal energy.

Each year the sun sends to the Earth an amount of solar energy that is:

- equivalent to **15 000** times the world's annual use of fossil and nuclear fuels and hydro power.
- roughly equivalent to **160** times the **TOTAL** energy stored in the world's proven reserves of fossil fuels.

By converting the short wave solar radiation into useful thermal energy or into electricity, solar energy can be used directly to substitute for conventional energy. The amount of solar radiation that is usable in the UK varies according to the map in **Figure 2-1**.

In addition the amount of solar energy intercepting a surface depends on the orientation (south facing being optimum) and tilt angle measured from the horizontal. **Figure 2-2** shows the relationship between the orientation and tilt angle that the solar radiation has with a surface.

[2] Including ultra violet light, visible light, and short wave infrared radiation – the solar spectrum.

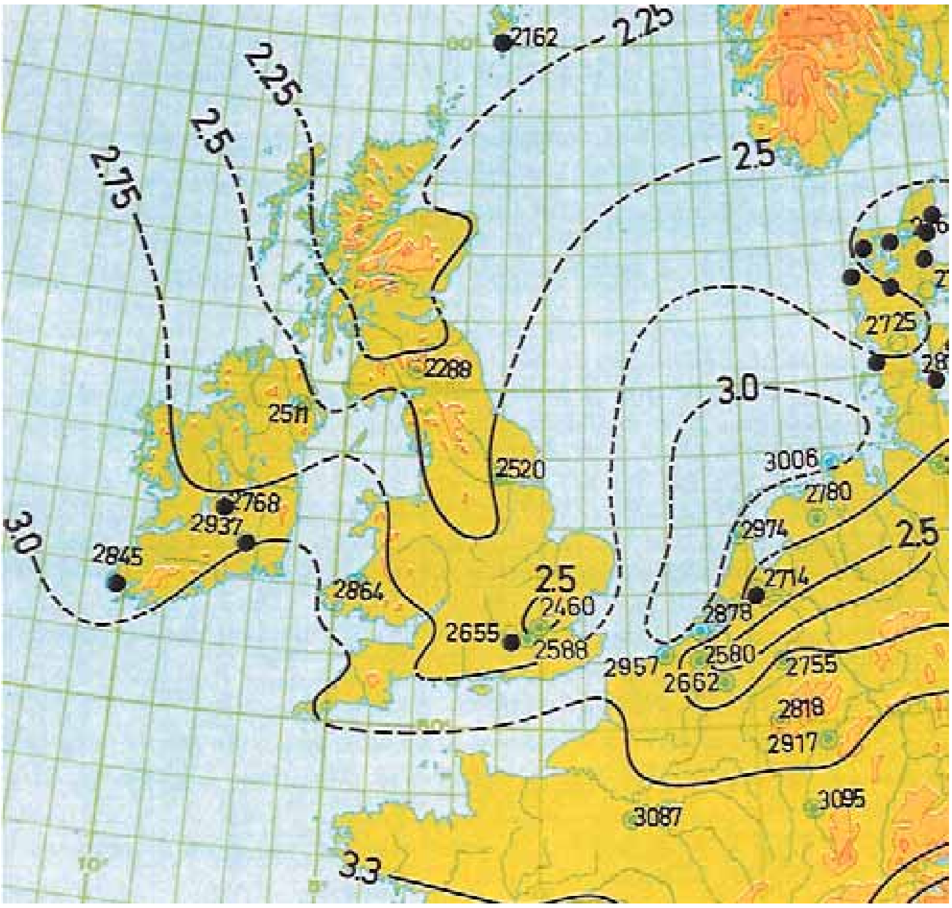

Figure 2-1: Map of solar radiation (*European Solar Radiation Atlas*)
Annual mean of daily sums of solar radiation kWh/m^2 (mean daily).

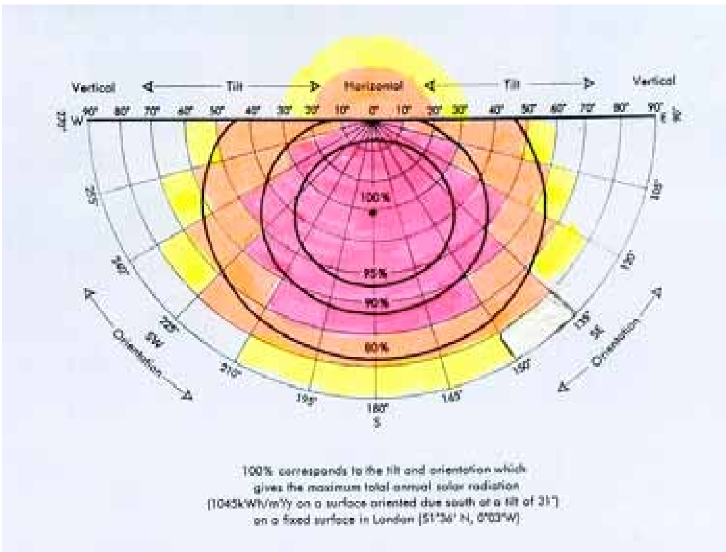

Figure 2-2: The effect of orientation & tilt angle on annual solar radiation for London. Solar radiation levels in Uttlesford will be slightly higher than those shown.

The direct utilisation of solar energy can take several forms.

Converting solar radiation into thermal energy can contribute to domestic hot water, space heating, induce convection in buildings for cooling and ventilation.

Buildings can be designed to maximise the natural day lighting characteristics and reduce the daytime usage of artificial lighting and, in combination with lighting controls, save electricity.

Certain semi-conductors, when exposed to light automatically generate electricity that can be used in buildings or for other purposes.

2.1 Solar Thermal Energy

Solar energy can be converted into heat which can then be used for heating domestic hot water, space heating, process heat or to induce convection to achieve ventilation and cooling.

In certain circumstances it is also possible to use heat from solar energy to create refrigeration or 'chilling' using the 'absorption heat pump' principle exploited in gas powered refrigerators[3].

When clear sky conditions[4] are the norm, solar concentrators can be used to achieve high temperature heating which can be used to power a heat engine or turbine which can be coupled to a generator to produce electricity.

2.1.1 Active Solar

2.1.1.1 Active Solar Thermal

Active solar thermal refers to the active conversion of solar energy into heat by means of a specially designed collector which consists of an absorber[5] coated with a selective surface designed to maximise absorption and minimise re-radiation, together with insulation to retain the heat in the collector. By circulating a fluid through the collector this heat can then be transferred to where it is required or where the heat can be stored.

2.1.1.2 Solar Water Heating Systems

The most common type of active solar thermal system is the solar water heating system. A solar water heating system consists of a collector connected by pipe work to a hot water cylinder. Solar water heating systems cost from about £1,500 upwards.

At the end of 2005, (according to the IEA) there was a global installed capacity of 111 GW_{TH}, solar thermal collectors with over 52 GW_{TH} in China and around 20 GW_{TH} in the USA - though the figures do include swimming pool systems and larger systems and not simply solar water heating systems. There are approximately 60,000 solar water heating systems operating in the UK, where between a half and two thirds of the typical annual domestic hot water requirements of a household can be provided by solar energy.

Flat plate or evacuated tubes are the types of collectors used in the UK[6].

A flat plate collector consists of a flat plate absorber (similar in appearance to a central heating radiator) mounted inside a thin flat box, glazed at the front[7] and insulated at the rear. **Figure 2-3** shows two examples of flat plate solar water heating collectors.

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[3] There are concerns that summer-time cooling and chilling needs are likely to become increasingly important impacts in the future so these applications of solar energy - in combination with solar shading devices - may also become much more relevant than they have to date in the UK.
[4] Not usually the case in the UK to date as cloudy skies are more typical. Clouds diffuse the solar radiation. Diffuse radiation can not be focused so it cannot be used to achieve high temperatures. Whether this remains the case will depend on the effects that climate change has on future Uttlesford weather conditions.
[5] Also a heat exchanger.
[6] Other types of solar collectors are being researched and developed by Altechnica and others including hybrid collectors and passive collectors which offer other attributes and potential performance benefits.
[7] Flat plate solar collectors can be used to heat swimming pools but do not need to be glazed, as lower temperatures are required.

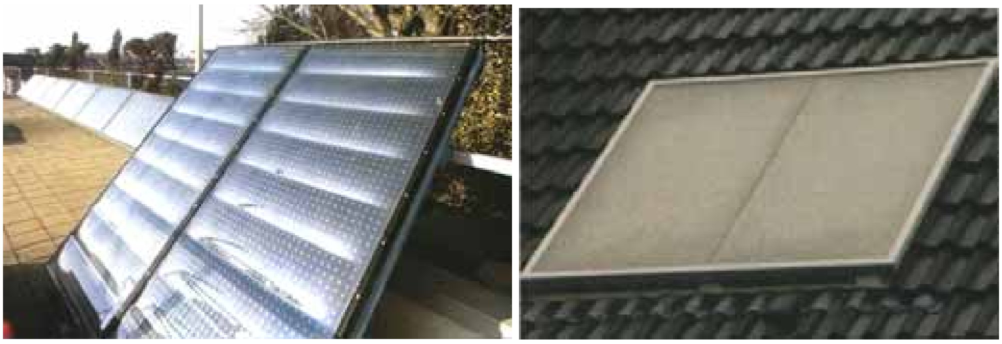

Figure 2-3: Two examples of UK manufactured Flat Plate Solar Water Heating Collectors

Figure 2-4: Two example of evacuated tube solar water heating systems.
Left - Heat-pipe type evacuated tube collectors.
Right - Direct flow circulated evacuated tube collectors

An evacuated tube collector[8] (**Figure 2-4**) consists of an absorber enclosed in an evacuated glass tube similar to a transparent vacuum flask or a clear fluorescent tube. The vacuum minimises the heat loss without reducing the transmission of solar radiation. Some evacuated tubes utilise a '*heat pipe*' as the absorber (**Figure 2.4** left) which provides an efficient means of conducting the heat from the collector and some designs, known as *direct-flow* types, circulate water or an 'antifreeze' fluid through the absorber (**Figure 2.4** right).

The *heat pipe* based evacuated tube collectors are frost resistant but have to be arranged such that the <u>tubes are aligned with the slope</u> of the roof and do not function if horizontally aligned. The *direct-flow* designs are horizontally aligned and can be laid horizontally on a flat or pitched roof, against a vertical south facing wall or even as a 'fence' (**Figure 2.4** right).

Evacuated tube solar collectors are generally more efficient in terms of collection area but the best flat plate collectors give very good performance and can achieve comparable overall system efficiency.

Flat plate collectors are easier to integrate into a roof (particularly a new roof) and can be designed to have the appearance of a roof light[9]. Both flat plate collectors and evacuated tube collectors can be retrofitted onto existing roofs.

In terms of the hierarchy of the usefulness of energy saving measures for domestic properties, solar water heating does not reduce as much CO_2 as having a high level of insulation, so increasing the insulation should normally be considered before solar collectors.

A survey of the housing stock (roof orientation restricted to +/- 45 degrees of south) in Cambridge showed that almost 63% of the houses could accommodate at least 3 m^2 of solar collectors on a roof or vertical wall and 53% of the housing stock could accommodate 5 m^2 of solar collectors (ETSU, 1985). "*74% of the housing built in Cambridge during the 1919-1939 period were south facing and in broad terms the 1919 - 1969 period seems to have been more favourable to southerly orientation than any other. A rather striking finding was that suitably oriented dwellings suffered only a 10% reduction in solar collection from*

[8] 90% of the solar thermal collectors in China are evacuated tubes, whereas in the rest of the world the collectors are more evenly split.
[9] A possibly important attribute if being mounted on buildings in conservation areas.

overshadowing. In terms of the main characteristics of the housing stock, it was found that the Cambridge Housing Survey agreed quite well with national figures and those of other surveys. "

Ii is not clear whether the Cambridge survey included buildings with flat roofs, but there are solar technologies available now that can capture useful amounts of solar energy from horizontal surfaces and in addition there are also solar technologies that can function well on east or west facing slopes (up to a certain pitch) and systems that can be configured as fences or walls.

Without carrying out a similar detailed survey of the housing stock, we cannot be sure, but It seems likely that a similar proportion of the houses in Uttlesford are physically suitable for retrofit type solar water heating systems.

When it is not possible to utilise an appropriately oriented roof, it may be possible to install porch/conservatory or canopy type systems (**Figure 2-5**) on gable ends or other suitable walls (inferring from the above survey it seems likely that almost 40% of the Cambridge housing stock might have potential for such retrofits).

Figure 2-5: Solar collectors as canopies.

In addition it is also possible to have ground mounted systems (**Figure 2-6**) when it Is not feasible to utilise a building surface - though there is more risk of overshadowing, even then optimally oriented pergola mounted systems (**Figure 2-7**) or pole mounted systems may be suitable, subject to plumbing and heat-loss limitations. There are at least two types of pole mounted solar water heating systems available that can follow the track of the sun (**Figure 2-8**) - which can increase the productivity when space is limited, though the cost of the tracking mechanism has to be taken into account.

Figure 2-6: Ground mounted collectors (Flat plate left + Evacuated tube right) (Thermomax).

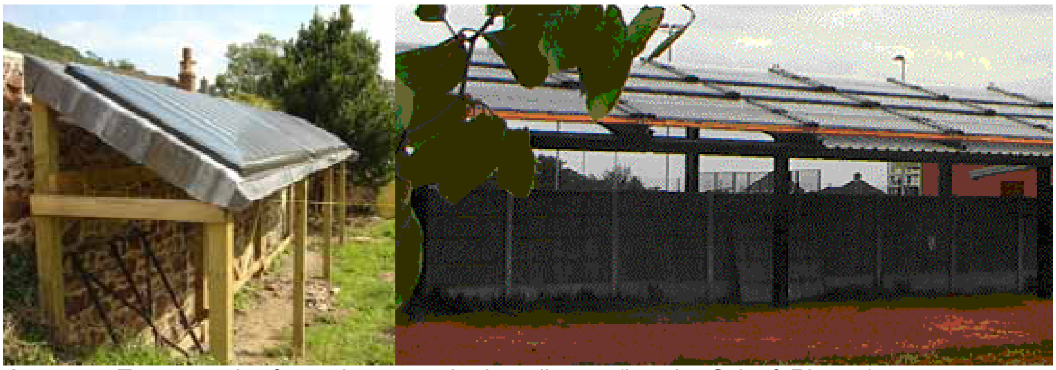

Figure 2-7: Two example of pergola-mounted solar collectors (Imagine Solar & Riomay)

Figure 2-8: Example of a pole mounted solar water heating system that can also be used to 'track the sun' or raised above shade obstacles.

Interestingly there may also be more scope than the Cambridge housing stock study implies (particularly during the summer months) because it turns out that north-west/north-east roof pitches of 30 degrees or less can capture over 70% of the maximum (that is available at optimum orientation and tilt angle) and capture more solar energy than vertical south facing surfaces between April and August. Also even north facing roof pitches of 30 degrees or less can capture over 66% of the maximum and also capture more solar energy than vertical south surfaces between April and August. So if there is sufficient space for larger collectors on these surfaces (and they are not overshadowed), useful solar energy could also be captured from these surfaces if these are the only options available, though of course they would be much less cost effective.

2.1.1.2.1 Solar Water Heating in Uttlesford

Solar radiation data for Cambridge was used to generate the graph in **Figure 2-9** which shows solar radiation available on south facing surfaces for tilt angles between 0 degrees (horizontal) and 90 degrees (vertical) together with south-west/south-east facing surfaces between 0 and 70 degrees tilt angles and west and east facing surfaces between 0 and 40 degrees tilt angles.

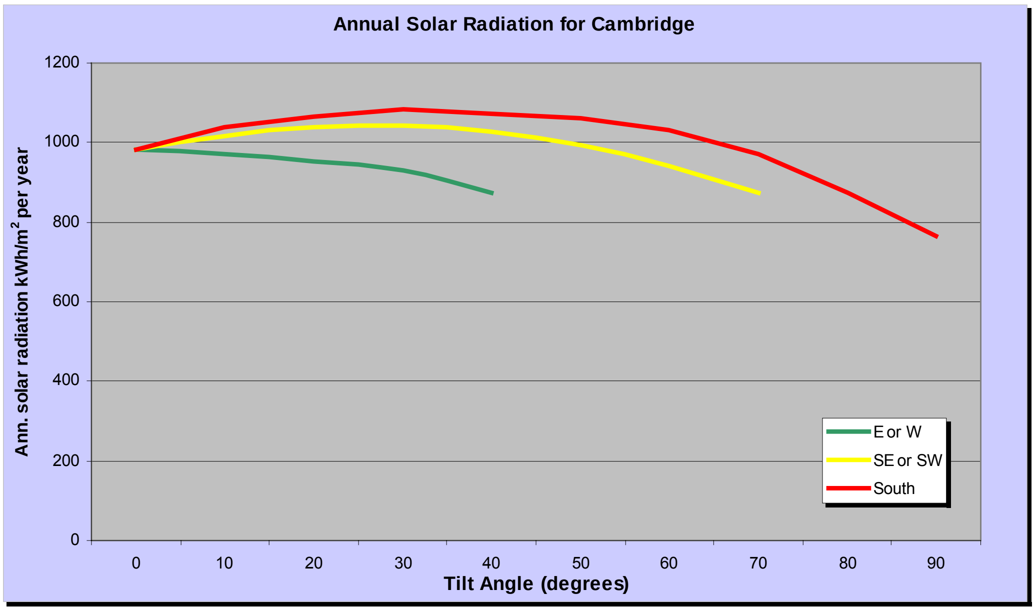

Figure 2-9 Annual Solar Radiation for Cambridge for South, SW, SE, E & W orientations

Figure 2-9 shows that the annual solar energy available for south facing surfaces ranges from 760 kWh/m² (vertical) and almost 1100 kWh/m² (at 32 degrees) with some 980 kWh/m² available on horizontal surface. It shows that the solar energy available on south-west/south-east surfaces ranges between 870/m² (70 degrees) and 1040 kWh/m² (30 degrees). On west/east facing surfaces the solar energy ranges between 870 (40 degrees) and 973 kWh/m² (10 degrees) which is equivalent to almost 90% of the maximum level.

This shows that it makes sense to take care when planning new buildings to orient them towards the south (or at least between SE and SW) and to choose a roof pitch angle between 30 and 40 degrees, even if it is not feasible to consider solar energy exploitation at the time of construction. This orientation makes it easier to retrofit - as solar energy can be maximised with little or no extra cost.

However **Figure 2-9** also shows that solar energy is able to be usefully exploited from a wide range of orientations and tilt angles[10], which is particularly important when considering the potential for utilising solar energy for existing buildings.

In order to estimate the potential contribution that solar water heating could play in housing in Uttlesford, the annual solar energy extracted for domestic water heating was estimated for a range of solar water heating systems for a range of orientations and tilt angles.

The average household size in Uttlesford is 2.5 adults/house and a number of 'standard' solar water heating systems are available that are sized to provide a useful contribution to the daily hot water demand for such households between spring and summer. Whilst it is preferable to match the solar water heating needs of the household, for the purposes of

[10] As mentioned earlier (but not shown in **Figure 2-9**) there may also be potential for NW/NE oriented roof pitches of 30 degrees or less as they can capture 70% of maximum potential and even north facing roof pitches of 30 degrees or less can capture 66% of maximum potential. However only the roof orientations and pitch angles shown in **Figure 2-9** were used for the study of solar water heating potential in Uttlesford.

estimating the ball-park potential contribution of solar water heating in Uttlesford, the 'standard systems' were used in this study.

Because of different approaches taken by different manufacturers in characterising their systems a series of side-by-side tests of a range of solar water heating systems were carried out by EMC in Milton Keynes. These included both flat plate and evacuated tube collectors in combination with hot water storage cylinders and all operated with identical patterns of daily hot water consumption. Whilst several new and potentially more efficient solar collectors have been introduced since these tests were completed it was decided to use the three best performing solar water heating systems from the tests in this study. These include two flat plate systems (**FP1** and **FP2**) and an evacuated tube collector based system (**ET1**) and are all manufactured in the UK. The performances of the collectors from the side by side tests were adjusted and **Figure 2.10** compares the collectors for various south-facing tilt angles.

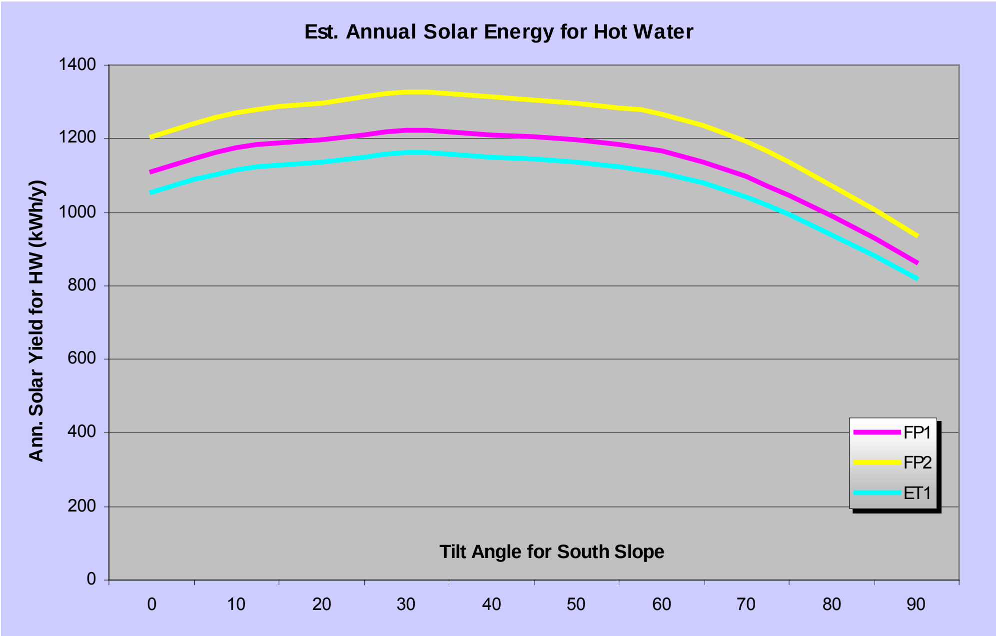

Figure 2.10: Estimated annual solar energy captured for hot water from flat plate & evacuated tube collectors adjusted from side by side tests for south facing tilt angles 0 to 90.[11]

Figure 2.10 shows that **FP2** flat plate system is the most productive of the three compared, though this is partly due to it having the largest collection area (3.998 m²). The **FP1** collector is 3.384 m², and the **ET1** collector is 2.819m².

To compare the effectiveness of these systems **Figure 2.11** shows the estimated annual solar energy captured per unit area of collector (kWh/m² per year).

[11] In actuality this evacuated tube collector will not function at 0 degrees - but other types of evacuated tube systems are specifically designed to operate when configured horizontally. It is not clear whether the flat plate collectors will function horizontally, but the values have been included for completeness.

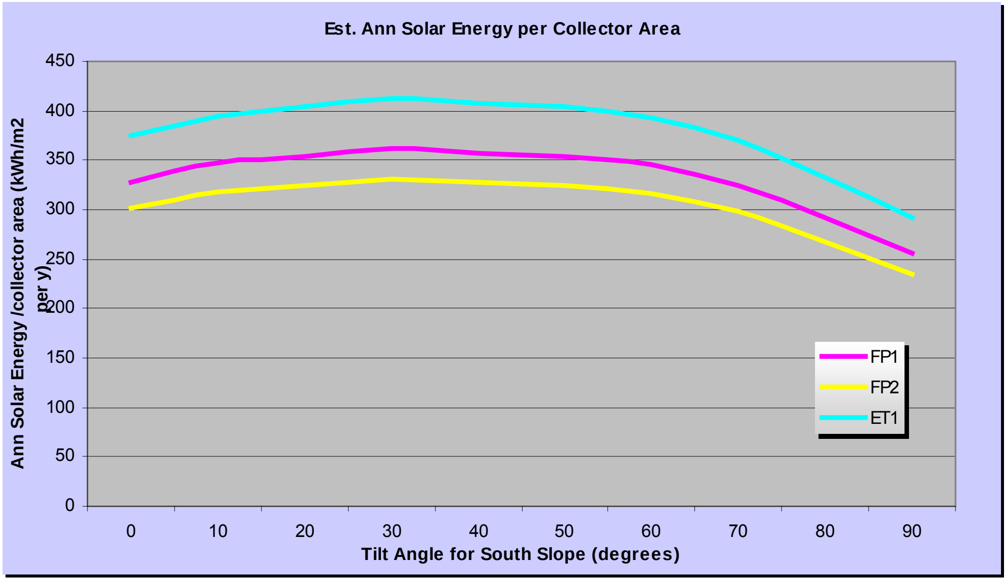

Figure 2.11: Effectiveness of considered solar collectors compared by annual solar energy captured for hot water provision per unit of collection area for flat plate and evacuated tube collectors adjusted from side by side tests for south facing tilt angles 0 to 90

When the collection area is taken into account, it can be seen from **Figure 2.11** that the position is reversed with the **ET1** evacuated tube collector achieving the best performance in terms of kWh/m^2 per year, with the **FP2** collector achieving the lowest kWh/m^2 value. This demonstrates the higher efficiency of evacuated tube collectors but it also shows that all the systems perform well so the choice will depend on both budget and the space available to mount the collectors.

In order to estimate the potential solar energy for producing solar hot water for the existing houses, the likely output for each type of system was estimated for the orientations and tilt angles shown in **Figure 2.9** and for the purpose of the estimates for this study the average of these annual productions was calculated for each of these. On this basis the **FP1** averaged annual output is estimated at **1100 kWh/y** (**3900 MJ/y**), the **FP2** at **1200 kWh/y** (**4300 MJ/y** and the averaged annual output for the **ET1** is estimated at **1050 kWh/y** (**3770 MJ/y**).

As well as avoided energy consumption the other desired attribute from a solar energy device is the amount of emissions abated - in particular CO_2 abated. Using the solar energy outputs from each collector system, the CO_2 emissions abated were calculated for the orientations and tilt angles shown in **Figure 2.9** and assumed to be off-setting gas, LPG or oil fired boilers or electric water heaters. The ball park estimates of CO_2 abated by the **FP1, FP2** and **ET1** collector systems for south facing configurations with tilt angles between 0 and 90 degrees are shown in **Figure 2.12, Figure 2.13** and **Figure 2.14.**

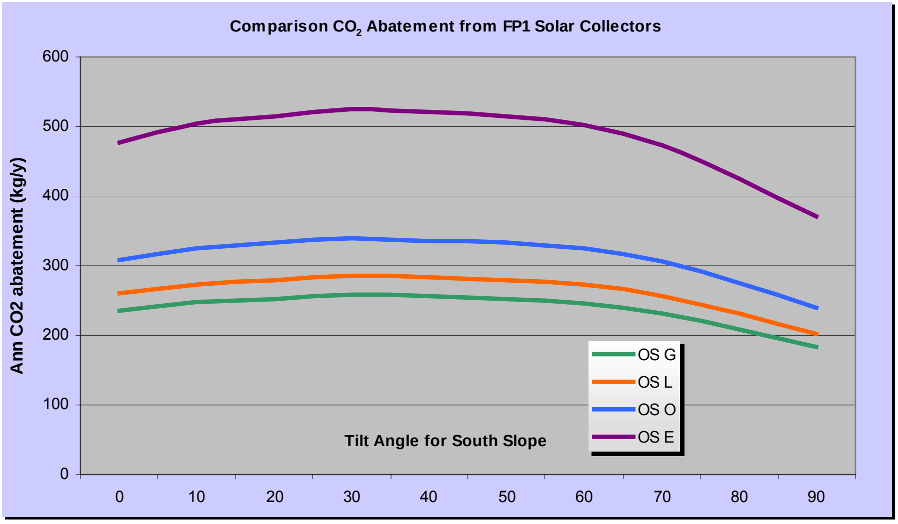

Figure 2.12: Comparison of CO_2 abatement from south facing **FP1** collector system assumed to be offsetting gas (OSG), LPG (OSL), oil (OSO) fired boilers or electric water heaters (OSE).

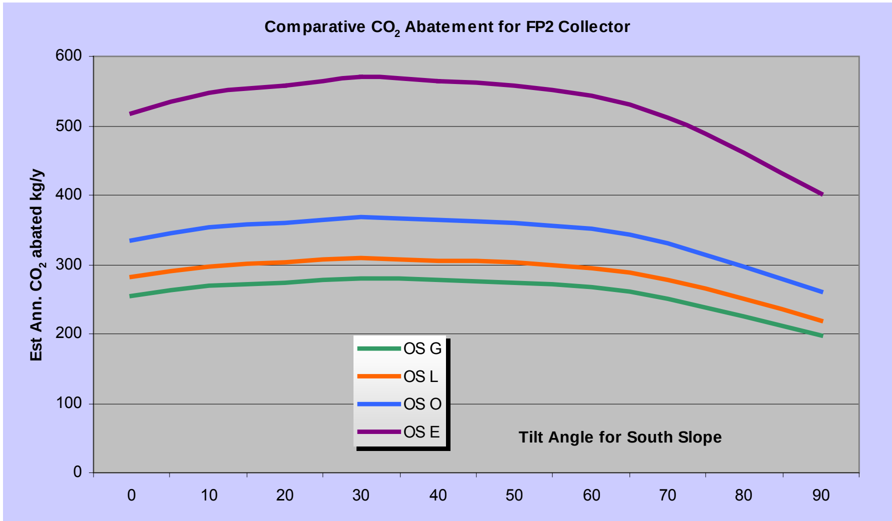

Figure 2.13: Comparison of CO_2 abatement from south facing **FP2** collector system assumed to be offsetting gas (OSG), LPG (OSL), oil (OSO) fired boilers or electric water heaters (OSE).

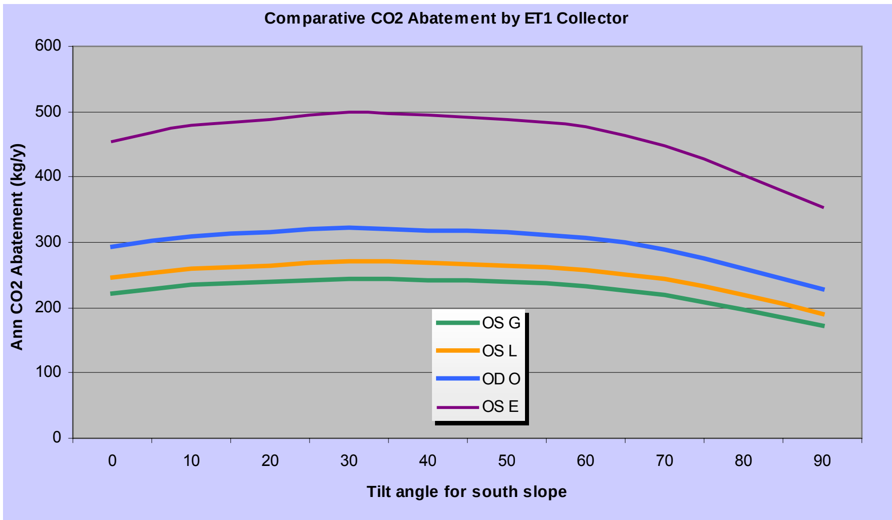

Figure 2.14: Comparison of CO_2 abatement from south facing **ET1** collector system assumed to be offsetting gas (OSG), LPG (OSL), oil (OSO) fired boilers or electric water heaters (OSE).

The CO_2 abatements for each collector were averaged for the range of orientations and tilt angles and shown in **Table 2.1**.

Table 2.1: Estimated Averaged Annual CO_2 abatements from **FP1**, **FP2** & **ET1** Collectors

Fuel/Energy Abated	**FP1** CO_2 kg/y	**FP2** CO_2 kg/y	**ET1** CO_2 kg/y
Gas	230	250	220
LPG	250	270	245
Oil	300	330	290
EWH	470	510	450

Gas[12]: Assumes gas condensing boilers @ 90% efficiency
LPG: Assumes LPG condensing boilers @ 90% efficiency
Oil: Assumes oil condensing boilers @ 90% efficiency
EWH: Electric resistance water heating (immersion heaters etc.) @ 100% efficiency

As can be seen from **Figures 2.12** to **2.14** and **Table 2.1** the levels of CO_2 abated are directly related to the type of fuel or energy off-set (as well as boiler efficiency). The averaged annual CO_2 abated ranges from **220** to **510 kgCO$_2$/y** according to collector type and energy source offset.

Figure 2-15 Shows the areas of Uttlesford where gas is available and as can be seen most of the larger settlements are connected to the gas network. The map also shows that most of the rural areas are not connected so have more scope and incentive to utilise solar water heating systems.

[12] Assumes CO_2 emission rates of 190 g/kWh for gas, 210 g/kWh for LPG, 250 g/kWh for oil and 430 g/kWh for electricity from Energy Savings Trust benchmarks. Values for CO_2 abatements offsetting gas, LPG or oil will be underestimates when not using condensing boilers.

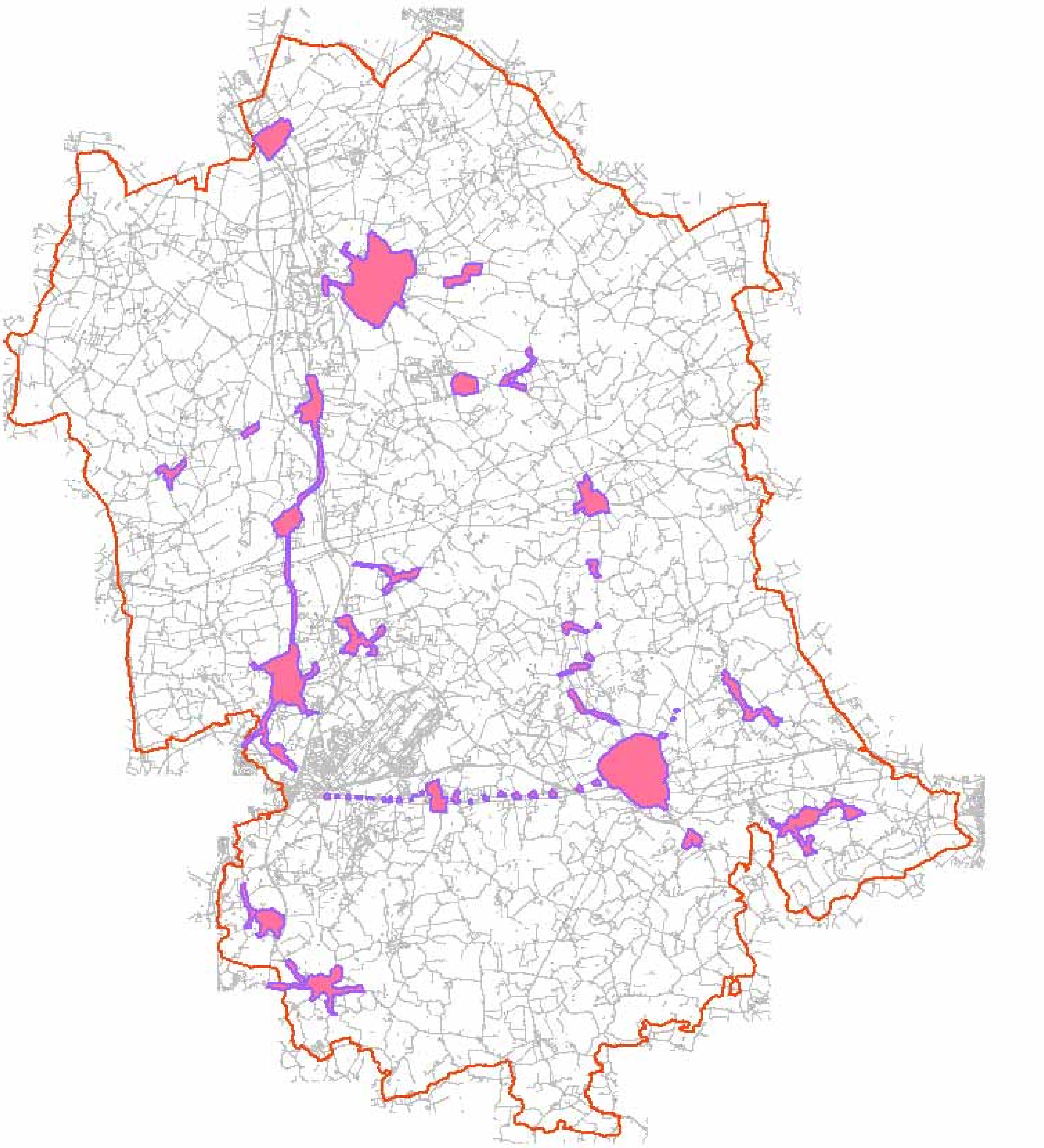

Figure 2-15: Areas in Uttlesford where gas is available (shown in red).

2.1.1.2.2 Potential Solar Water Heating Contribution to Uttlesford

Assuming 2001 Census information there are 28,500 households in Uttlesford, so **Figure 2.16** provides ball park estimates of the aggregated solar energy output of the averaged outputs of the **FP1**, **FP2** and **ET1** solar water heating systems assuming 10 to 100% of the households that have such a solar water heating system.

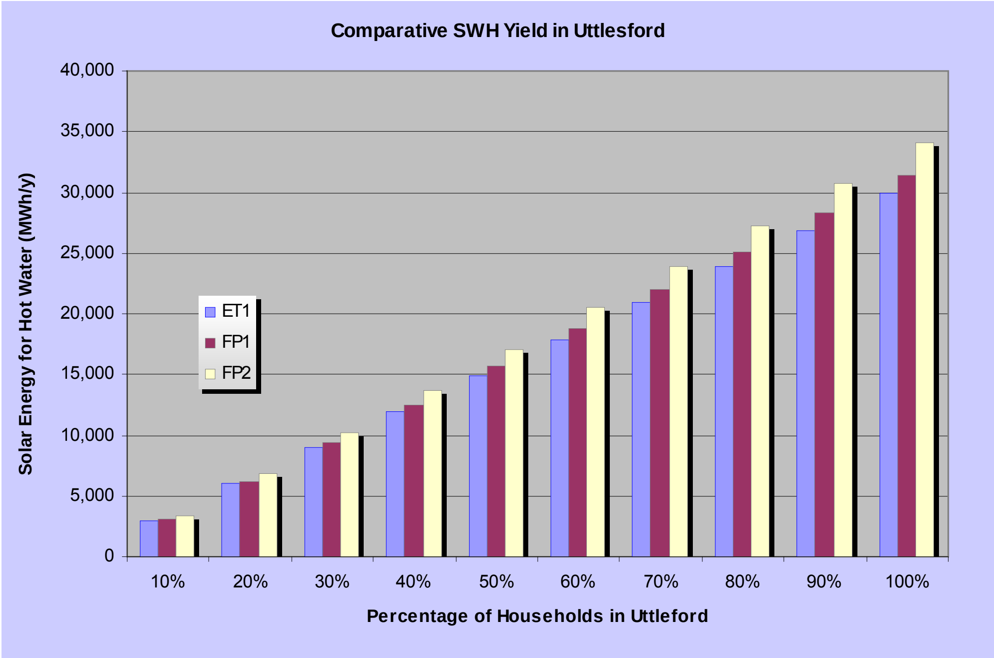

Figure 2.16: Ball park estimates of solar energy contribution to domestic water heating for households in Uttlesford (based on average orientation/tilt angle) assuming **FP1**, **FP2** or **ET1** based solar water heating systems. 100% of households = 28,500 (Census 2001).

Assuming **10% of the housing stock in Uttlesford** employed solar water heating systems the estimated ball park solar energy contribution to domestic water heating would be between **2.9** (assuming all were **ET1**) and **3.41 GWh/y** (assuming all were **FP2**).

It is unlikely that 100% of the households in Uttlesford could utilise a solar water heating system (unless those without suitable roof or wall surfaces also have scope for ground or pole mounted systems or can consider NE/NW or N low pitch systems or can be linked to groups solar schemes), however if we assume that **50% of the households** can incorporate a solar water heating system the estimated ball park solar energy contribution to domestic water heating would be between **14.9** and **17.1 GWh/y**.

If we assume a comparable proportion (to Cambridge) of the housing stock to be suitable for accepting solar collectors then between 60% and 70% of the households could employ solar water heating systems. So assuming solar water heating systems on **60 % of the households in Uttlesford,** the estimated ball park solar energy contribution to domestic water heating would be between **17.9** and **20.5 GWh/y**; and on **70%** of the households, the estimates would be between **20.9** and **23.9 GWh/y**.

2.1.1.2.3 CO_2 Abatement Potential from Solar Water Heating in Uttlesford

Using these ball park estimates of the solar water heating contribution we can estimate the potential CO_2 abatement in Uttlesford. According to *DUKES06* statistics, there are some 19k domestic gas consumers in Uttlesford, and according to the 2001 Census data, there are some 28.5k households in Uttlesford. This leaves some 9.5k households not consuming gas for space or water heating. Whilst some of these will be using electric water heating or LPG based heating, it seems probable that the majority are using oil fired boilers - though households using oil based boilers may be more likely to be using electric immersion heaters during the summer months.

Figure 2.17 provides ball park estimates of the aggregated CO_2 abatement from the averaged outputs of the **FP1**, **FP2** and **ET1** solar water heating systems assuming 10 to 100% of the households have such a solar water heating system. For the 100% households band, 19k are assumed to be offsetting gas and the remaining 9.5k households are assumed to be using electric water heaters. For the smaller percentages of the households displayed on the graph the proportion of gas to electric water heating households is assumed to be a constant ⅔ of the number of households considered, though most non-gas connected households are in rural areas and thus are likely to have space for solar collectors and have more of an economic incentive to use solar water heating.

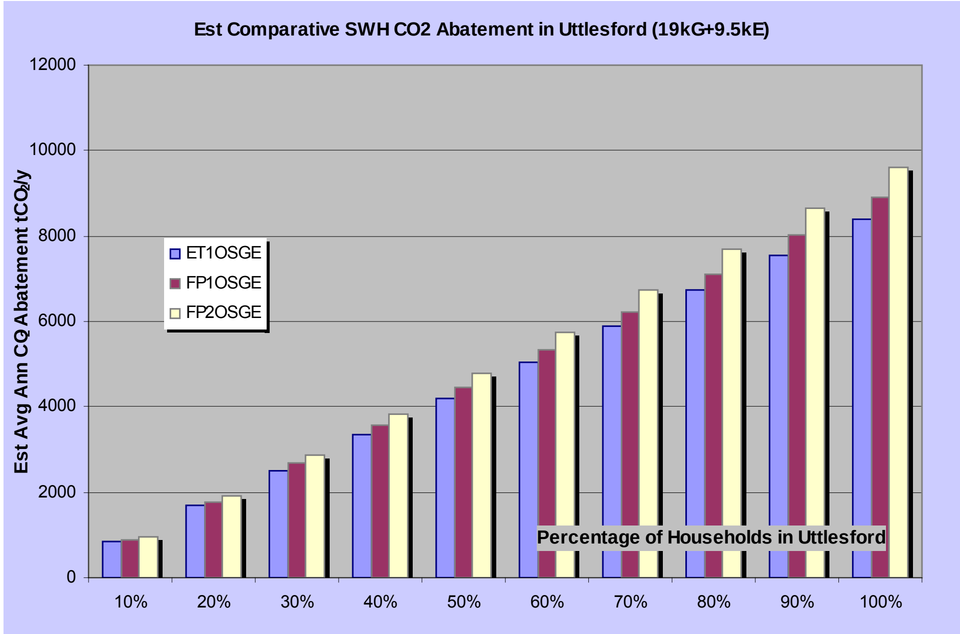

Figure 2.17: Ball park estimates of potential CO_2 abatement from solar energy contribution to domestic water heating for households in Uttlesford (based on average orientation/tilt angle) assuming **FP1**, **FP2** or **ET1** based systems - assuming ⅔ are offsetting gas water heating & ⅓ offsetting electric water heating. 100% of households = 28,500 (Census 2001).

From **Figure 2.17,** the estimated CO_2 abatement from **10% of Uttlesford housing stock** using solar water heating systems would be between **840** (assuming all were **ET1**) and **960 tonnes CO_2/year** (assuming all were **FP2**).

Similarly if we assume that **50%** of the households can incorporate a solar water heating system the estimated **CO_2 abatement** would then be between **4,200** (assuming all were ET1) and **4,800 tonnes CO_2/year** (assuming all were FP2).

If we assume a comparable proportion - to Cambridge - of the housing stock to be suitable for accepting solar collectors and assuming solar water heating systems on **60 % of the households in Uttlesford,** the estimated CO_2 abatement would then be between **5,000** and **5,700 tonnes CO_2/year**; and on **70%** of the households, the estimates would be between **5,800** and **6,700 tonnes CO_2/year**.

However while it may be correct to assume that non-gas households use electric water heating in the summer months, it was also considered appropriate to examine the level of CO_2 abatement if the non-gas households were assumed to be using oil fired boilers.

Figure 2.18 therefore provides ball park estimates of the aggregated CO_2 abatement from FP1, FP2 and ET1 solar water heating systems - assuming 10 to 100% of the households have such systems. As in the previous **Figure 2.17,** ⅔ of the households considered for each percentage band are assumed to be offsetting gas, but in this case the remaining ⅓ are assumed to be using oil fired water heating.

The proportion of gas to oil water heating households is assumed to be constant, though as mentioned before, most non-gas connected households are in rural areas and thus are likely to have space for solar collectors and have more of an economic incentive to use solar water heating.

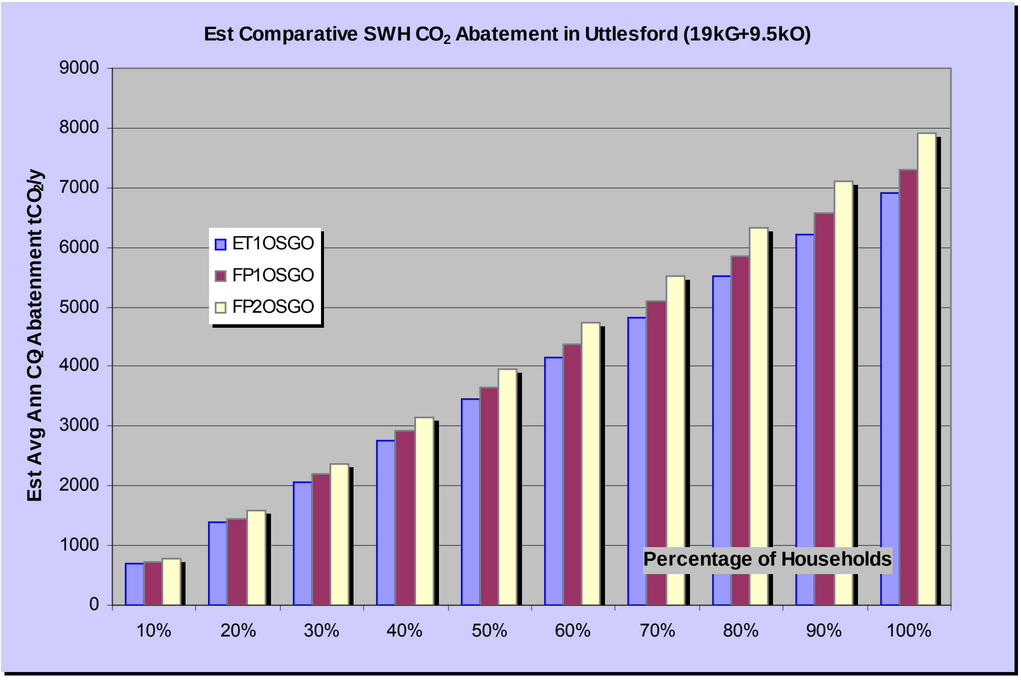

Figure 2.18: Ball park estimates of potential CO_2 abatement from solar energy contribution to domestic water heating for households in Uttlesford (based on average orientation/tilt angle) assuming FP1, FP2 or ET1 based systems - assuming ⅔ are offsetting gas water heating & ⅓ offsetting oil fuelled water heating. 100% of households = 28,500 (Census 2001)

From **Figure 2.18**, the estimated CO_2 abatement from **10% of Uttlesford housing stock** using solar water heating systems would be between **690** (assuming all were ET1) and **790 tonnes CO_2/year** (assuming all were **FP2**).

Similarly if we assume that **50%** of the households can incorporate a solar water heating system the estimated **CO_2 abatement** would then be between **3,450** (assuming all were **ET1**) and **3,950 tonnes CO_2/year** (assuming all were **FP2**).

If we assume a comparable proportion - to Cambridge - of the housing stock to be suitable for accepting solar collectors and assuming solar water heating systems on **60 % of the households in Uttlesford** the estimated CO_2 abatement would then be between **4,100** and **4,700 tonnes CO_2/year**; and on **70%** of the households the estimates would be between **4,800** and **5,500 tonnes CO_2/y**ear.

Under these assumptions, solar water heating systems can make a useful contribution to reducing the CO_2 emissions in Uttlesford.

One of the constraints that solar water heating has faced in the UK includes the fact that a back up system is required to provide hot water during the winter months and as the 'back up system' is capable of providing hot water during the summer months as well, it has been harder to justify the capital expenditure for the solar collector.

Another factor is that until recently, natural gas has been so inexpensive that there has not been an economic advantage in including a solar water heating system. However the price of gas has become much more variable and as the UK is now an importer of natural gas, it seems reasonable to assume that the price of gas is likely to remain uncertain. As such solar water heating systems that provide hot water without fuel or electricity consumption may now begin to grow in popularity. For non gas households relying on oil or electric heating there is more of an economic incentive to use solar water heating as these methods of heating and hot water provision are more expensive than gas.

It is also worth remembering that the insulation standards in the existing building stock are often low or non-existent. Therefore substantially more CO_2 emissions can be reduced by adding extra insulation compared to adding a solar water heating system, so that option should usually be addressed first, though it is acknowledged that adequately insulating old buildings can be very difficult. Similarly if the house is currently heated with an old inefficient boiler then switching to a condensing boiler may also have a bigger impact on CO_2 emissions because of the larger proportion of household energy required to space heat typical UK houses compared to the hot water demand[13].

However if the insulation standards of a house are equivalent at least to those specified in the new Building Regulations or better, then adding a solar water heating system will further reduce energy consumption and CO_2 emissions.

If installed in such a way that all members of the household understand how a solar water heating system works (and with clear meters and temperature displays etc) and can adjust their lifestyle accordingly, then solar water heating systems can help to raise awareness about energy and environmental issues and as a result have a bigger indirect impact on CO_2 emissions than those achieved directly from using solar heated hot water. When solar water heating systems are installed without these, then it may not be used effectively and awareness may not be raised.

If incorporated into the roofs of new buildings the extra cost of solar water heating can be reduced considerably, particularly for housing associations or developers installing large numbers of collectors.

The current economics of solar water heating systems can also be improved by the encouragement of Solar Clubs. These have been very successful in Austria and a few are being developed in the UK. There are two types of solar clubs: one acts as a bulk buying club[14], which is able to reduce the capital cost of the components, the other type of solar club helps those interested in constructing their own simple but reasonably efficient D.I.Y. solar collectors. Solar Clubs can also provide independent advice together with practical guidance, training options and plumbing skills etc.

Another potential approach could be the encouragement of *Solar Street Associations* which could combine the attributes of the Solar Clubs but have the additional benefits of common location, bulk purchasing, mutual support, awareness raising and - where appropriate - scope for larger scale systems or group systems and access to large scale grant funding.

[13] However one still has to take the REBOUND effect into account. This essentially means that if one only carried out energy efficiency measures without also including renewable energy measures there is a risk that national levels of CO_2 emissions may rise as a result of the money saved from reduced fuel bills being spent on other energy consuming activities in the economy such as travel or energy consuming gadgets or appliances etc. If the money saved on reduced fuel bills was invested in solar water heating or some other renewable energy device then this effect would be less problematic.

[14] Energy Service Companies (ESCOs) can also include solar water heating as part of the measures offered.

2.1.1.3 Active Solar Space Heating Systems

If houses are built (or upgraded) to Super-Insulation standards so that the space heating loads have been cut by 80% or more, then it may be feasible to utilise active solar space heating, as it would only be required on the coldest days. This would mean that a high proportion of a south-facing roof would also be a solar collector as well as being the roof covering. In addition a heat store is required to store the heat from summer to winter. The store would be heated by the excess solar hot water in the summer months.

Such applications of solar energy have to be well understood by designers and architects as the design of the house impinges on the viability of such a system. However there are prefabricated active solar roof panels becoming available in some European countries so the concept may become a possible approach to achieving zero CO_2 space heating systems.

In addition to wet based active solar space heating systems, it is also possible to utilise fan[15] assisted (or thermo-siphon) solar hot air collectors to transfer the solar heat to a heat store consisting of a rock or pebble bed, hypocaust[16], hot water or latent heat storage materials. Heat is then transferred to space heated areas via fan assisted hot air heating ducts or under floor heating.[17]

A further variant of active solar space heating systems is the Solar Heat Pump System which utilises low cost, low efficiency (glazed or unglazed) solar collectors or special 'roof tiles' or wall cladding to capture the solar heat. Heat is accumulated in the summer months into a hot water heat store. In winter, heat is extracted from the heat store via a heat pump and usually delivered via under floor heating systems.

No matter what the type of active space heating system, it is unlikely to be viable if its design[18] is not integrated with the design of the building.

Active Solar Space Heating is certainly possible in Uttlesford, but it only makes real sense in the UK climate if it is part of a package which includes in particular very high levels of insulation and high performance windows. It is more viable on new build projects but it is possible to retrofit. If the building's heat loss is not also addressed then the viability is questionable.

2.1.1.4 Large Scale Active Solar Systems

An approach which is growing in several European countries (over 50 schemes currently), particularly in Sweden and Denmark where large scale solar heating systems are installed on large groups of houses or blocks of flats. The systems tend to be more economically viable than individual installations because of the benefits of scale and common equipment.

The schemes have varied in their approach, but in many cases they involve the use of a prefabricated solar roof panel system which has a dual function as a structural roof panel and includes the building insulation but also has *built-in* active solar panels as the roof covering. This has savings over conventional solar panels because the panels are built-in and they are installed as part of the roofing installation. It also has installation savings as a separate roof covering installation process (laying of roofing tiles etc) is also avoided.

Some large scale active solar systems also utilise large numbers of ground mounted collectors (similar to those in **Figure 2-6**) or pergola-mounted collector systems (similar to those shown in **Figure 2-7**).

[15] Which can be powered by small PV modules.
[16] A kind of underfloor heat store consisting of dense bricks or blocks laid in such a way as to allow the passage of air between. The term is derived in part from classical Roman under floor heating terminology.
[17] Solar hot air systems have the advantage of operating at lower temperatures compared to wet systems, but the ductwork is bulkier than pipes, though they can be incorporated into the structure if planned for.
[18] Particularly the solar hot air based systems.

Such large-scale solar systems can be combined with district heating systems and potentially with combined heat and power (CHP) installations. In these arrangements they also help to reduce fuel consumption.

Such schemes may also be appropriate for schools, college campuses, hospitals, hotels, retail developments and certain other non-domestic applications as well as residential schemes. Schemes can be high rise or low rise.

If they are included with a residential Community Heating or Community Energy Scheme, possibly as part of an ESCO (Energy Services Company) project, then they may also be eligible for grant support.

There may be scope for such projects in Uttlesford depending on developers or housing associations becoming aware of the advantages of group heating or where there are existing district-heating schemes in need of renewal and when building cladding is being upgraded or where new schemes are including district heating.

As well as new schemes there may be scope to incorporate such systems as part of major renovation projects.

2.1.1.5 Large Scale Active Solar Systems with Interseasonal Thermal Storage

These systems are similar to those described in the previous section except that a large inter-seasonal heat store is included. Such heat stores can be more viable in large scale installations because of the benefits of scale and also the performance improves with increasing size due to the fact that the surface area to volume ratio improves and this reduces the rate of heat loss for a particular volume of hot water.

The heat store is heated up in the summer months and the heat is stored until the winter months when it is retrieved. The present schemes have tended to be located in countries with longer heating seasons and shorter summers compared to the UK, so they should be even more technically viable in the UK climate. The heat stores can also be additionally charged by heat extracted from the building for cooling during the summer months. In addition heat pumps can be combined for charging or extracting heat energy to/from the store.

These systems are usually district heating scale schemes and can be 100% solar or can be added to existing district heating schemes as a means of fuel saving. Likewise they can also be combined with a CHP scheme. They can also be linked to a biofuel district-heating scheme.

Such heat stores could also utilise excess wind generated electricity during periods of high winds - either from neighbouring 'community wind turbines' or via smart metering from other wind turbines.

One advantage is that using a large heat store also means that the heating supply is less susceptible to the vagaries of the weather and breakdowns in fuel supply.

The scope for such systems in Uttlesford depends on developers or housing associations becoming aware of the advantages of group heating and of large scale inter-seasonal heat stores or whether new district heating systems are being planned or whether existing district heating networks are due for rehabilitation etc. Residential schemes may also be eligible for grant support under the Community Heating or Community Energy initiatives that are being supported by government.

Such schemes may have a role to play in Conservation Areas or for supplying renewable energy to listed buildings which have a range of particular technical and heritage related constraints, though it would require appropriate space being available for both heat store and the solar collectors which could also be used to provide shade canopies/rain shelters or covered walkways or pergolas or solar cladding over arcades or car parking areas and the like if they are not able to be incorporated into buildings.

2.1.1.6 Active Solar Systems for Process Heat

Active solar systems can be used to provide hot water for a variety of commercial or industrial purposes. One example is the large-scale installation at Gatwick Airport. If utilising the prefabricated solar roofing panels, then it would be possible to incorporate appropriately oriented roofs to contribute solar heated water for a variety of applications. Once installed it would reduce the fuel consumption during the summer months and as a side benefit would help to cool building roofs reducing air conditioning needs. In addition there would be some benefit to organisations subject to the Climate Change Levy (CCL) as renewable energy sources are exempt from the CCL.

The potential for such schemes in Uttlesford depends on the number of organisations which have both the appropriate roof orientation combined with both appropriate hot water demand and plans for a new building (or scope to install an active solar pergola structure or canopy which can also provide shaded areas).

2.1.2 Passive Solar Design

Passive solar design involves the design of a building or part of a building to act as a 'solar collector' and as such maximise the 'trapping' of useful solar gains to contribute to space heating or to induce convection in order to ventilate or cool a building. It is beyond the scope of this study but it is covered briefly in the following.

2.1.2.1 PASSIVE SOLAR HEATING & INTEGRATED LOW ENERGY DESIGN

2.1.2.1.1 Definition

Passive solar heating (PSH) consists of designing a building so that the building itself is a solar thermal collector. It utilises the building fabric in combination with the form of the building and its orientation as a means of maximising its solar gain to reduce the fuel consumption required to heat the building.

There are a number of key factors involved in passive solar heating design and they interact with each other. An understanding of the effects of all of them needs to be understood otherwise a house designed to be passively solar heated can easily be a less energy efficient house than if it had been designed conventionally. These factors include: -

Orientation
Thermal mass
High performance glazing
High insulation standards
Site/estate layout
Landscaping and planting design
Shelter from winds
Designing to minimise winter time shading or shadowing

2.1.2.1.2 Passive Solar Heating

Passive solar heating (PSH) works best in climates which have cold temperatures but clear skies and it has been a design philosophy which has been successfully utilised in locations such as New Mexico and the like.

Unfortunately these conditions do not occur in the UK very often, and whilst occasionally a winter month experiences these conditions, **Traditional PSH** has tended to be most useful in the spring and autumn.

There are misunderstandings and a good deal of naivety related to the benefits of **Traditional PSH** in the UK and it is generally more effective to provide the maximum possible level of insulation as this will reduce the fuel consumed even during the coldest months of the year. High levels of insulation can be expected to reduce more annual CO_2 emissions compared to Traditional PSH!

Nonetheless the space heating requirements of individual houses <u>can</u> be reduced by around 1,000 kWh/year through the adoption of simple PSH measures. More complex traditional PSH measures can increase this to about 2,000 kWh. **Super-Passive Solar Heated Buildings** which <u>combine</u> high performance PSH measures with <u>very</u> high levels of insulation <u>and</u> high performance glazing can be designed to achieve zero space heating performance.

However it is also very easy for inadequately designed Traditional Passive solar heating design measures to be net energy wasting features, therefore for Traditional PSH to be an effective net energy contributor it is very important that those designing the buildings are able to demonstrate that the buildings will genuinely have a positive <u>net</u> heat benefit.

A further crucial factor that influences the viability of passive solar heating is the behaviour of the occupants. Because passive solar heating is reliant on the thermal characteristics of various building components and the way they interact with each other (without immediate feedback to the user), the performance of passive solar heated buildings can be compromised if the building occupants do not understand how it is supposed to function.

In order to achieve more effective Passive Solar Heating, a checklist has been included in the appendix, which if followed should help to avoid some of the pitfalls involved.

Passive solar heating can be utilised either by direct gain measures or special passive solar features such as sunspaces, atria and solar roof spaces.

2.1.2.1.3 Direct Gain Passive Solar Systems

Direct Gain passive solar heating on appropriately oriented buildings is the simplest application of PSH and is dependent on using large south facing windows to collect solar heat. A direct gain passive solar heated house, **Figure 2-19**, is essentially a large solar collector. The windows for a direct gain passive solar building should be at the very least double-glazed[19] with a 'Low E coating'.

Figure 2-19: Example of a fully glazed Direct Gain Passive Solar Heated House.
Solar Courtyard Houses in *Milton Keynes Energy World* (Fielden Clegg)

Direct Gain PSH is the easiest method of utilising passive solar gains and it can be achieved with little or no extra cost if considered early enough in the design and planning process.

[19] Traditional Passive solar heated houses with low performance glazing are usually net energy wasters because the night time heat loss usually exceeds the solar gains.

2.1.2.1.4 Solar Sunspaces

Conservatories or attached greenhouses, popular in Victorian times, can have good energy conservation benefits **PROVIDED THEY ARE UNHEATED & NOT AIR CONDITIONED** and can be designed to be integral with the building. To be more specific the term Solar Sunspace will be used to refer to unheated variants.

Solar Sunspaces can contribute to saving heating energy in four ways:-

1. Acting as *sun-traps* & increasing the solar radiation conducted into the house.
2. Sheltering the side of the building acting as 'extra thermal insulation'.
3. Sheltering the side of the building from wind and driving rain.
4. Passive solar preheating of ventilation air entering the building via the Sunspace.

A Solar Sunspace covering 12 m^2 of the south facing wall on an wall on a quite well insulated terraced house in Milton Keynes was monitored in the early 1980s (Ford, 1982). This monitoring indicated that the Sunspace yielded heat energy savings of about 800 kWh/year.

Computer modelling of Sunspaces (Baker, 1985) suggests much higher savings (as high as 2,800 kWh/year - which would save about 500 kg/year of CO_2 emissions) on poorly insulated houses. However a package of insulation and draught stripping measures could probably save an equivalent amount of energy at a lower cost and once carried out would also reduce the heating season.

Conservatories have become a popular purchase by people interested in extending their living space or for growing exotic delicate plants. Unfortunately, because the thermal resistance of the glazed walls and roofs of conservatories is generally so low, these are thermally volatile environments and they become cold in winter and usually become overheated in the summer time. This usually means that a very high proportion of conservatories are heated in the winter time and actively cooled or air conditioned in the summer time. This means that rather than saving energy, conservatories are usually considerable energy wasting features and a cause of CO_2 emissions, but most people are completely unaware that it is a problem. There are proposals for future upgrades to the Building Regulations to address this issue, but at the present time it is a growing problem in serious need of awareness raising and education initiatives. Perhaps a leaflet provided with planning permission guidance information would be worthy of consideration.

2.1.2.1.5 Atria

Also related to Solar Sunspaces are atria, glazed facades and glazed courtyards of commercial buildings. These can act as thermal buffer zones and shelter from the wind. Similarly, glazing over light wells in existing buildings and between buildings can offer energy savings.

Depending on their design, atria are usually more valuable for their contribution to passive ventilation or to natural daylighting rather than as a means of contributing to space heating.

As with conservatories, these features will only be net energy contributing if they are not heated or air-conditioned spaces. There are similar concerns that many of the current atria spaces are indeed heated or air-conditioned - so again if the benefits are to be achieved, perhaps a requirement of planning permission could be a demonstration that such spaces are indeed net energy saving features.

2.1.2.1.6 Super Passive Solar Heated Houses

Insulating a house to super insulated levels shown in **Table 2-2** can reduce the space heat demand by 90% in the south of England including Uttlesford.

TABLE 2-2: Insulation levels to achieve Super-Insulation

Building Element	Maximum U-value (W/m² K)
Wall	0.12
Roof	0.1
Floor	0.12
Window	1.2

In this circumstance, provided high thermal capacity materials and provided also that very high performance glazing is employed, it becomes possible to deliver the space heating demand by a combination of internal heat gains (from occupants and appliances) and passive solar gains.

Altechnica has designed the first such Super Passive Solar Heated House (the *Energy Showcase Project* with and for David Olivier) (**Figure 2-20**) in the UK. It is currently under construction in Herefordshire and is designed to operate without space heating. **Figure 2-21** shows the predicted internal and external temperatures during the winter months demonstrating the lack of a need for space heating.

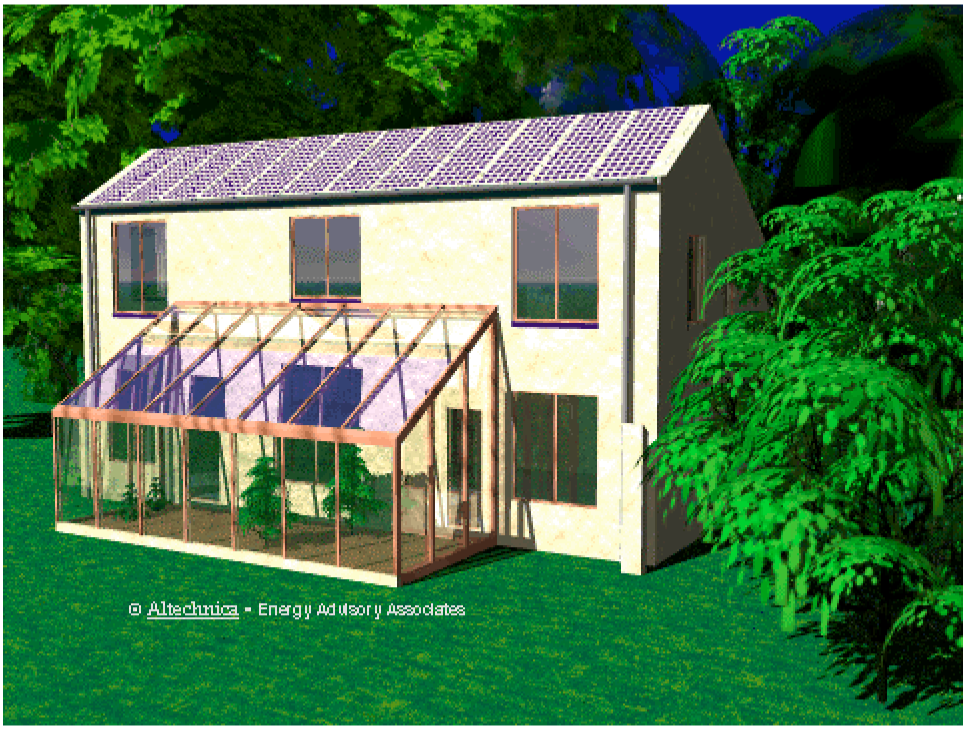

Figure 2-20: Energy Showcase Project – A *Super Passive Solar Heated House*

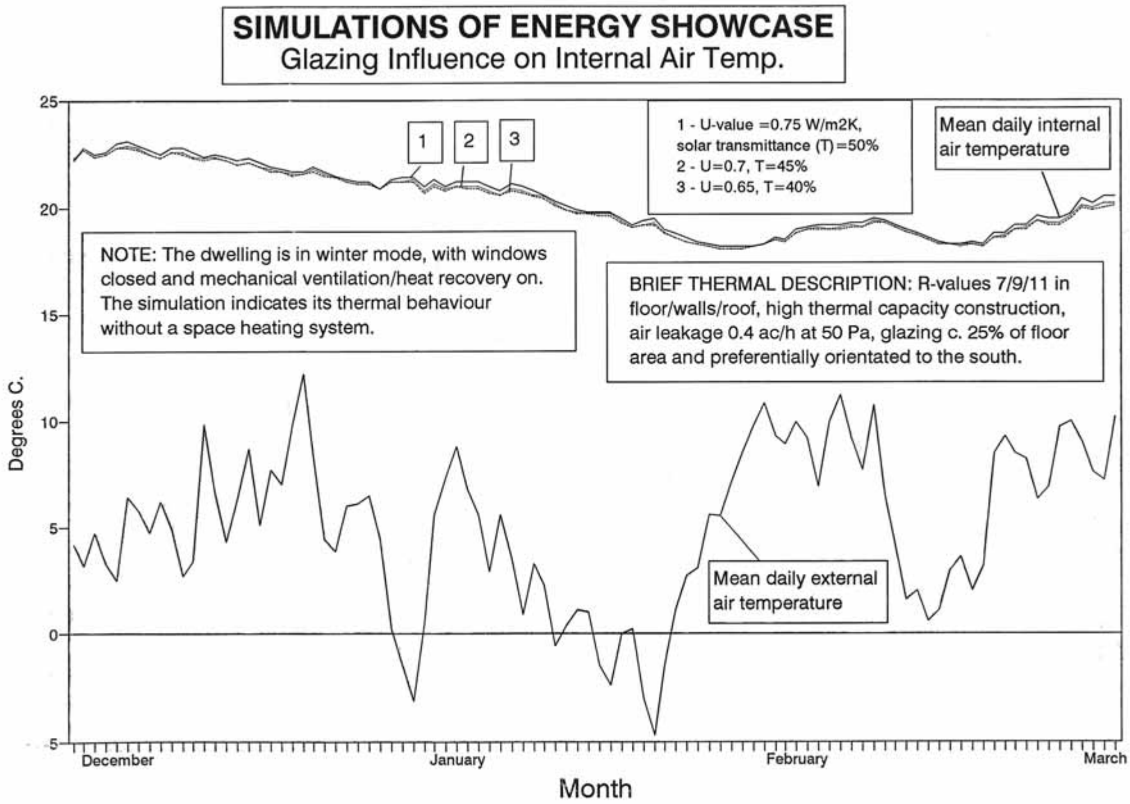

Figure 2-21: Energy Showcase Project: Internal Temperature Simulations without space heating.

This building also incorporates a solar PV roof, experimental passive solar hot water system, Canadian standard super windows, air tight wall construction and high thermal capacity inside a 300+ mm external insulation envelope protected by render. Insulation levels of this level are much higher than the requirements of even the latest update of the Building Regulations, but avoid the capital, servicing and maintenance costs of a central heating system and the periodic costs of replacement of a large central heating boiler.

Unlike the vast majority of new buildings (even so called 'green' or 'sustainable' or energy efficient buildings), the space heating of Super Passive Solar Heated Houses like the Energy Showcase are expected not to add to the national energy demand and CO_2 emissions. As such it is expected to be the first Zero Energy Design to be heated by Passive Solar Heating.

The Energy Showcase is based on a poured concrete construction[20], which is a relatively slow construction method when not able to use standardised shuttering. However if one employed the kinds of standardised reusable shuttering available in Europe, it could become a rapid and economic means of zero energy house construction, which could also be adapted to be usable by self-builders. Externally insulated solid masonry or dense concrete blockwork or cob[21] walls will also function in a similar way thermally but require greater care to maintain air tightness. The design of the external appearance is such that visually it does not look dramatically different from many typical rendered houses in the UK.

Many of the measures employed in this approach can also be applied to the many existing buildings with solid walls and when such buildings are to be renovated a Super Passive Solar

[20] Poured dense concrete construction provides a very air tight means of construction - which also provides high thermal capacity. It is a widely used method of house building in many parts of Europe where standardised shuttering is available.

[21] Cob is a traditional vernacular wall construction method that uses unbaked earth from the site. Other earth construction methods that can be employed include 'clay lump' and 'rammed earth' but they do tend to require relatively thick walls to function. Various earth block methods such as compressed stabilised soil blocks or adobe blocks would be appropriate and provide an alternative to using standard concrete blocks or baked bricks.

Heated makeover could be considered[22]. However as such an approach relies on external insulation the outside appearance is likely to be altered, so planners will need to realise the importance of such alterations rather than insisting on visual appearance factors at the expense of sustainability. Such external insulation can be clad with render, boarding[23], tile hanging, ceramic tiles, brick slips or panels or a variety of sheet based cladding materials.

As an alternative approach Altechnica is also developing a further Super Passive Solar Heated House concept (the *Altechnica Photon Houses*) that uses a more lightweight fast assembly method to facilitate construction. The concept utilises other forms of sensible and/or latent heat storage methods that avoid the need for heavy construction methods or thick walls. It is hoped to build a prototype house based on this method (and which also utilises additional building integrated renewable energy technologies).

2.1.2.1.7 Earth Sheltered Passive Solar Heated Houses

Another approach which can produce highly energy efficient PSH buildings and which has many proponents overseas (particularly in the USA and Australia) is Earth Sheltered Passive Solar Heated Housing.

Earth Sheltered PSH buildings are oriented such that the high performance windows are located on the southerly side whereas on the northern side, earth is banked up against north walls (often also against the east and west walls) and usually over the roof. The earth is planted with turf, herbs, wildflowers or other forms of vegetation. It still requires high levels of insulation but as the temperature below ground level tends to be higher than ambient air during the winter months there is smaller temperature difference through the external walls and consequently a lower rate of heat loss. In addition, earth sheltering improves the air tightness of the building, provides additional thermal capacity and the northerly earth sheltered wall protects the building from the effect of cold north winds.

There has been resistance to earth sheltered buildings in the UK, so only a very few have so far been constructed, but there have been a couple of successful Earth Sheltered Passive Solar Heated buildings constructed.

The first is the *Berm House* at the *Caer Llan Field Studies Centre* in Gwent (designed by Peter Carpenter) which consists of a row of eight study bedrooms. It has a turf roof and is built into the southwest facing side of an earth bank. It incorporates a southwest facing insulated masonry wall with a 'Solar Corridor' between the living spaces and the outside. It maintains an internal temperature between 19 and 22 ºC for most of the year. The annual energy required, including lights and kettle, is 60 MJ/m^2 (or 16.6 kWh/m^2 year).

The Hockerton Earth Sheltered Houses in Nottinghamshire designed by Robert and Brenda Vale form the other successful Earth Sheltered PSH project. This is a terrace of five houses occupied in 1997. Each house has its own unheated Solar Sunspace across the entire front of each house. The north wall is earth sheltered and the roof is covered with continuous turf. Insulation is 300 mm throughout, windows are triple glazed and the concrete floor has a high thermal capacity.

These represent some of the most energy efficient groups of houses in the UK, each with an estimated 90 % energy saving compared to a conventional house.

[22] Even if the orientation is inappropriate for exploiting passive solar gains, this external super-insulation approach can be an effective way of upgrading the insulation standards of old buildings and, unlike internal insulation does not impinge on the internal floor area. Also it can be a less disruptive way of thermal upgrading of a housing association's building stock as the tenants do not have to vacate the premises and it avoids the need for internal redecoration.

[23] Weatherboard cladding is a vernacular cladding used in Essex so externally insulated buildings clad with weatherboarding should be visually acceptable within the area.

2.1.2.2 PASSIVE SOLAR VENTILATION & COOLING

2.1.2.2.1 Definition

Air conditioning and mechanical cooling are increasingly being used or aspired to being used in buildings and involve increased energy consumption and CO_2 emissions. However solar energy can also be exploited passively to induce ventilation for buildings and avoid the need for air conditioning equipment offering savings in capital, maintenance and servicing costs as well as reducing electricity consumption and running costs.

As such Passive Solar Ventilation and Cooling (PSVC) can be much more important than PSH and, unlike PSH, the solar energy source that drives PSVC is generally available at the same time of year as the peak demand. Also unlike PSH, the conventional energy source that is offset by this approach is expensive on peak electricity. As such it is easier to justify the exploitation of PSVC economically and it also has a bigger impact on CO_2 emissions. The working environment of PSVC buildings are also generally preferred by users compared to air-conditioned buildings.

Passive solar ventilation and cooling (PSVC) creates temperature gradients to induce convection to both draw warm air out of the building and cooler[24] fresh air into the building.

In its simplest form, natural ventilation means opening windows or vents to allow for cross-ventilation.

More sophisticated passive ventilation and cooling involves using atria, passive stack effects and Solar Chimneys or Ventilation Cooling Towers. Hybrid schemes involve fan-assisted[25] convection combined with these features.

Factors that influence the performance and viability of PSVC include the following

Orientation
Thermal capacity
High performance glazing
High insulation standards
Solar shading[26]

It makes sense to keep summertime solar gains out of the building to reduce the cooling requirements, solar shading schemes should be combined with PSVC schemes. Also buildings which have high thermal capacity materials <u>inside</u> the insulated envelope provide more stable temperatures and are more tolerant to overheating and are therefore easier to control passively than a lightweight building with low thermal capacity materials.

PSVC is particularly appropriate for many types of non-domestic buildings (but of increasing importance to domestic buildings, particularly if highly glazed) and can offset the need for air conditioning. As such it can avoid the capital, maintenance and servicing costs as well as saving electricity.

2.1.2.2.2 Passive Solar Ventilation and Cooling with Atria

Atria can be used to induce passive ventilation for non-domestic buildings, but (like conservatories) if not designed or used correctly they can overheat, need cooling and become net energy wasting features.

If designed and used correctly, atria can help to moderate the temperature fluctuations and buffer the building from outside conditions.

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[24] So long as the temperature of the source of outside air is lower than the internal temperature it will have a cooling effect.
[25] Which could be powered by solar power via photovoltaic modules.
[26] Solar shading devices can also be dual function as they can be mounted with solar photovoltaic modules for electricity generation.

2.1.2.2.3 Solar Chimneys / Ventilation Cooling Towers

Solar energy can also be used to create a 'passive stack effect' induced by temperature gradients in solar chimneys (or ventilation cooling towers). This causes convection which draws warm air out of the building and cooler air into the building.

This approach echoes buildings of the past by punctuating the roofline with 'chimneys' which are functionally similar to their precursors except that instead of dispersing smoke from the building, these are designed to ventilate and cool the building.

Examples of buildings which take this approach include the Queens Building at De Montfort University in Leicester (**Figure 2-22**) and the Environmental Office building at the Building Research Establishment in Watford (**Figure 2-23**). The new Parliament building also utilises this approach.

Figure 2-22: Queens Building at De Montfort University which uses cooling towers to passively ventilate and cool the building. Designed by Short Ford & Partners.

Figure 2-23: BRE Environmental Office which also uses cooling towers. Designed by Fielden Clegg & Partners.

2.1.2.2.4 *Passivent* Passive Stack Ventilator

Another passive stack ventilation system is the *Passivent* system (**Figure 2-24**) which adjusts the amount of ventilation according to levels of humidity present in the air. A hygroscopic trigger activates vents from kitchen and bathroom when particular humidity levels are reached. Temperature gradients drive the system without extract fans. As soon as the humidity levels are reduced the vents close automatically, so whilst it does result in a brief loss of heat, this is only as long as the humidity levels are too high and it avoids risks of condensation and also avoids any risk of stuffiness that may otherwise occur in air tight houses.

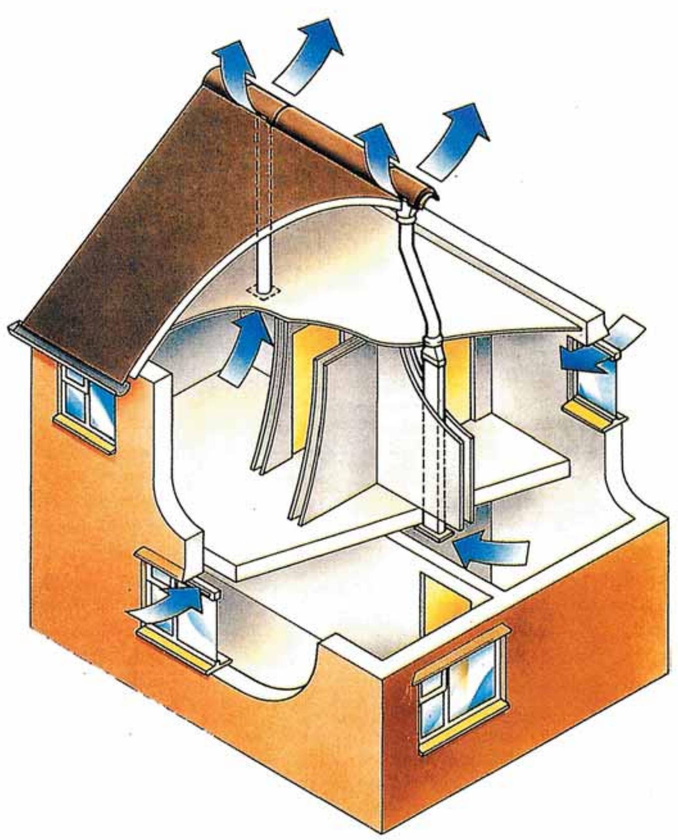

Figure 2-25: *Passivent* system

2.1.2.2.5 Hybrid Fan Assisted Passive Solar Ventilation & Cooling

In some circumstances it is not always possible to rely only on thermal gradients and in these situations using fan assistance can enhance the passive performance. But if this approach is adopted, it is very important to use fans with efficient electric motors to avoid the energy required to operate the fans outweighing the energy saved on cooling.

If the fans are powered by solar photovoltaics (PV) then the system does not become dependent on conventional electricity consumption. Also the electricity from the PV modules tends to be available at the same time as the requirement for fan power.

2.1.2.2.6 Opportunities in Uttlesford for Passive Solar Ventilation & Cooling

As elsewhere there are likely to be considerable opportunities for PSVC in Uttlesford at the sites where non-domestic development is taking place. In addition PSVC features can be incorporated into new school buildings where often there is a larger annual requirement for cooling rather than heating[27].

However it is more complex to design such buildings and access to appropriate computer modelling tools is essential if they are to work as planned.

The potential energy savings and avoided future CO_2 emissions could be significant but apart from adding atria, adding PSVC measures to existing buildings is less straightforward but may be possible with masonry buildings with concrete floors. It would be more difficult to add PSVC measures to lightweight buildings, but if the façade is to be replaced or modified then these buildings could also be adapted to be PSVC buildings.

[27] In school buildings that are well insulated, the incidental gains from the large numbers of pupils can avoid a major requirement for space heating. Likewise these incidental gains need to be exhausted from the building in the summer months.

2.2 Natural Daylighting

Electricity consumption for lighting is estimated to be a substantial proportion of the electricity consumed in non-domestic buildings (and increasingly in domestic buildings) and represents about 17% of the CO_2 emissions from the service sector. The incidental heat emitted from inefficient lamps creates an additional requirement for mechanical summer cooling and conditioning, involving additional electricity consumption and thence CO_2 emissions. Therefore, if daytime demand for artificial lighting can be reduced, then CO_2 emissions can be reduced substantially.

Up to 85 % energy savings from lighting have been achieved in demonstration projects.

Naturally daylit buildings create preferable conditions to live and work in compared to artificially lit spaces. It is therefore also worthwhile to provide natural daylight to create comfortable environments for a building's occupants.

Designing for natural day-lighting and using responsive lighting controls is relatively well known and can be cost effective, but has to be considered early on in order to reduce electricity consumption and thus CO_2 emissions.

Natural Daylighting performance is related to the following factors:-

- the building's form
- plan shape
- the building's width and depth,
- the building's height
- light transmission characteristics of glazing materials
- type and thickness of window or roof light frame
- orientation and inclination of windows and roof lights
- glazing to exterior wall ratios
- glazing to floor area ratios
- room heights
- responsive lighting controls
- number of storeys
- over-shading from adjacent buildings, structures, trees or vines etc.
- overhangs
- interior décor, colour, texture and reflectivity of internal surfaces
- colour, texture and reflectivity of exterior materials

In addition particular daylight enhancing features such as light wells, light shelves, light pipes, reflecting louvres, interior mirrors, translucent interior partitions and doors can all improve the natural day lighting conditions. Additional technologies such as diffusers, prismatic glazing and optical fibres can also be employed where appropriate.

It is also important when designing for Natural Daylighting to take account of the impact on heat losses. For instance, providing a North Light style roof-light may give good lighting levels free from glare, but could easily increase heat losses unless the specification of the glazing is adjusted and measures to reduce night time heat losses are also provided.

It is also important to take account of the interaction between daylighting and solar shading to avoid conflicting measures.

Atria can also improve diffused daylighting and protect the parent building from summertime glare. The geometry of an atrium will affect the amount of daylight reaching the atrium floor. The wider and shallower the atrium, the better the contribution from direct daylighting from the sky.

Other factors influencing the daylighting performance of atria include the following: -

- Roof construction
- Roof glazing
- Atrium walls and floor
- Glazing between occupied space and atrium
- Dimensions of the occupied space
- Interior reflectances of the occupied space
- Transmission of glazing
- Shading devices and controls

2.2.1 Responsive Lighting Controls and Low Energy Lamps

Controlling electric lights by daylight sensors will permit better use of daylight.

In addition other methods including time switches, movement sensors and individual switches can control the lamps.

Of course if low energy lamps are employed the amount of electricity and CO_2 emissions can be further reduced. There is now a substantial range of low energy lamps available and the costs have been reduced considerably. In addition it is now possible to have special fittings which can only be used with low energy lamps to avoid subsequent exchanging of low energy lamps with inefficient conventional equivalents.

The same amount of light produced by a 60-watt incandescent lamp can be produced by a modern 11-watt compact fluorescent lamp, which should also last six times as long.

Twenty 11 watt compact fluorescent lamps would consume sufficiently less electricity (compared to twenty 60 watt incandescent lamps) to avoid the emission of over half a kilogram of CO_2 for each hour of use - assuming current conventional UK sources of electricity.

2.2.2. Opportunities for Improved Natural Day-Lighting Provision in Uttlesford

There are opportunities for exploiting improved Natural Daylighting in Uttlesford within new non-domestic buildings and domestic buildings. The Essex Design guide encourages good practice in designing buildings with improved Natural Daylighting.

Perhaps it could be taken one stage further and require developers to justify when not using enhanced Natural Daylighting.

It is very important to encourage new buildings to make use of Natural Daylight, as it is much more difficult to improve Natural Daylighting to existing buildings.

However there are measures that can be added to existing buildings which can improve Natural Daylighting. These include: -

- Roof lights
- Light wells
- Light pipes and solar tubes
- Light shelves
- Redecoration of interior with light colours
- Replacing solid doors with transparent versions where appropriate
- Use of mirrors or reflecting films and foils
- Glazing over courtyards or adjacent spaces into atria

Apart from employing the above features to make best use of Natural Daylight and lighting controls it would be advantageous at the same time to promote the replacement of lamps with low energy equivalents.

While not strictly natural daylight except in a time shifting sense, there are a range of innovative solar PV (photovoltaic) powered lighting products becoming available usually based on LED (Light Emitting Diodes) and often use some battery system. One form looks like a tinted window during the day, but which at night time becomes a light emitting wall panel. Developments in PV powered lights for the boating, camping and outdoor market may also have a role particularly as battery technology improves as a result of innovation in lap top computers, *iPods*, mobile phones and the like.

2.3 Solar Photovoltaics

2.3.1 Definition

Solar photovoltaics (PV) utilises specially treated semiconductor[28] materials to convert light into electricity. These are known as **PV cells** and sometimes referred to as solar cells (**Figure 2-25**). PV cells are grouped together into a panel, which is known as a **PV module**. A PV installation involves a **PV array** consisting of a number of modules wired together.

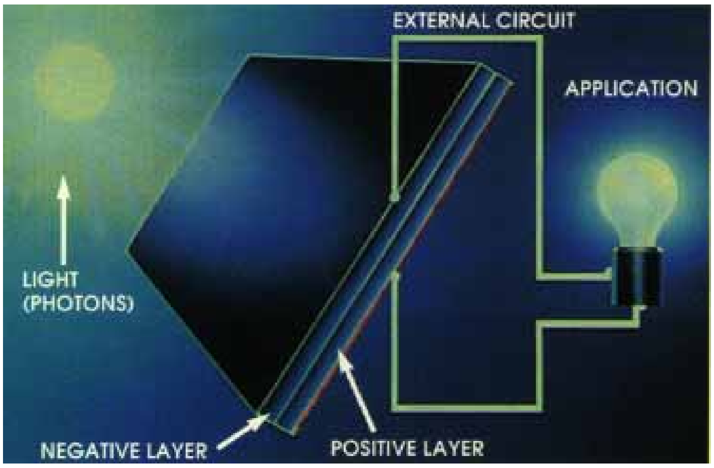

Figure 2-25: When exposed to light a photovoltaic cell generates DC electricity.

DC electricity is generated when the PV cells are exposed to sunlight (both direct sunlight and diffuse light reflected from the sky[29]) and the amount generated is related to the intensity of the light intercepted by the PV cells - though if they are allowed to become very hot, the efficiency declines even in high solar intensity conditions.

The orientation and tilt angle also influence the rate of electricity generation (see **Figure 2-2** and **Figure 2-9**), though even flat roofs or west or east facing sloping roofs with low pitch (up to 15 degrees) can produce up to 90% of the electricity compared to the optimum orientation and tilt angle. This means that a great variety of building surfaces and orientations are able to produce PV generated electricity, but the lower the tilt angle, the more *summer-loaded* is the electricity generation[30].

As mentioned earlier there may also be potential for NW/NE oriented roof pitches of 30 degrees or less as they can capture 70% of maximum potential and even north facing roof pitches of 30 degrees or less can capture 66% of maximum potential. These surfaces are also able to exploit more solar energy than vertical south facing surfaces between April and August. It may be easier to exploit such surfaces for photovoltaics rather than for solar water heating systems though such surfaces are unlikely to be economically viable until PV becomes much less expensive, but it does show that the potential solar resource may be bigger than is often considered.
At the end of 2006 the global installed capacity of PV was over 6,600 MWp (compared to 1,200 WP at the end of 2000). PV is one of the fasted growing forms of energy and there is considerable investment taking place constructing new factories which is expected to substantially increase the cell/module production from 2008. Globally the annual production is worth more than 9 Billion Euros/year.

Germany is the country with the largest installed capacity of PV with over 2,500 MWp (of which 750 MWp was installed in 2006) in place. In contrast at the end of 2005 the installed capacity in the UK was almost 11 MWp. At the end of 2005 there were 479 MWp in the USA

[28] Derived from the electronic semiconductor (computer chip) industry.
[29] Unlike sunny countries, the diffuse component of solar radiation is an important fraction of the usable solar energy in the UK.
[30] But most of the solar energy is available during the summer months in any case.

(624 MWp at the end of 2006) and 1,422 MWp in Japan (1,708 end of 2006) and 1,429 MWp in Germany.

The differences in the installed capacity between the UK and Germany helps to demonstrate why there is a relatively low awareness of the potential significance of PV as an important potential form of electricity generation.

2.3.2 Types of PV Cells

There are nine main types of silicon PV cells/modules currently available. The most efficient (13% to 15% or more) and most expensive type of PV cells are monocrystalline cells (MCSi), produced from long cylindrical crystals which are sliced into thin wafers and made into square-shaped cells (with clipped corners). Polycrystalline[31] cells are the next most efficient cells (about 10 to 12%), but are also less expensive (**Figure 2-26**) and are available in a range of colours (**Figure 27**). Polycrystalline silicon PV modules are available in relatively large single modules rated at 300Wp.

There are a number of newer types of polycrystalline technologies which offer more cost effective methods of producing crystalline silicon solar cells with low embodied energy, these include String Ribbon Polycrystalline (PCSi-R); EFG (Edge defined Film-fed Growth) type polycrystalline cells (PCSi-EFG) used to manufacture modules with 12 to 14.5% efficiency; and so called Thick Film[32] Polycrystalline (PCSi-F) based modules.

Apart from crystalline cells, silicon PV cells are also made from a single thin film of amorphous (non-crystalline) silicon and known as single junction amorphous silicon (ASi-SJ) cells. These are the least expensive but also have very low efficiency and are not often used on buildings, but are widely used on low power or portable products with built in solar cells such as solar calculators, solar radios, solar garden lights and fountains etc. By combining two amorphous layers, one above the other, another type of silicon PV is known as Tandem Junction PV (ASi-2J) cells (about 5% efficient). Three layered variants are known as Triple Junction PV (ASi-3J) cells (**Figure 2-28**) which are about 6% efficient though a more recent variant is said to be achieving higher efficiencies. ASi-3J cells are available in a range of formats including flexible modules, metal roofs, flat roof membranes and as roof shingles (which have a similarity to roof slates). Several manufacturers are producing transparent tinted glass PV glazed modules based on thin film amorphous silicon (ASi-Trans) that can be used to reduce solar gains as well as generate electricity, though because of the transparency the productivity is reduced (these are different to semitransparent modules which are transparent between the cells and which are usually made from MCSi or PCSi modules).

In addition to crystalline and amorphous varieties of silicon PV cells, there is a hybrid variant that consists of monocrystalline silicon PV cells surrounded by ultra-thin amorphous silicon. The hybrid modules are available with efficiencies of 15 to 17%.

PV cells made of other materials are also being developed and the most advanced and commercially available at the present time are the so called CIS (Copper Indium di Selenide) cells which represent a new thin film technology. Another thin film technology, Cadmium Telluride (CdTe), is also a promising option for reducing the cost of PV in large-scale production. Both operate at about 10% efficiency. CIGS (Copper Indium Gallium di Selenide) cells also have some promise due to the relatively low cost manufacturing process.

Other types of solar cells include various organic materials based on light sensitive dyes and these offer low cost flexible and transparent options but have low efficiencies.

[31] Also known as multi-crystalline silicon.
[32] Also known as microcrystalline thin film

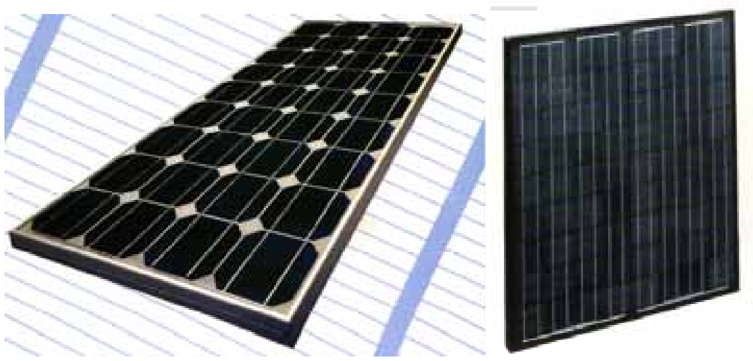

Figure 2-26: Monocrystalline PV (left) & Polycrystalline PV silicon modules (right) (BP Solar)

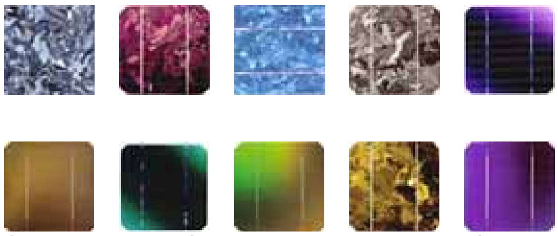

Figure 2-27: Some examples of additional colours available for Polycrystalline Silicon PV Cells.

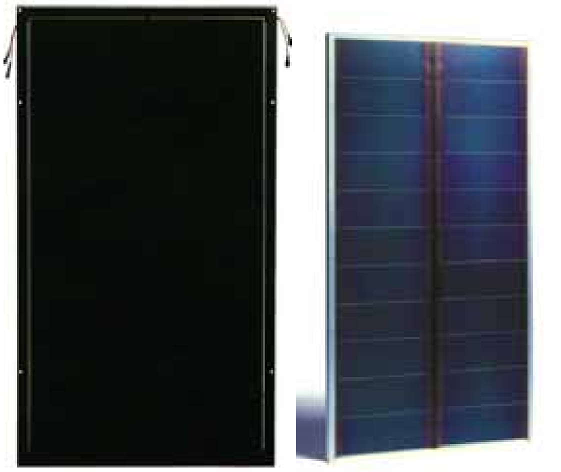

Figure 2-28: Modules made from Tandem Junction (ASi-2J)(left) and Triple Junction (ASi-3J) Amorphous Silicon PV cells (right) (UniSolar).

Figures 2-29 to **2-31** compare the performance characteristics of the various types of PV currently available in the UK. **Figure 2-29** compares the peak power per square metre, which shows that crystalline silicon modules have a better peak power to area ratio with MCSi requiring the least area per peak power reflecting the higher efficiency. The single junction amorphous silicon requiring the greatest area. **Figure 2-30** shows the array areas required for 1 kWp ratings. From this it can be seen that the MCSi requires about half the array area for 1 kWp compared to the triple junction amorphous modules (ASi-3J and ASi-3JSh) and around three and half times less than ASi-SJ modules. This helps to explain why ASi-SJ is rarely used for BIPV.

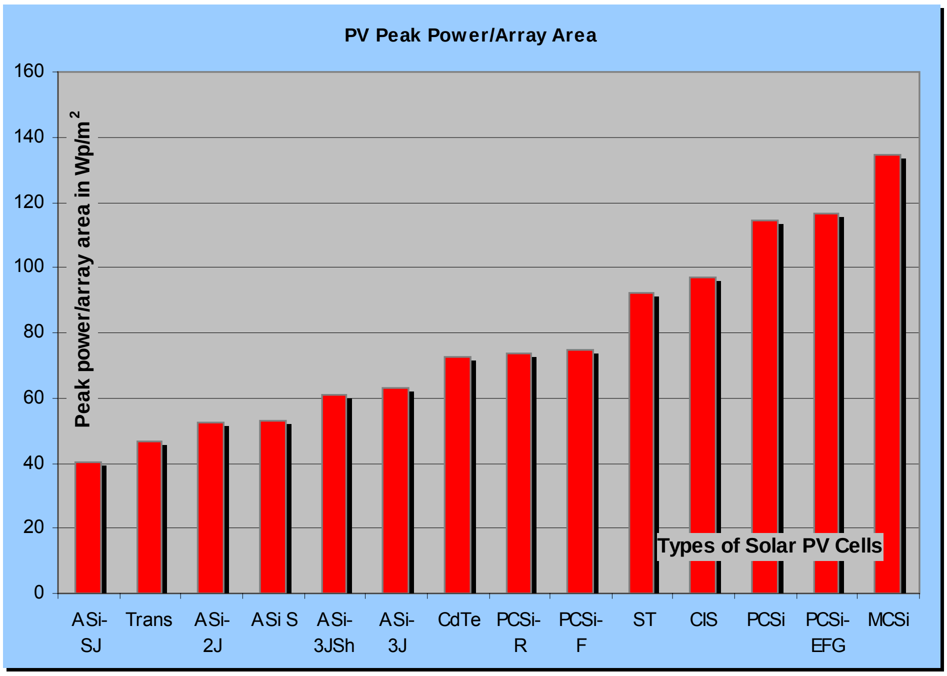

Figure 2-29: Comparison of peak power rating per square metre of array area in Wp/m^2

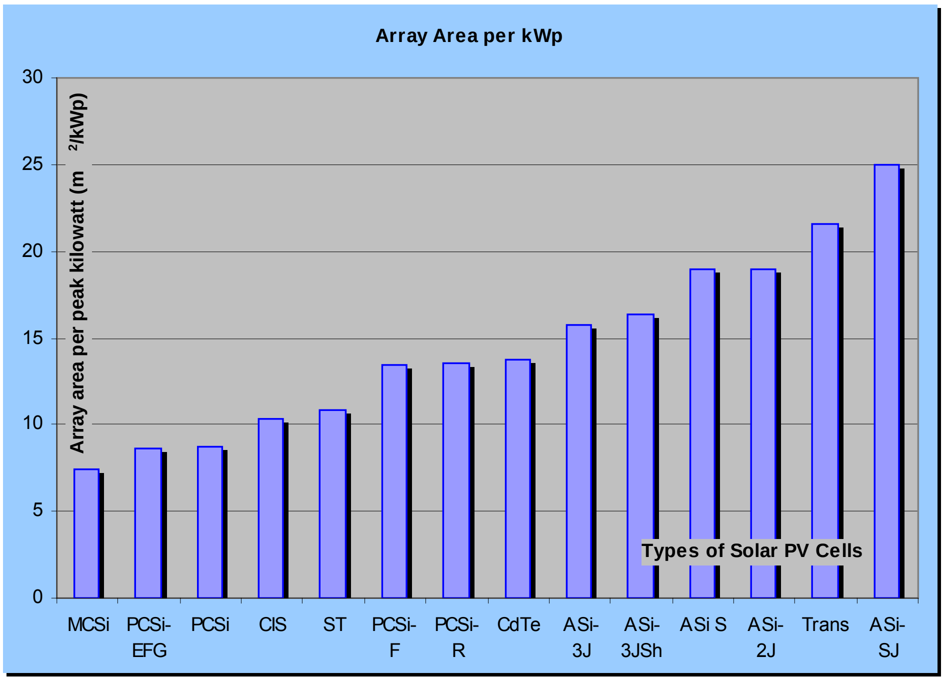

Figure 2-30 Array areas required for 1 kWp installations for available types of PV cells[33].

Figure 2-31 compares the estimated maximum potential yields (in annual kWh output per peak kilowatt rating) based on measured performance under UK conditions and assuming

[33] The ASiS array is also double junction amorphous silicon but from a different manufacturer to the other ASi-2J.

south facing arrays. This shows some interesting results as it can be seen that all of the double or triple junction amorphous silicon and the majority of the newer polycrystalline silicon based modules all achieve higher yields than the MCSi modules and the CIS array achieves the highest yield at around 1000kWh/kWp. **Figure 2-32** shows a somewhat different picture as it shows the annual kWh/m² outputs for the arrays. The MCSi array achieves just over 100 kWh/m² per year, which is about twice that of the ASi-3J and about five times that of the single junction amorphous silicon array. The CIS array achieves the second highest output at around 97 kWh/m².

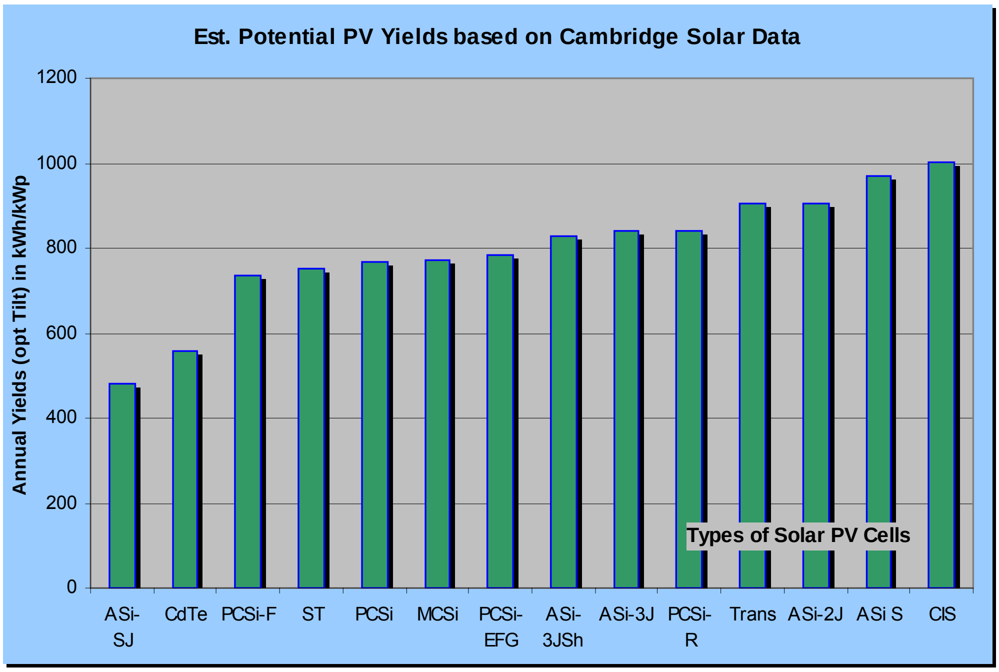

Figure 2-31: Estimated potential yields from different PV modules for south facing arrays.

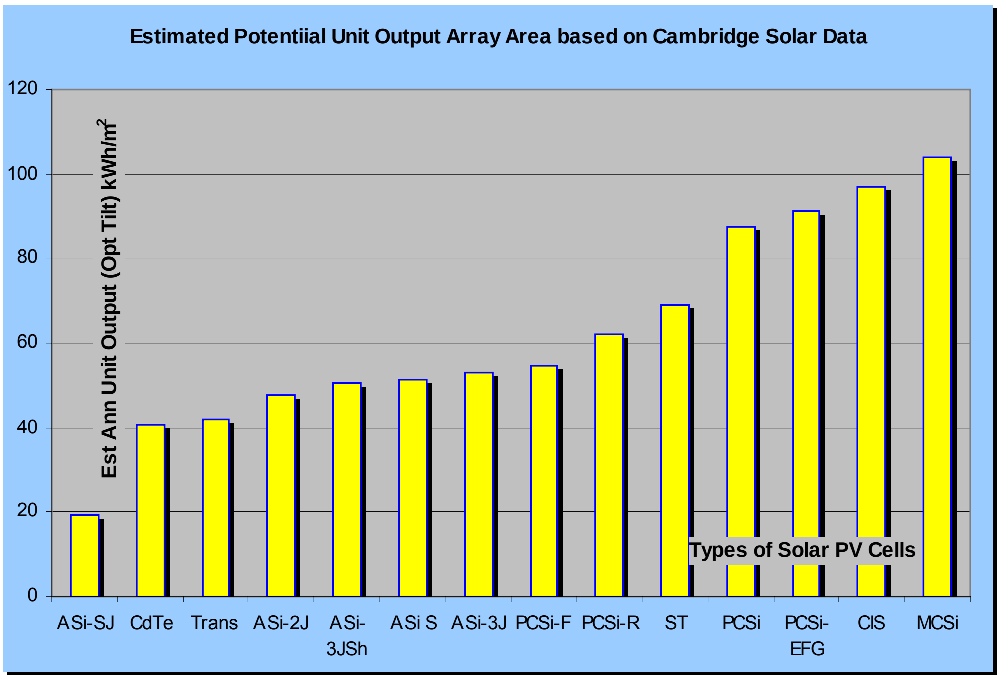

Figure 2-32: Estimated potential effectiveness of different PV modules for south facing arrays. Based on annual kWh/m² of array area.

These figures show that the performance of PV and the choice will depend on a variety of factors ranging from required output, roof or wall area available for the installation as well as the budget. The MCSi modules tend to have the highest capital costs but do have the highest productivity for a given area. However if more area is available and there is less need to get the maximum output from that area then one of the other options may be the more appropriate choice.

2.3.3 Types of Applications of PV

PV can be used for generating electricity for a variety of applications. Until the last decade or so the relatively high cost of PV meant that most applications tended to be either for powering space craft, remote locations in sunny regions and also for professional installations such as remote telecommunications stations and light houses[34].

As the cost has fallen, it has become more feasible to use PV for other applications, including battery charging for small boats and caravans, charging batteries for electric vehicles, pumping water, PV parking meters and PV powered street lights. PV has also been incorporated into a variety of small power products including solar calculators, solar radios, solar watches, solar powered lanterns, solar powered garden lights, and solar powered fountains and water features. There are also a number of solar assisted electric power boats available and even solar powered aeroplanes have been built and flown.

A number of small PV power stations (also known as solar farms or solar parks) have also been built in the USA, Italy and Spain. There may be scope for small village or neighbourhood scale community PV power stations (or hybrid stations with PV combined with other renewable energy technologies) particularly if such can be combined with other uses such as shade canopies, carport or rain shelters. The application of PV which has attracted the most interest is PV for buildings, either building integrated (BIPV) or attached to the building (BAPV).

2.3.4 Options for Building Integrated PV (BIPV)

The options for integrating into buildings are only limited by the imagination. Some of the options tried so far are mentioned below.

Building Integrated PV (BIPV) consists of cladding on walls or roofs, which include PV modules as the cladding or roofing material (**Figure 2-33** & **2-34**). There are also various methods for incorporating PV modules onto flat roofs (**Figure 2-35**) and there are various types of PV roof tiles, slates and shingles (**Figure 2-36**) designed to be mixed with or mimic roof slates and tiles.

There are various metal roofing systems which are coated with PV cells. Semi-transparent modules (in which the gaps between cells are transparent) can be used instead of glazing and for atrium roofs (**Figure 2-37**) permitting a level of day lighting combined with PV generating elements. Transparent PV modules can be used as tinted glazing (**Figure 2-38**).

[34] PV modules power virtually all of the lighthouses around the UK.

Figure 2-33: PV clad office building at the University of Northumbria. 40 kW peak power.

Figure 2-34: PV Modules used a roof covering on the Oxford Solar House. 4 kWp of monocrystalline silicon PV modules. The house also utilises active solar water heating, and passive solar heating via direct gains and from a solar sun-space. (Altechnica)

Figure 2-35: An example of PV systems installed on a flat roof. (Solar Century)

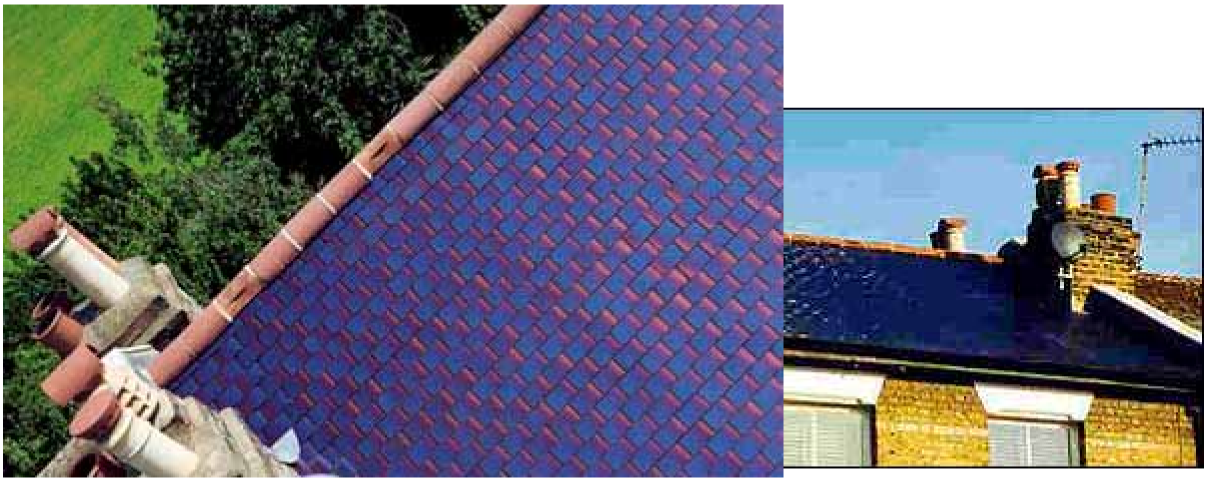

Figure 2-36: Example of a PV roof cladding which mimics roof slates (solar shingles based on ASi-2J) on a house in Richmond (Solar Century)

Figure 2-37: Semi-transparent PV/Glazing for PV and daylight Doxford. (Altechnica)

Figure 2-38: 'Tinted' transparent PV/Glazing for PV and daylight provision (Schott)

In addition PV can form the south slope of *North-Light* roof lights (**Figure 2-39**) and PV modules can be integrated into the exposed surface of solar shading devices, louvres or shutters (**Figure 2-40**). It can also be integrated into shade-canopy roofs.

Figure 2-39: PV Clad North-Light Roof-lights. BP Solar.

Figure 2-40: PV Solar shading devices (Romag and Schuco).

In most circumstances the PV is fixed in place but in some situations it can be movable and its tilt angle optimised seasonally (incrementally each month by manual adjustment or via an automatic mechanism). In addition it can be configured to follow the sun across the sky. Tracking the sun does increase the production from a PV module where the space available is limited but the cost of the tracking system has to be taken into account.

2.3.5 Options for Building Attached PV (BAPV)

In the case of existing buildings it may not be possible to incorporate the PV into the structure/fabric of the building and in that case there are a variety of systems for attaching the PV modules above the roof surface or on to a wall surface. However the appearance needs to be considered carefully.

There are also specially designed prefabricated lightweight triangular or flat units designed for installing PV on to existing flat roofs.

Further options are to install a free-standing PV clad pergola type structure (**Figure 2-41 left**)or shade canopy (**Figure 2-41 right**) for a garden or terrace or a PV clad car port type structure (**Figure 2-42 left**) or a Pole mounted PV array (**Figure 2-42 right**).


Figure 2-41: Left Example of a PV Canopy Right PV Shade canopy/loggia


Figure 2-42:Left Example of a PV Carport Right Pole mounted PV System

2.3.6 Grid Connected PV

There is a variation in the intensity of solar energy throughout the year and of course solar energy is not available through the hours of darkness. Therefore there is a need for either storing the energy between winter and summer or between day and night or using a back up system.

For buildings which already have a mains connection, there is no need to have electric storage batteries, but whilst it is possible to have a parallel electrical system (i.e. one based on PV and one based on the mains), it is less wasteful if the excess PV generated electricity is exported into the electricity grid. When the PV is not generating electricity the shortfall can be imported from the grid as normal.

Whilst in the past it was very difficult to connect a PV system to the grid, it has become more straightforward and the electricity supply companies have become more helpful.

An electricity import/export scheme, which addresses this issue, has been pioneered in other European countries and is known as 'net-metering'. This essentially means that the price paid for imported and exported electricity is the same in both directions. This means that the PV production is saving electricity and effectively means that the electricity meter can be "wound backwards". If the annual production of the PV exceeds the electricity imported, then the PV is virtually providing annual 'free electricity'.

There is considerable pressure for expansion of 'net-metering' in the UK and there are electricity companies in the UK prepared to offer such a scheme so there are expectations that this approach will expand. In addition there are a number of green electricity tariff companies prepared to offer a guaranteed price for PV generated electricity and there is also scope to obtain ROCs (Renewable Obligation Certificates). 1 MWh of electricity from a renewable source is worth one ROC.

Germany, the country with largest installed capacity of PV has a special ***feed in tariff*** in which building owners with a PV array receive a premium price for each kWh exported into the grid.

2.3.7 Stand-alone PV

For remote buildings and cabins etc which are not grid connected, the economics of using PV is more favourable because the cost of connecting to the grid may be very high. In this situation a standalone PV system can be a viable proposition, but it is essential to make sure that only low energy lights and high efficiency low power appliances are used.

In this case rechargeable batteries will be required together with a back up system consisting of a petrol, diesel or LPG generator set (and/or in combination with a small-scale wind generator). The cost of the fuel is such that the cost of electricity that a generator-set produces is higher than the price of mains electricity so the production from PV is also worth considerably more when compared to grid connected PV.

2.3.8 PV Battery Charging

PV can be used to charge electric batteries for a variety of non-grid connected applications, particularly for boats and caravans and electric fencing. This application is well established and several suppliers and manufacturers are successful in providing for these markets where they are usually powered by one or two PV modules.

2.3.9 Domestic applications of PV

On average the roof area of a house can accommodate sufficient PV modules to potentially provide an equivalent amount of electricity close to the household's requirements, though the more efficient the electrical appliances and lamps the less roof area is required.

If the house is occupied during the day or provides workspace accommodation used during daylight hours then there is a good demand match for some of the PV generated electricity.

However if the house is largely unoccupied during the day then the PV generated electricity needs to be either stored or exported to the grid during the day and retrieved or imported during the night-time. Therefore for this kind of domestic application of PV to be successful requires some form of net metering or green export tariff to be available.

For large scale or grouped dwellings, there may be scope for PV roofing to be provided by an ESCO[35] and the householder only has to continue to purchase the electricity from the ESCO who would manage the electricity provision and importing and exporting of electricity. This approach overcomes the capital investment barrier for individual householders interested in using PV and is being used in some domestic PV schemes in the Netherlands.

There can also be potential for cladding the walls and roofs of blocks of flats to provide a contribution to electricity demand of the tenants/flat owners.

2.3.10 Commercial/Industrial applications of PV

Commercial applications of PV range from cladding the walls of office buildings as well as their roofs. If solar shading is employed to keep out unwanted solar gains, the PV can be employed as part of the shading devices. PV can also be employed on the roofs and sides of atria and on the roofs of shade canopies. In addition, PV can be employed over parking bays.

PV can also clad the large walls and roofs of warehouse, factories and retail centres.

PV is likely to be more economically attractive on commercial/industrial buildings as the owners/tenants are likely to be subject to the climate change levy.

[35] Energy Services Company

2.3.11 PV on Public Buildings

PV can also make a useful contribution to electricity provision for many kinds of public buildings which may have large roof or wall surfaces, particularly libraries, council buildings, leisure centres, village halls, sports complexes and the like.

Installing PV on public buildings also helps to raise awareness about the technology and help to inform the public about PV.

2.3.12 PV Use in Schools

PV can be used in schools in a variety of ways. It can help to offset the electrical demands of the school and reduce electricity bills and CO_2 emissions. In addition, it can provide a vehicle to educate the schools' students about a range of subjects. It can also help to raise awareness about PV technology, as well as energy and environmental issues, with both the students and their parents.

As schools are subject to the Climate Change Levy, electricity produced from a PV installation will be more valuable as it is exempt from the levy.

Provided life cycle costs can be taken into account, rather than requiring a prompt payback, a PV installation may be a viable proposition.

If a school is to make the best use of PV, it is vital to work on reducing the electrical demand as it does not make economic sense to try and supply PV generated electricity for inefficient lights and appliances. It is therefore strongly recommended that if schools are considering the installation of PV, it should only be carried out as part of a package of measures which include replacing lights and appliances with low energy equivalents together with lighting controls and, if possible improvements to natural day lighting. By reducing the electrical demand, the size of the PV array can be reduced, minimising the investment needed.

2.3.13 PV Powered Parking Meters and Street Lamps

PV powered parking meters have the benefit of not having to be connected to the grid and having low power requirements. These benefits have encouraged a number of manufacturers to offer parking meters and numerous local authorities have successfully installed them around the country.

PV powered street lighting is another viable application of PV and offers the potential for providing more streetlights into areas (such as parks etc.) which would otherwise be very difficult to light. In new highway developments, it would also save on providing electrical power lines for streetlights. There are a variety of such streetlights available commercially.

The relevant authorities in Uttlesford should be encouraged to install PV powered parking meters and streetlights.

2.3.14 PV Powered Parking Bays/Charging Stations

Another application for PV is to provide shaded parking bays/charging stations, which can be used to recharge electric vehicles. Because of the high energy cost of conventional vehicle fuels, the economics of using PV for charging electrical vehicles (EVs) or plug in hybrid electric vehicles (PHEVs) is more favourable than just substituting electricity supplied to buildings. See wind energy section of this study.

There are a number of car companies offering electric vehicles with acceptable commuting performance and who also lease the battery pack[36], which reduces the total cost of purchasing electric vehicles. A number of HEVs are currently available and PHEVs have been demonstrated. Most of the major car companies have announced intentions to bring out PHEVs and long range EVs. Closer to home, East Anglian-based Lotus Engineering

[36] Which is then recycled by the car company after its operational life.

is involved in a number of EV, Hybrid projects. However there is a need for parking provision with electric charging facilities to encourage more use of electric vehicles and if these can be powered by PV (**Figure 2-43**) (or wind energy), then the vehicles can achieve total as well as local zero emissions[37]. EDF recently announced a collaboration with Toyota to provide local authorities with electrical charging stations when Toyota announced the PHEV version of its successful *Prius* hybrid-electric car (**Figure 2-44**).

Figure 2-43: PV Car ports for car parking (sources: Schott (left)& Kyocera (right:.

Figure 2-44: EDF Charging station for EVs and PHEVS (Sources: EDF and Toyota)

Any initiatives to stimulate the use of electrical vehicles/PHEVs in Uttlesford should ideally include the installation of PV powered parking bays and to promote the concept amongst private car parking providers. Vehicle transport is one sector which looks unlikely to reduce CO_2 emissions without some intervention, so any initiative which improves the viability of total zero emission vehicles has to be an improvement. With the right promotion, more organisations and individuals will be more likely to change their vehicles.

2.3.15 Solar-Hydrogen Systems

As an alternative to battery charging, the storing of PV generated electricity by electrolysing water to produce hydrogen is the subject of considerable research and investment.

The hydrogen can be stored in gas storage tanks, in liquid form in low temperature storage tanks or in solid metal hydrides.

The energy can then be recovered by using an internal combustion engine in which the only by-product is water. A number of car manufacturers are researching this emission free approach.

Another approach, which can achieve higher energy conversion efficiency, is the fuel cell system. The fuel cell is a kind of electric battery but which operates on the controlled reaction of hydrogen and oxygen. The reaction produces both clean electricity and water. The fuel cell is likely to be available in tiny forms for powering computers or mobile phones, but most of the research is into fuel cells that can power electric vehicles by hydrogen.

There are several multinational car manufacturers planning to offer fuel cell[38] powered electric vehicles within a few years. Another promising use for fuel cells is for stationary zero emissions combined heat and power (CHP) units such as the fuel cell component of the

[37] Electrical vehicles charged with mains electricity operate without local emissions, but there are emissions created at the power stations. If on the other hand PV (or other renewables) generates the electricity, then the vehicle is genuinely a zero emission vehicle.

[38] However conventional fuels converted into hydrogen on board the vehicle will fuel the initial variants.

Woking CHP scheme. Such fuel cells can be fuelled by hydrogen produced from water by PV generated electricity[39].

At the present time the fuel cell is an expensive option but its high conversion efficiency (once the hydrogen has been obtained) combined with its zero emission characteristics, is stimulating much activity and the considerable efforts in achieving lightweight fuel cells is expected to be driven by both portable computers and mobile phones as well as long range electric vehicles.

The main limitations at the moment are the conversion losses and infrastructure requirements when one is deriving the hydrogen from PV or other renewable electricity sources. There is considerable activity in fuel cell powered vehicles, however it seems unlikely that solar derived hydrogen can be a viable mechanism for powering large numbers of vehicles rather than fossil fuel derived hydrogen or fossil fuel derived methanol.

The conversion losses may be less of an issue when used as a stationery energy storage-fuel cell system[40] as it potentially offers value added benefits from storing variable energy sources such as wind and solar generated electricity.

[39] Or other renewable sources of electricity such as wind power, water power or tidal power etc.
[40] Particularly if one can recover useful heat by using it as a CHP unit.

2.3.16 Potential for Solar Photovoltaics in Uttlesford

If we assume that the 28,500 households are consuming electricity at the UK average rate of 4,700 kWh/year, the amount of annual domestic electricity needs in Uttlesford would be of the order of 134 GWh/y. The estimated land area that would be required to generate this level of annual production of electricity would be about a **quarter of 1% of the land area of Uttlesford** if installed as solar electricity parks. If we assumed that there were 30,000 houses, the amount of land required would be around 0.27 of a percent. According to DUKES06 the average household electricity consumption in Uttlesford is more like 5,800 kWh/y, which would require about ⅓ of one percent of the land area of Uttlesford.

This shows that there is substantial potential to utilise PV to match the domestic electricity demand of Uttlesford (and abate of the order of 76,000 to 99,000 tonnes of CO_2/year[41]) if land could be allocated for such and there may be scope to consider such a 'solar-farm' approach particularly where there is also a benefit from providing shaded areas or providing shelter from the elements.

PV has the benefit of being able to be integrated into a building or attached to a building which offsets the cost of a support structure and of a scale that could potentially contribute a useful proportion of the household electricity consumption.

The potential for BIPV production in the UK is estimated to be to between 25% and 100% of the national electricity demand.

A resource study (Hill etal, 1992) has estimated the potential from BIPV on the entire building stock[42] in the UK: if all appropriate surfaces were clad with PV, it would generate[43] up to 208 TWh/year[44]. If BAPV options were also included the potential capacity would be still larger.

Uttlesford is better suited than many UK districts to make use of PV so we can therefore assume that at least similar rates of PV production are possible.

The largest proportion of this estimated UK BIPV generating capacity is estimated to be from the roofs of domestic buildings because the roof areas available for BIPV cladding is so much larger for this sector than for commercial or industrial buildings. As there is generally a poor match between supply and demand, the electricity from domestic roofs would need to be exported into the electricity distribution grid.

However as cladding all of the UK building stock is not feasible, this study also proposed an initial target to apply BIPV to 10% of the UK building stock, to supply 12 GW of the UK's average daytime electrical load. The electricity generated by this area of BIPV cladding would be of the order of 37 TWh/year and reduce the CO_2 emissions by 36 million tonnes per year[45].

PV is more economically viable on non-domestic buildings as there is a better match between summertime electrical demand and PV electrical production. Also the cladding of many non-domestic buildings is driven by image rather than economics and more organisations developing 'green' or sustainability plans are aware of their green image. Investing in BIPV is a way some companies can demonstrate their commitment to sustainability.

Organisations subject to the Climate Change Levy are incurring higher electricity bills (the levy adds around 0.4p to each kWh of electricity consumed), but electricity generated from PV is exempt so this provides a further incentive to incorporate BIPV.

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[41] Depending on 28.5 k households or 30k households and depending on average household electricity consumption values of 4.7 to 5.8 MWh/y.

[42] Solar input per km^2 of land area is based on 107.1 MW/km^2 for Commercial buildings, 76.1 MW/km^2 for Industrial buildings, 42.7 MW/km^2 for Residential (high rise) buildings and 38.4 MW/km^2 for Residential (housing) buildings.

[43] Assuming an average solar radiation value for all walls (N, E, S and W) for the south of England and an average PV efficiency of 13%.

[44] Or 354 TWh/year assuming projected 2020 technology.

[45] Total CO_2 emissions from UK electricity generation assumed to be 290 million tonnes/year (Hill etal, 1992).

For the purposes of this study only PV on domestic buildings are considered. Given the range of PV technologies available there is some uncertainty of the total potential capacity in Uttlesford, so three typical established PV technologies were assumed to be employed on the households in Uttlesford.

Monocrystalline Silicon PV Arrays

Figure 2-45 compares the estimated annual yields (in kWh/kWp) from monocrystalline silicon modules assuming solar radiation data for the range of orientation and tilt angles shown in **Figure 2-9**.

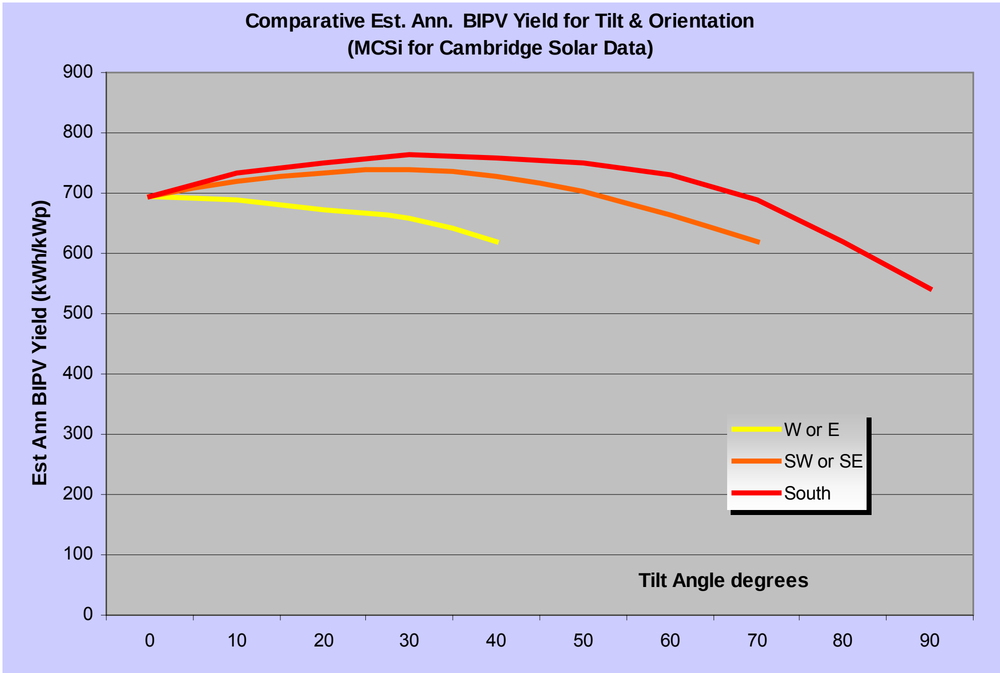

Figure 2-45: Estimated annual yields for MCSi PV modules at a range of tilt angles for S, SW/SW, W/E orientations and based on solar radiation data for Cambridge.

From **Figure 2-45** the estimated annual yields for MCSi arrays range from 540 kWh/kWp (S90) to 765 kWh/kWp (S30) with 695 kW/kWp from horizontally aligned modules. The average yield (averaged from all of the orientations and tilt angles in **Figure 2-45**) is estimated at 690 kWh/kWp.

When the array area is also taken in to account the annual outputs for MCSi arrays range from 73 kWh/m^2 (S90) to 103 kWh/m^2 (S30) with 94 kWh/m^2 from horizontally aligned modules. The average output is estimated at 93 kWh/m^2. The array area for 1kWp from MCSi modules would be around 7.4 m^2, though the actual area and rectangular shape would depend on the form factor of the individual modules.

Using the CO_2 emission abatement rate of 568 gCO_2/kWh for PV generated electricity included in the current Building Regulations the average output of 690 kWh/y would abate 390 kgCO_2/y.

To generate 1000 kWh/y, the average peak power rating would be **1.45 kWp** which would involve an array area of around **10.8 m^2** (e.g. equivalent to a rectangle of just over 5 m x 2 m) and result in 568 kgCO_2/y being abated. To generate annual electricity production equivalent to the UK average household electricity demand of 4.7 MWh/y from an average MCSi array would require a **6.8 kWp** array with an array area of 51 m^2, e.g. a rectangular area of just over 10 m x 5 m (for comparison a south facing MCSi array at optimum tilt angle to generate 4.7 MWh/y would be rated at around 6.1 kWp). To generate the Uttlesford average household electricity of 5.8 MWh/y from an average MCSi array would need to be sized at 8.4 kWp.

Polycrystalline Silicon PV Arrays

Figure 2-46 compares the estimated annual yields (in kWh/kWp) from polycrystalline silicon (PCSi) modules assuming solar radiation data for the range of orientation and tilt angles shown in **Figure 2.9**.

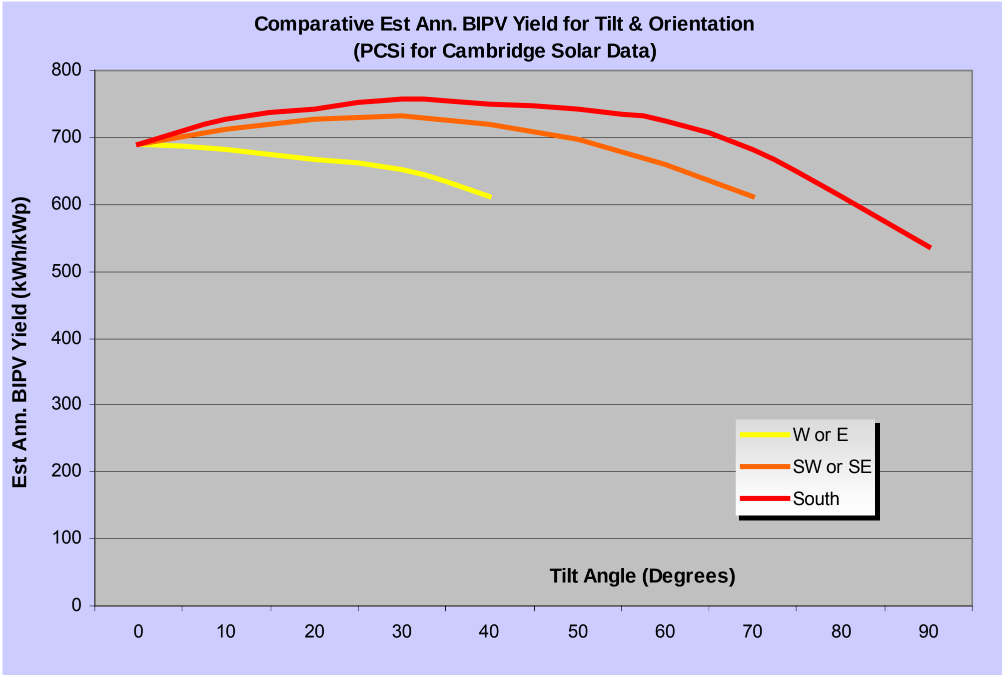

Figure 2-46: Estimated annual yields for PCSi PV modules at a range of tilt angles for S, SW/SW, W/E orientations and based on solar radiation data for Cambridge.

From **Figure 2-46** the estimated annual yields for **PCSi** arrays range from 536 kWh/kWp (S90) to 758 kWh/kWp (S30) with 690 kW/kWp from horizontally aligned modules. The average yield (averaged from all of the orientations and tilt angles in **Figure 2-46**) is estimated at **685 kWh/kWp**.

When the array area is also taken in to account the annual outputs for **PCSi** arrays range from 60 kWh/m^2 (S90) to 87 kWh/m^2 (S30) with 79 kWh/m^2 from horizontally aligned modules. The average output is estimated at **78 kWh/m^2**. The array area for 1kWp from PCSi modules would be around 8.8 m^2, though the actual area and rectangular shape would depend on the form factor of the individual modules.

Using the CO_2 emission abatement rate of 568 gCO_2/kWh for PV generated electricity included in the current Building Regulations the average output of 685 kWh/y would abate 389 kgCO_2/y.

To generate 1000 kWh/y, the average peak power rating would be **1.47 kWp** which would involve an array area of around **12.8 m^2** (e.g. or equivalent to a rectangle of just over 6 m x 2 m) and result in 568 kgCO_2/y being abated.

Triple Junction Amorphous Silicon PV Arrays

Figure 2-47 compares the estimated annual yields (in kWh/kWp) from triple junction amorphous silicon based PV Shingles[46] (ASi-3J-Sh) assuming solar radiation data for the range of orientation and tilt angles shown in **Figure 2-9**.

[46] These are similar in appearance t

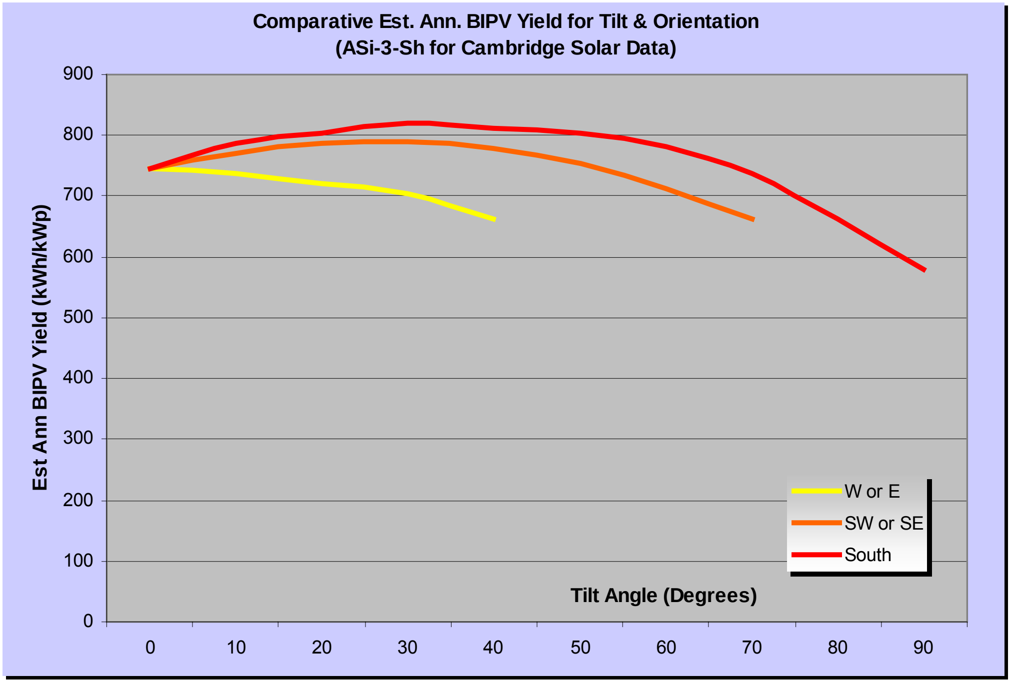

Figure 2-47: Estimated annual yields for ASi 3J-Sh PV shingles at a range of tilt angles for S, SW/SW, W/E orientations and based on solar radiation data for Cambridge.

From **Figure 2-47** the estimated annual yields for **ASi-3J-Sh** arrays range from 670 kWh/kWp (S90) to 830 kWh/kWp (S30) with 754 kW/kWp from horizontally aligned modules[47]. The average yield (averaged from all of the orientations and tilt angles in **Figure 2-47**) is estimated at **750 kWh/kWp**.

When the array area is also taken in to account the annual outputs for **ASi-3J-Sh** arrays range from 37 kWh/m^2 (S90) to 53 kWh/m^2 (S30) with 48 kWh/m^2 from horizontally aligned modules. The average output is estimated at **48 kWh/m^2**. The array area for 1kWp from ASi-3J-Sh modules would be around 15.8 m^2, though the actual area and rectangular shape would depend on the form factor of the individual modules.

Using the CO_2 emission abatement rate of 568 gCO_2/kWh for PV generated electricity included in the current Building Regulations the average output of 750 kWh/y would abate 426 kgCO_2/y.

To generate 1000 kWh/y, the average peak power rating for the PV shingles would be **1.34 kWp** which would involve an array area of around **21.2 m^2** (e.g. or equivalent to a rectangle of just over 7 m x 3 m) and result in 568 kgCO_2/y being abated.

Comparative production from the PV Arrays

Table 2-3 compares the sizes and areas for PV arrays (based on the above types of modules) and average of orientations and tilt angles ranging from 500Wp to 10 kWp.

Table 2-3 Comparison of PV Array Sizes and Outputs for Average Orientation & Tilt Angle[48]

[47] The **ASi-3J-Sh** PV Shingles would not be able to be mounted horizontally but other ASi-3J modules form the same manufacturer can be mounted horizontally so these values have been included for completeness.
[48] Note: values in the table for outputs and abatements are rounded down and array areas are rounded up.

Approximate PV Array Sizes & Outputs for Average Orientation & Tilt Angle

Peak Power kWp	MCSi Array Area m^2	MCSi Ann Output kWh/y	MCSi Ann CO_2 abate kg/y	PCSi Array Area m^2	PCSi Ann Output kWh/y	PCSi Ann CO_2 abate kg/y	ASi-3J-Sh Array Area m^2	ASi-3J-Sh Ann Output kWh/y	ASi-3J-Sh Ann CO_2 abate kg/y
0.5	3.8	340	190	4.4	340	190	8.2	370	210
1.0	7.5	690	390	8.8	680	380	16.4	750	420
1.5	11.2	1040	590	13.2	1020	580	24.6	1120	630
2.0	14.9	1390	780	17.6	1370	770	32.8	1500	850
2.5	18.7	1730	980	22.0	1710	970	41.0	1870	1060
3.0	22.4	2080	1180	26.4	2050	1160	49.2	2250	1270
3.5	26.1	2430	1380	30.8	2390	1360	57.4	2620	1490
4.0	29.8	2780	1570	35.2	2740	1550	65.6	3000	1700
4.5	33.6	3120	1770	39.6	3080	1750	73.8	3370	1910
5.0	37.3	3470	1970	44.0	3420	1940	82.0	3750	2130
5.5	41.0	3820	2170	48.4	3760	2130	90.2	4120	2340
6.0	44.7	4170	2360	52.8	4110	2330	98.4	4500	2550
6.5	48.5	4510	2560	57.2	4450	2520	106.6	4870	2760
7.0	52.2	4860	2760	61.6	4790	2720	114.8	5250	2980
7.5	55.9	5210	2960	66.0	5130	2910	123.0	5620	3190
8.0	59.6	5560	3150	70.4	5480	3110	131.2	6000	3400
8.5	63.4	5900	3350	74.8	5820	3300	139.4	6370	3620
9.0	67.1	6250	3550	79.2	6160	3500	147.6	6750	3830
9.5	70.8	6600	3750	83.6	6500	3690	155.8	7120	4040
10.0	74.5	6950	3940	88.0	6850	3890	164.0	7500	4260

2.3.16.1 Potential for Solar Electricity in Uttlesford from Residential BIPV/BAPV

If we assume that the mix of housing stock in Uttlesford is comparable to that of Cambridge, then a high proportion of the buildings will have scope for incorporating a PV array, however in order to err on the conservative side for estimates only 500 Wp, 1 kWp, 2 kWp, 3kWp and 4 kWp arrays will be assumed in assessment of the potential for providing solar electricity form BIPV (also including BAPV) for the existing households in Uttlesford.

This means that is unlikely for BIPV/BAPV on existing households to provide all of average household electricity requirements (unless householders also reduce their electricity demands) but there is possibly scope for larger sized arrays particularly for households with large houses (or gardens suitable for ground mounted or pole mounted arrays).

As all the households are not the same size and for the purposes of this assessment detached houses are assumed to have larger sized arrays than semi-detached houses. According to the 2001 Census information, there are approximately 12,200 detached houses or bungalows (DH) and there are 13,300 semidetached and terraced houses and bungalows (SDH).

Residential BIPV/BAPV Option 1 *(1kWp+500Wp Arrays)*

Figure 2-48 shows ball park estimates of the potential annual outputs from PV arrays based on **MCSi**, **PCSi** and **ASi-3J-Sh** modules which assumes that the detached houses/bungalows will utilise 1 kWp arrays (7.5, 8.8 and 16.4 m^2 array areas) and semi-detached/terraced houses/bungalows will utilise 500Wp arrays (3.8, 4.4, 8.2 m^2 array areas) based on average outputs for orientation and tilt angle. The figure estimates the potential for between 10% and 100% of the combined DH and SDH housing stock, but for each percentage of the total the proportion of DH to SDH is maintained at 48%DH and 52%SDH.

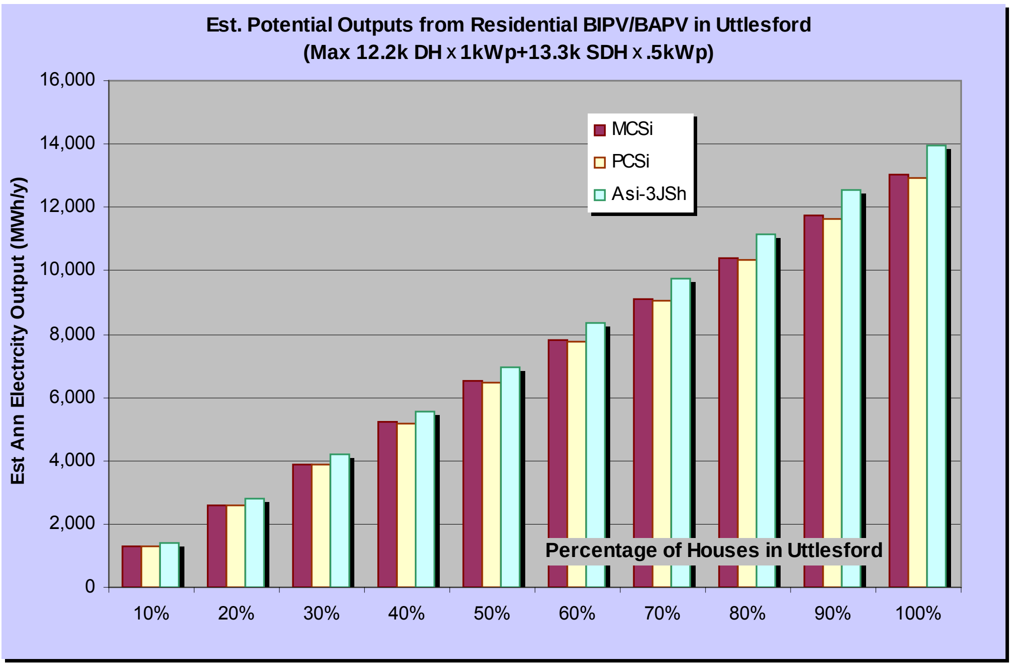

Figure 2-48: Ball-park estimates of potential solar electricity from residential **BIPV/BAPV Option 1** for the DH & SDH households in Uttlesford (based on average orientation/tilt angle) MCSi, PCSi & ASi-3J-Sh PV modules rated at 1 kWp for DH and 500Wp for SDH households.

Assuming **10% of the housing stock in Uttlesford** employed PV systems the estimated ball park solar energy contribution to domestic electricity needs would be between **1.29** (assuming all were **PCSi**) and **1.39 GWh/y** (assuming all were **ASi-3J-Sh**) - though the area of the arrays of the ASi-3J-Sh systems would be around twice that of both the MCSi and PCSi-based systems.

Whether 100% of the households in Uttlesford could utilise a PV system seems unlikely (unless those without suitable roof or wall surfaces also have scope for ground or pole mounted systems or can consider NE/NW or N low pitch systems or can be linked to groups PV schemes), however if we assume that **50% of the households** can incorporate a BIPV/BAPV system, the estimated ball park solar electricity contribution to domestic electricity needs would be between **6.45** and **6.97 GWh/y**. This is equivalent to around 5 % of the household electricity requirements in Uttlesford.

If we assume a comparable proportion - to Cambridge - of the housing stock would be suitable for accepting PV systems then between 60% and 70% of the households could employ PV systems. So assuming PV systems on **60% of the households in Uttlesford** the estimated ball park solar contribution to domestic electricity needs would be between **7.74** and **8.36 GWh/y** (e.g. equivalent to around 6 to 7% of the household electricity requirements in Uttlesford) and on **70%** of the households the estimates would be between **9** and **9.76 GWh/y** (equivalent to around 7 to 8% of the household electricity requirements in Uttlesford).

Residential BIPV/BAPV Option 2 ***(2kWp+1kWp Arrays)***

Figure 2-49 shows ball park estimates of the potential annual outputs from PV arrays based on MCSi, PCSi and ASi-3J-Sh modules on 10% to 100% of the detached houses/bungalows (at 2 kWp per DH) (15, 17.6 and 33 m^2 array areas) and semidetached/terraced houses/bungalows (at 1 kWp per SDH) (7.5, 8.8 and 16.4 m^2 array areas) based on average outputs for orientation and tilt angle.

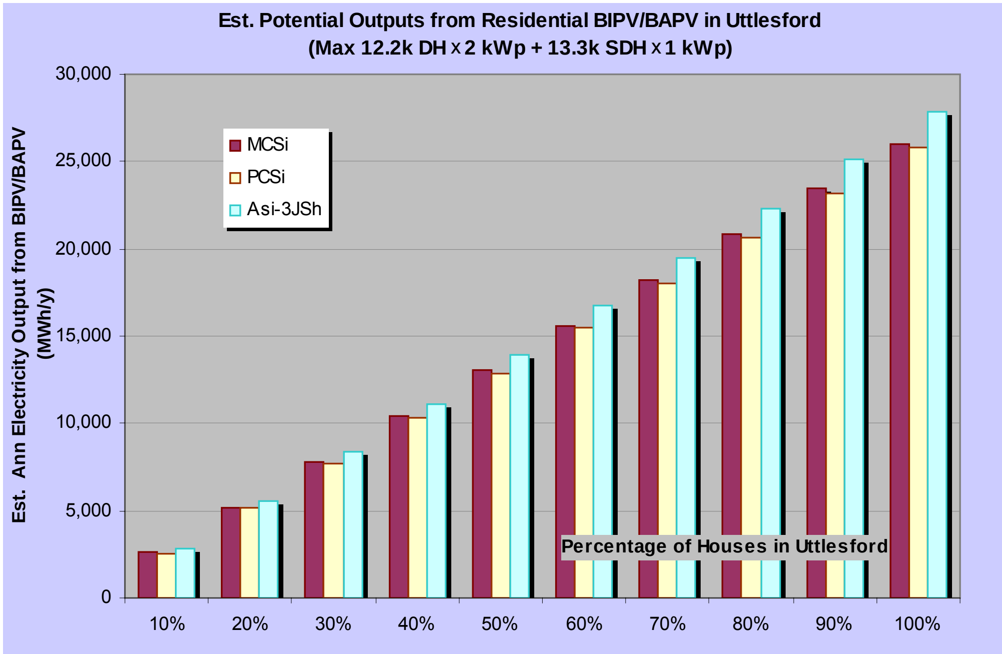

Figure 2-49: Ball-park estimates of potential solar electricity from residential **BIPV/BAPV Option 2** for the DH and SDH households in Uttlesford (based on average orientation/tilt angle) MCSi, PCSi & ASi-3J-Sh PV modules rated at 2 kWp for DH and 1 kWp for SDH households.

Assuming **10% of the housing stock in Uttlesford** employed PV systems (2 kWp and 1 kWp) the estimated ball park solar energy contribution to domestic electricity needs would be between **2.58** (assuming all were **PCSi**) and **2.78 GWh/y** (assuming all were **ASi-3J-Sh**) - e.g. equivalent to around 2% of household electricity demand in Uttlesford.

Similarly if we assume that **50% of the households** can incorporate these PV systems, the estimated ball park solar contribution to domestic electricity needs would be between **12.9** and **13.94 GWh/y**. This is equivalent to around 10 to 11 % of the household electricity requirements in Uttlesford.

Assuming PV systems (2kWp + 1kWp) on **60% of the households in Uttlesford** the estimated ballpark solar contribution to domestic electricity needs would be between **15.48** and **16.73 GWh/y** (11 to 13% of the household electricity requirements in Uttlesford) and on **70%** of the households the estimates would be between **18** and **19.51 GWh/y** (equivalent to around 13 to 16% of the household electricity requirements in Uttlesford).

Residential BIPV/BAPV Option 3 *(3kWp+2kWp Arrays)*

Figure 2-50 shows ball park estimates of the potential annual outputs from PV arrays based on MCSi, PCSi and ASi-3J-Sh modules on 10% to 100% of the detached houses/bungalows (at 3 kWp per DH) (23, 27 and 49 m² array areas) and semidetached/terraced houses/bungalows (at 2 kWp per SDH) (15, 17.6 and 33 m² array areas) based on average outputs for orientation and tilt angle.

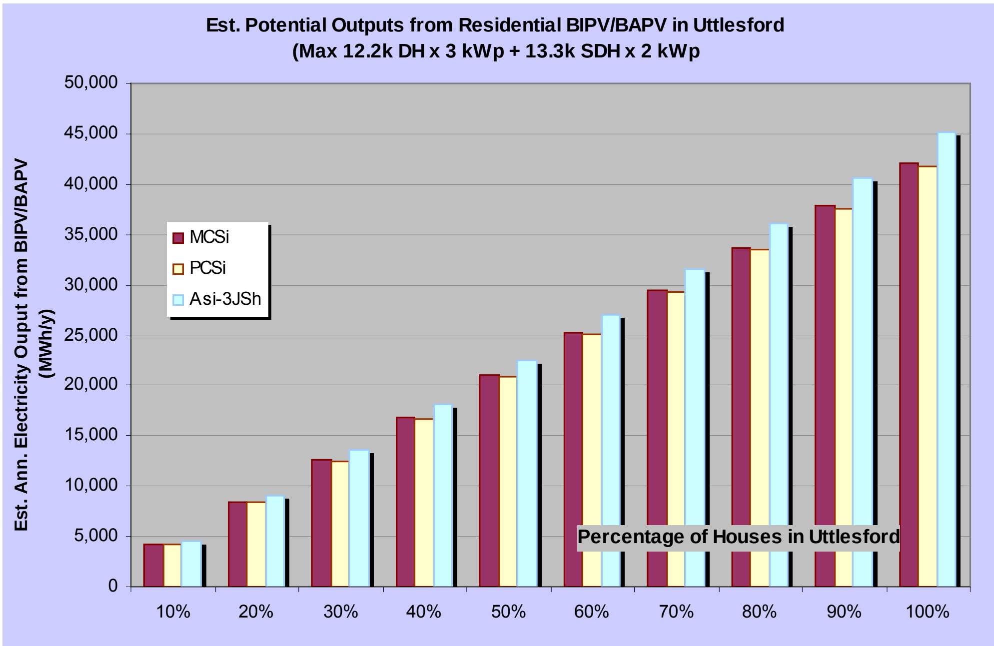

Figure 2-50: Ball-park estimates of potential solar electricity from residential **BIPV/BAPV Option 3** for the DH and SDH households in Uttlesford (based on average orientation/tilt angle) MCSi, PCSi and ASi-3J-Sh PV modules rated at 3 kWp for DH and 2 kWp for SDH households.

Assuming **10% of the housing stock in Uttlesford** employed PV systems (3 kWp and 2 kWp) the estimated ball park solar energy contribution to domestic electricity needs would be between **4.17** (assuming all were **PCSi**) and **4.5 GWh/y** (assuming all were **ASi-3J-Sh**) - e.g. equivalent to around 3% to 3.5% of household electricity demand in Uttlesford.

Similarly if we assume that **50% of the households** can incorporate these PV system, the estimated ball park solar contribution to domestic electricity needs would be between **20.88** and **22.56 GWh/y**. This is equivalent to around 15 to 18 % of the household electricity requirements in Uttlesford.

Assuming PV systems (3kWp + 2kWp) on **60% of the households in Uttlesford** the estimated ballpark solar contribution to domestic electricity needs would be between **25** and **27 GWh/y** (18 to 22% of the household electricity requirements in Uttlesford) and on **70%** of the households the estimates would be between **29.23** and **31.58 GWh/y** (equivalent to around 21 to 26% of the household electricity requirements in Uttlesford).

Residential BIPV/BAPV Option 4 *(4kWp+3kWp Arrays)*

Figure 2-51 shows ball park estimates of the potential annual outputs from PV arrays based on MCSi, PCSi and ASi-3J-Sh modules on 10% to 100% of the detached houses/bungalows (at 4 kWp[49] per DH) (30, 35 and 66 m^2 array areas) and semidetached/terraced houses/bungalows (at 3 kWp per SDH) (23, 27 and 49 m^2 array areas) based on average outputs for orientation and tilt angle.

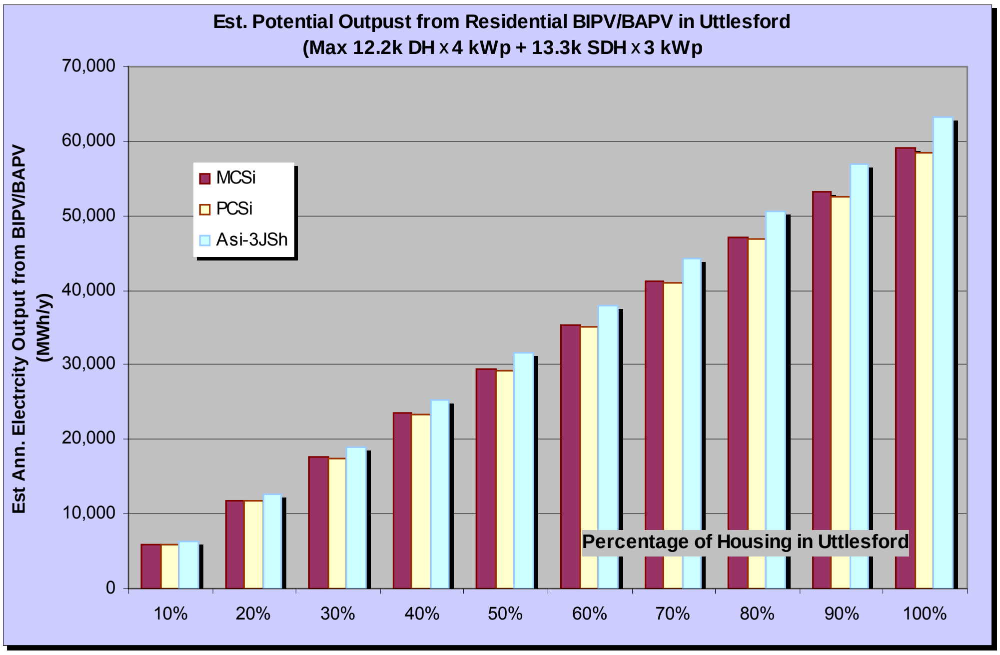

Figure 2-51: Ball-park estimates of potential solar electricity from residential **BIPV/BAPV Option 4** for the DH and SDH households in Uttlesford (based on average orientation/tilt angle) MCSi, PCSi and ASi-3J-Sh PV modules rated at 4 kWp for DH and 3 kWp for SDH households.

Assuming **10% of the housing stock in Uttlesford** employed PV systems (4 kWp and 3 kWp) the estimated ball park solar energy contribution to domestic electricity needs would be between **5.86** (assuming all were **PCSi**) and **6.31 GWh/y** (assuming all were **ASi-3J-Sh**) - e.g. equivalent to around 4% to 5% of household electricity demand in Uttlesford.

Similarly if we assume that **50% of the households** can incorporate these PV system, the estimated ball park solar contribution to domestic electricity needs would be between **29.24** and **31.59 GWh/y**. This is equivalent to around 21 to 26 % of the household electricity requirements in Uttlesford.

Assuming PV systems (4kWp + 3kWp) on **60% of the households in Uttlesford** the estimated ballpark solar contribution to domestic electricity needs would be between **35** and **37.9 GWh/y** (26 to 31% of the household electricity requirements in Uttlesford) and on **70%** of the households the estimates would be between **40.9** and **44.22 GWh/y** (equivalent to around 30 to 36% of the household electricity requirements in Uttlesford).

Residential BIPV/BAPV Options in Uttlesford

The previous sections on Options 1 to 4 indicate that residential BIPV/BAPV systems could make a useful contribution to the household electricity needs, though it seems unlikely that they could provide more than 30 to 36% of the current average household electricity demand (UK average of 4.7 MWh/y or Uttlesford average of 5.8 kWh/y) household electricity at the current rates of consumption (without assuming larger sized arrays which may be possible on a proportion of houses but would have a larger significant visual impact). However if electricity consumption per household was reduced by a half or by two thirds then matching household demand in Uttlesford with residential BIPV/BAPV seems potentially feasible.

When available space is limited crystalline silicon modules may be feasible, but if a roof has to be replaced then it might be possible to re-tile the roof with the **ASi-3J-Sh** shingles (as in

[49] The Oxford Solar House uses a 4 kWp PV roof integrated BIPV array.

Figure 2-36) which for a 4kWp array (as shown in Option 4 above) would require a roof area of 66 m2 (e.g. equivalent to 11 m x 6 m) to be available (other more efficient PV tile systems based on crystalline PV are also available which require about half the area for equivalent outputs).

However there may be a possible conflict with available space with solar water heating collectors so this would adjust the potential estimates of both residential solar water heating and solar electricity.

There is potential to supplement the residential BIPV/BAPV systems with free standing arrays either as group solar arrays, pole mounted arrays, car ports and cladding large industrial buildings.

2.3.16.2 CO_2 Abatement from Residential BIPV/BAPV in Uttlesford

Using the same residential BIPV/BAPV options used to estimate the potential electricity contribution, we can calculate ballpark estimates of the potential contribution to CO_2 abatement in Uttlesford.

CO_2 Abatement from Residential BIPV/BAPV Option 1 *(1kWp+500Wp Arrays)*

Figure 2-52 shows ball park estimates of the aggregated CO_2 abatement from the averaged outputs of the BIPV/BAPV arrays based on **MCSi**, **PCSi** and **ASi-3J-Sh** modules which assumes that the detached houses/bungalows will utilise 1 kWp arrays (7.5, 8.8 and 16.4 m^2 array areas) and semi-detached/terraced houses/bungalows will utilise 500Wp arrays (3.8, 4.4, 8.2 m^2 array areas) based on average outputs for orientation and tilt angle.

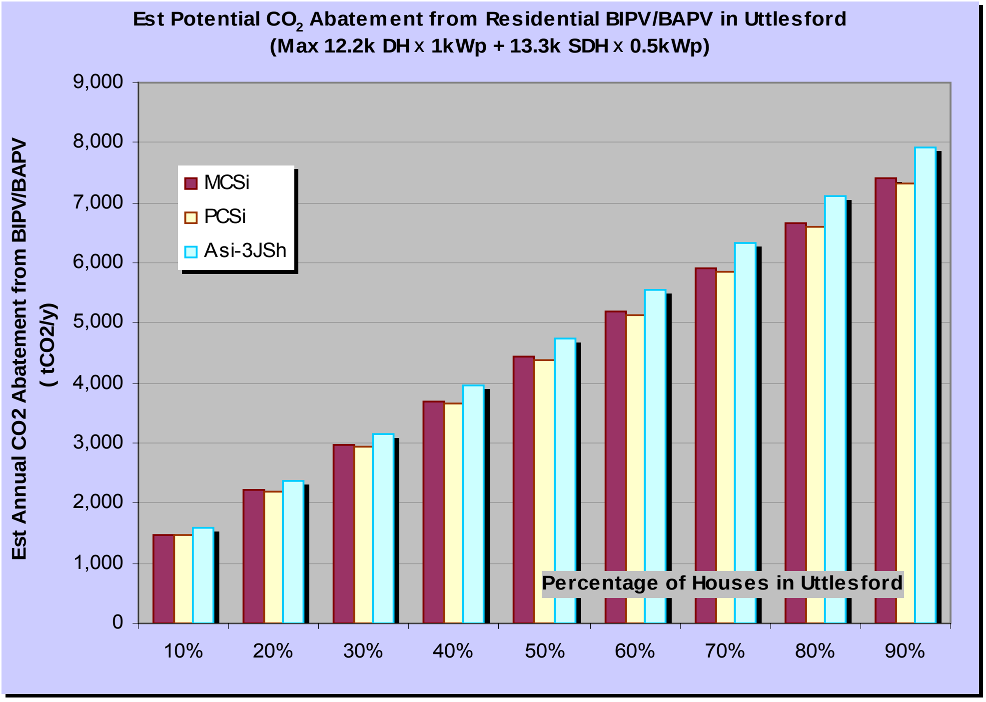

Figure 2-52: Ball-park estimates of potential CO_2 abatement from solar electricity generation from residential **BIPV/BAPV Option 1** for the DH and SDH households in Uttlesford (based on average orientation/tilt angle) assuming MCSi, PCSi and ASi-3J-Sh PV modules rated at 1 kWp for DH and 500Wp for SDH households.

From **Figure 2-52** the estimated CO_2 abatement from **10% of Uttlesford housing stock** using BIPV/BAPV systems would be between **730** (assuming all were **PCSi**) and **790 tonnes CO_2/year** (assuming all were **ASi-3J-Sh**) - though the area of the arrays of the ASi-3J-Sh systems would be around twice that of both the MCSi and PCSi-based systems.

Similarly if we assume that **50%** of the households can incorporate a BIPV/BAPV system the estimated **CO_2 abatement** would then be between **3,600** (assuming all were PCSi) and **3,950 tonnes CO_2/year** (assuming all were ASi-3J-Sh).

If we assume a comparable proportion - to Cambridge - of the housing stock would suitable for accepting PV arrays and assuming BIPV/BAPV systems on **60 % of the households in Uttlesford** the estimated CO_2 abatement would then be between **4,390** and **4,750 tonnes CO_2/year** and on **70%** of the households the estimates would be between **5,130 and 5,540 tonnes CO_2/y**ear.

CO_2 Abatement from Residential BIPV/BAPV Option 2 *(2kWp+1kWp Arrays)*

Figure 2-53 shows ball park estimates of the aggregated CO_2 abatement from the averaged outputs of the BIPV/BAPV arrays based on **MCSi**, **PCSi** and **ASi-3J-Sh** modules which assumes that the detached houses/bungalows will utilise 2 kWp arrays (15, 17.6 and 33 m^2 array areas) and semi-detached/terraced houses/bungalows will utilise 1 kWp arrays (7.5, 8.8 and 16.4 m^2 array areas) based on average outputs for orientation and tilt angle.

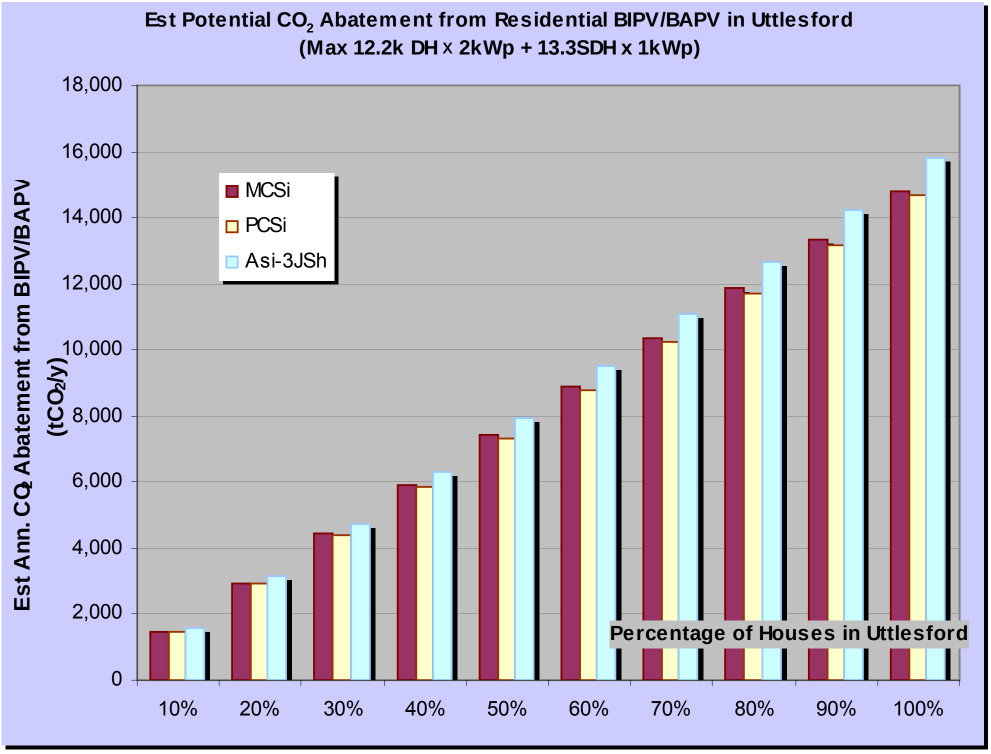

Figure 2-53: Ball-park estimates of potential CO_2 abatement from solar electricity generation from residential **BIPV/BAPV Option 2** for the DH and SDH households in Uttlesford (based on average orientation/tilt angle) assuming MCSi, PCSi and ASi-3J-Sh PV modules rated at 2 kWp for DH and 1 kWp for SDH households.

Assuming **10% of the housing stock in Uttlesford** employed BIPV/BAPV systems (2 kWp and 1 kWp) the estimated ball park annual CO_2 emissions abated from the solar energy contribution to domestic electricity needs would be between **1,450 tonnes/y** (assuming all were **PCSi**) and **1,570 tonnes/y** (assuming all were **ASi-3J-Sh**).

Similarly if we assume that **50% of the households** can incorporate these PV systems, the estimated ball park annual CO_2 abatement from the solar contribution to domestic electricity needs would be between **7,320** and **7,910 tonnes/y**.

Assuming BIPV/BAPV systems on **60% of the households in Uttlesford** the estimated ball park annual CO_2 abatement from the solar contribution to domestic electricity needs would be between **8,790** and **9,490 tonnes/y** and on **70%** of the households the estimates would be between **10,260** and **11,000 tonnes/y**.

CO_2 Abatement from Residential BIPV/BAPV Option 3 *(3kWp+2kWp Arrays)*

Figure 2-54 shows ball park estimates of the aggregated CO_2 abatement from the averaged outputs of the BIPV/BAPV arrays based on **MCSi**, **PCSi** and **ASi-3J-Sh** modules which assumes that the detached houses/bungalows will utilise 3 kWp arrays (23, 27 and 49 m^2 array areas) and semi-detached/terraced houses/bungalows will utilise 2 kWp arrays (15, 17.6 and 33 m^2 array areas) based on average outputs for orientation and tilt angle.

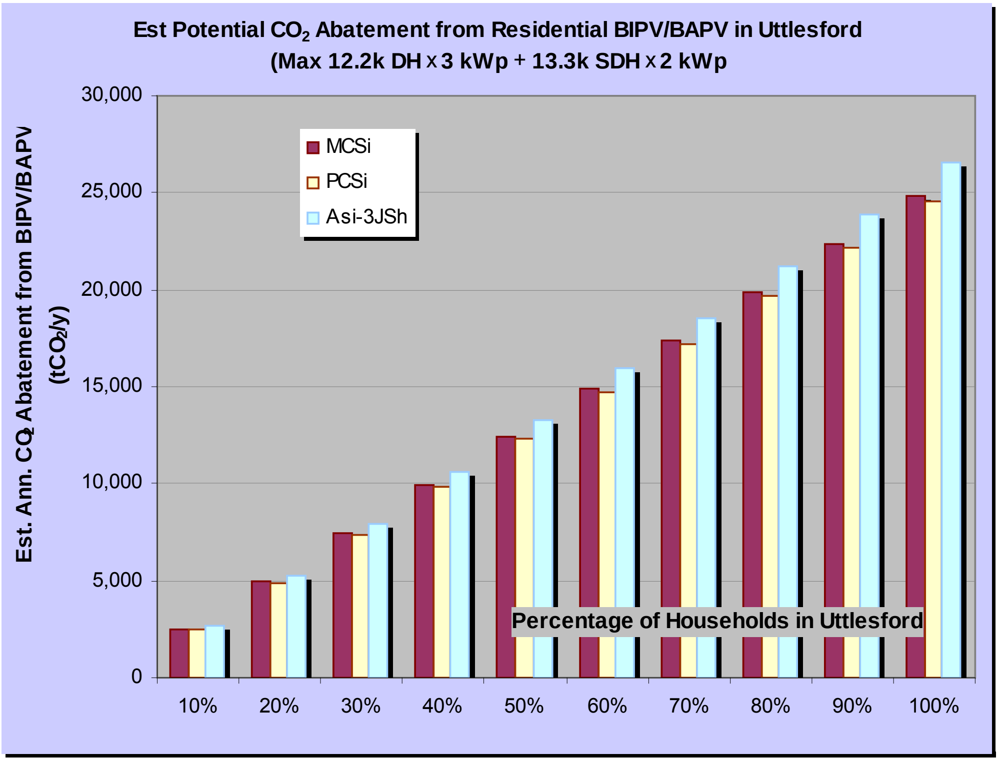

Figure 2-54: Ball-park estimates of potential CO_2 abatement from solar electricity generation from residential **BIPV/BAPV Option 3** for the DH and SDH households in Uttlesford (based on average orientation/tilt angle) assuming MCSi, PCSi and ASi-3J-Sh PV modules rated at 3 kWp for DH and 2 kWp for SDH households.

Assuming **10% of the housing stock in Uttlesford** employed BIPV/BAPV systems (3 kWp and 2 kWp) the estimated ballpark annual CO_2 emissions abated from the solar energy contribution to domestic electricity needs would be between **2,450 tonnes/y** (assuming all were **PCSi**) and **2,640 tonnes/y** (assuming all were **ASi-3J-Sh**).

Similarly if we assume that **50% of the households** can incorporate these PV systems, the estimated ballpark annual CO_2 abatement from the solar contribution to domestic electricity needs would be between **12,280** and **13,260 tonnes/y**.

Assuming BIPV/BAPV systems on **60% of the households in Uttlesford** the aggregated estimated ball park annual CO_2 abatement from the solar contribution to domestic electricity needs would be between **14,740** and **15,920 tonnes/y** and on **70%** of the households the estimates would be between **17,200** and **18,500 tonnes/y**.

CO_2 Abatement from Residential BIPV/BAPV Option 4 *(4kWp+3kWp Arrays)*

Figure 2-55 shows ball park estimates of the aggregated CO_2 abatement from the averaged outputs of the BIPV/BAPV arrays based on **MCSi**, **PCSi** and **ASi-3J-Sh** modules which assumes that the detached houses/bungalows will utilise 4 kWp arrays (30, 35 and 66 m^2 array areas) and semi-detached/terraced houses/bungalows will utilise 3 kWp arrays (23, 27 and 49 m^2 array areas) based on average outputs for orientation and tilt angle.

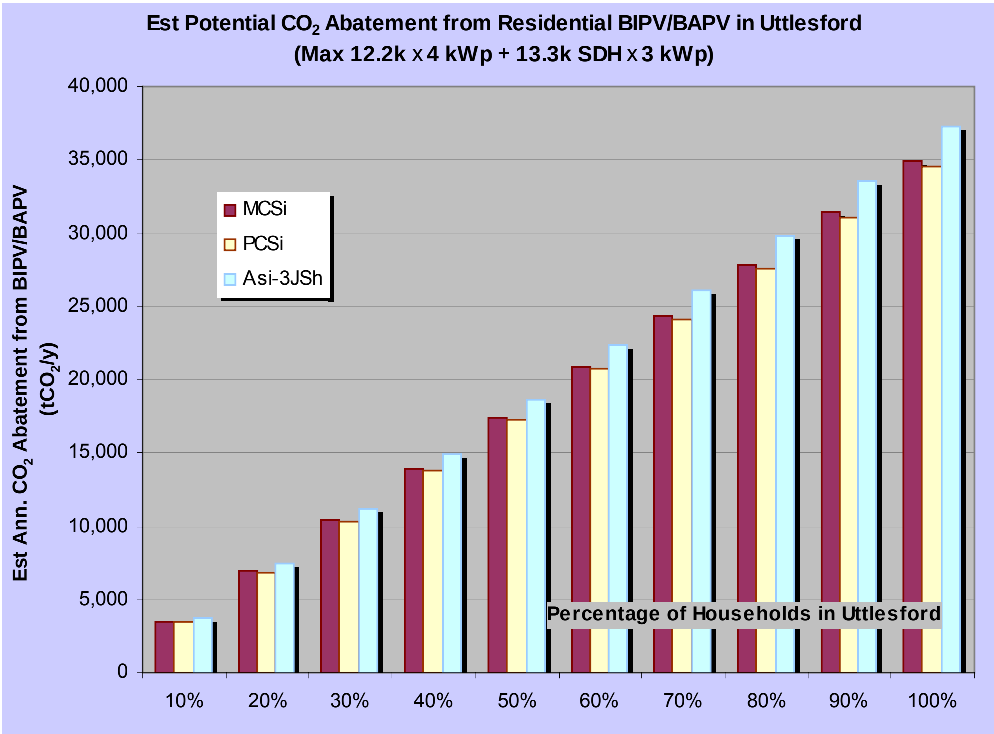

Figure 2-55: Ball-park estimates of potential CO_2 abatement from solar electricity generation from residential **BIPV/BAPV Option 4** for the DH and SDH households in Uttlesford (based on average orientation/tilt angle) assuming MCSi, PCSi and ASi-3J-Sh PV modules rated at 4 kWp for DH and 3 kWp for SDH households.

Assuming **10% of the housing stock in Uttlesford** employed BIPV/BAPV systems (4 kWp and 3 kWp) the estimated ballpark annual CO_2 emissions abated from the solar energy contribution to domestic electricity needs would be between **3,440 tonnes/y** (assuming all were **PCSi**) and **3,710 tonnes/y** (assuming all were **ASi-3J-Sh**).

Similarly if we assume that **50% of the households** can incorporate these PV systems, the estimated ballpark annual CO_2 abatement from the solar contribution to domestic electricity needs would be between **17,250** and **18,610 tonnes/y**.

Assuming BIPV/BAPV systems on **60% of the households in Uttlesford** the aggregated estimated ball park annual CO_2 abatement from the solar contribution to domestic electricity needs would be between **20,690** and **22,340 tonnes/y** and on **70%** of the households the estimates would be between **24,140** and **26,000 tonnes/y**.

CO_2 emissions from Residential BIPV/BAPV Options in Uttlesford

The previous sections on CO_2 emissions abatement for BIPV/BAPV Options 1 to 4 indicate that residential BIPV/BAPV systems could make a useful contribution to the household electricity needs - potentially up to 24,000 tonnes of CO_2 per year. Though it seems unlikely that they could abate more than 30 to 36% of household emissions due to household electricity demand in Uttlesford at the current rates of consumption.

Nonetheless it seems probable that residential BIPV/BAPV systems could make a useful contribution to reducing the CO_2 emissions arising in Uttlesford.

2.3.16.3 PV Carport Solar Electricity Generation from Car Parking Sites

In order to assess the potential for PV Carport Power Stations ball park assessments were made for the car parking areas at Stansted Airport and also some of the public car parks in the towns in Uttlesford. **Figure 2-56** shows some examples of potential PV Car port systems that could be considered.

Figure 2-56 Examples of PV Carport solar electricity generation stations
Sources: Kyocera & Powerlight

PV Carport Power Stations on Stansted Airport On-Airport Car Parks

Using the number of parking spaces[50] allocated to the on-airport passenger car parks (Short-stay, Mid-stay and Long Stay) at Stansted as a guide, the installed power rating was estimated (33.6 MWp total) assuming MCSi modules and shown in **Figure 2-57**.

[50] It has been assumed that all of the car parking spaces are surface parking. If there is a multi-storey parking proportions then these assumptions will overestimate the potential.

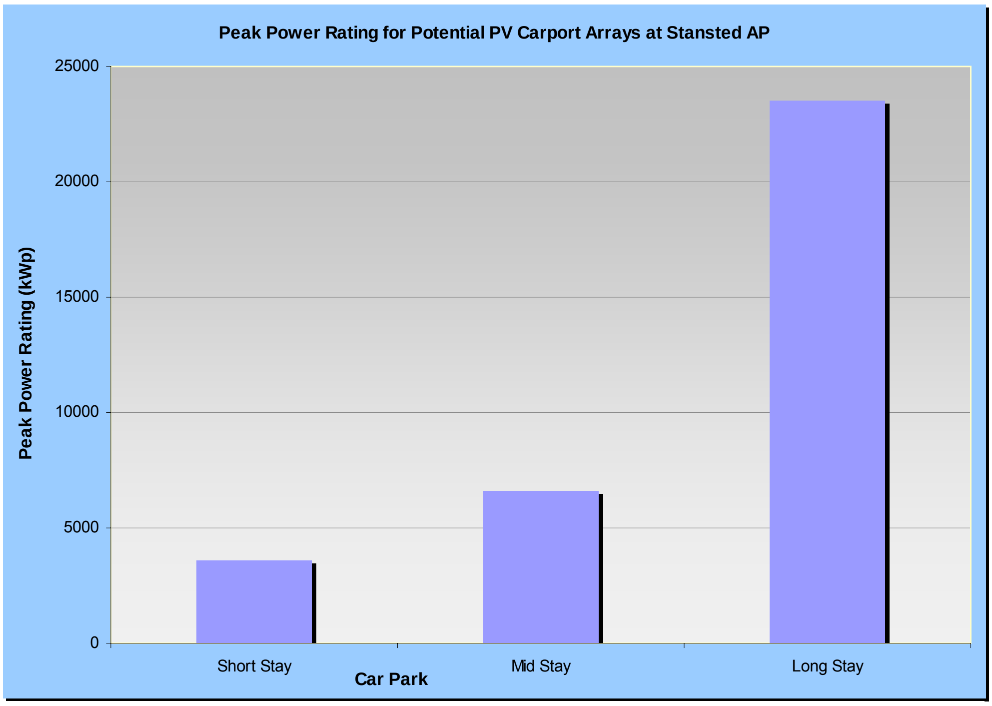

Figure 2-57: Peak Power Ratings assumed for PV Carport Solar Power Stations for Stansted Airport Car Parks

Using the yields derived from Cambridge solar radiation data, the ball park potential electrical outputs from the PV-Carport Power Station arrays was estimated for both horizontally aligned (0 degrees tilt angle) and optimum tilt (32 degrees) south facing arrays (S32 Deg). These estimates are shown in **Figure 2-58**.

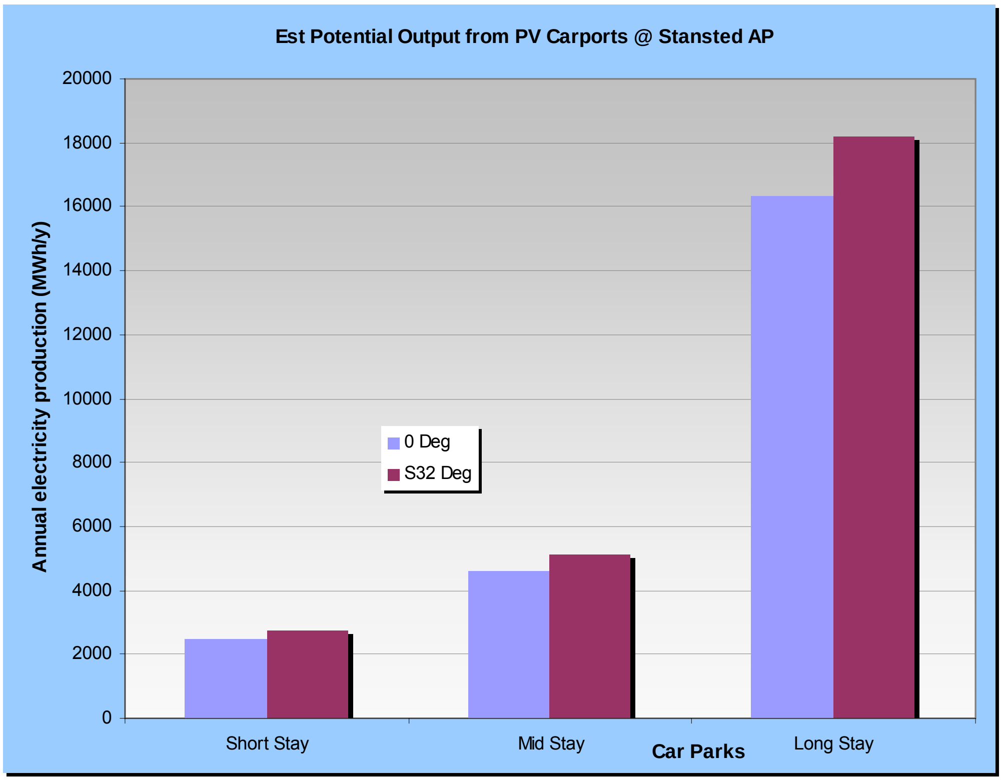

Figure 2-58: Ball-Park estimates of the potential electrical output for PV Carport Solar Power Stations for Stansted Airport Car Parks

From **Figure 2-58**, it can be seen that the ball park estimates indicate annnual electricity productions of **2,470 MWh/y** (short-stay), **4,600 MWh/y** (mid-stay) and **16,340 MWh/y** (long-stay) for the 0 degree tilt arrays and **2,700 MWh/y** (short-stay), **5,120 MWh/y** (mid-stay) and **18,160 MWh/y** (long-stay) for the south facing 32 degree optiumim tilt arrays. The total aggregated electrciicty productions are estimated as **23,430 MWh/y** (0 Deg) and **26,000 MWh/y** (S32 Deg). At the rate of 4.7MWh/y, this would provide electricity needs of **4,800** to **5,540 households** (or for **17 to 19%** of the household electricity needs of Uttlesford).

Using these estimates the abated CO_2 was calculated on the same basis as the BIPV/BAPV arrays and shown in **Figure 2-59**.

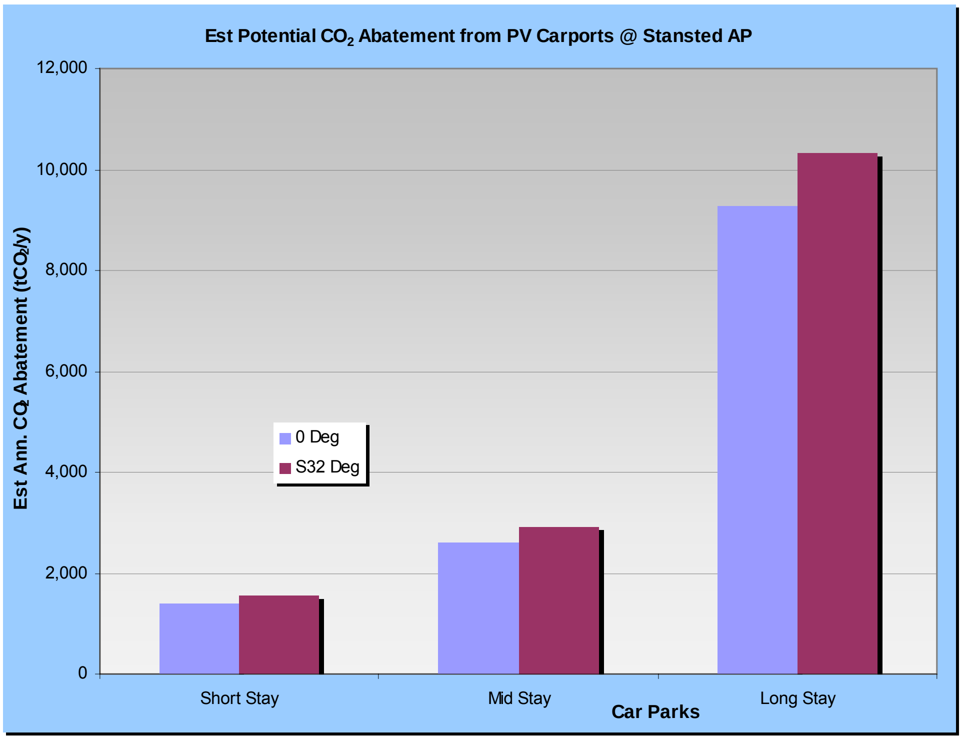

Figure 2-60: Ball-Park estimates of the potential CO_2 abatements from electrical output for PV Carport Solar Power Stations for Stansted Airport Car Parks

From **Figure 2-60**, it can be seen that the ball park estimates indicate annnual CO_2 abatements of **1,400 tonnes/y** (short-stay), **2,600 tonnes/y** (mid-stay) and **9,200 tonnes/y** (long-stay) for the 0 degree tilt arrays and **1,560 tonnes/y** (short-stay), **2,900 tonnes/y** (mid-stay) and **10,310 tonnes/y** (long-stay) for the south facing 32 degree optiumim tilt arrays. The total aggregated CO_2 emissions abated are estimated as **13,310 tonnes/y** (0 Deg) and **14,790 tonnes /y** (S32 Deg)[51].

These estimimates assume that the PV arrays located on the car parkng areas free from over-shadowing.

As well as generating CO_2-free electricity and abating CO_2 emmisions, PV Carports could also capture rainwater which would be used to reduce water consumption and also reduce surfacewater run off at Stansted Airport.

[51] If the CO_2 abatements were calculated on the same basis as CO_2 abatement from wind farms the aggregated emissions abated would then be around **20,150 tonnes/y** (0 Deg) and **22,390 tonnes/y** (S32 Deg). If the electricity outputs w ere used to charge electric vehicles, the abated CO_2 emissions would be higher still.

PV Carport Power Stations on Public Car Parks in Towns in Uttlesford

In order to assess the potential for PV Carport Power Stations ball park assessments were made for the car parking areas at some of the public car parks in the towns in Uttlesford. Using the number of parking spaces[52] allocated to the public car parks in Saffron Walden (4 car parks), Great Dunmow (3 car parks), Stansted Mountfitchet (2 car parks) and Thaxted (1 car park) as a guide, the installed power rating was estimated (1.64 MWp total) assuming MCSi modules.

Using the yields derived from Cambridge solar radiation data, the ball park potential electrical outputs from the PV-Carport Power Station arrays was estimated for both horizontally aligned (0 degrees tilt angle) and optimum tilt (32 degrees) south facing arrays (S32 Deg). These estimates are shown in **Figure 2-61**.

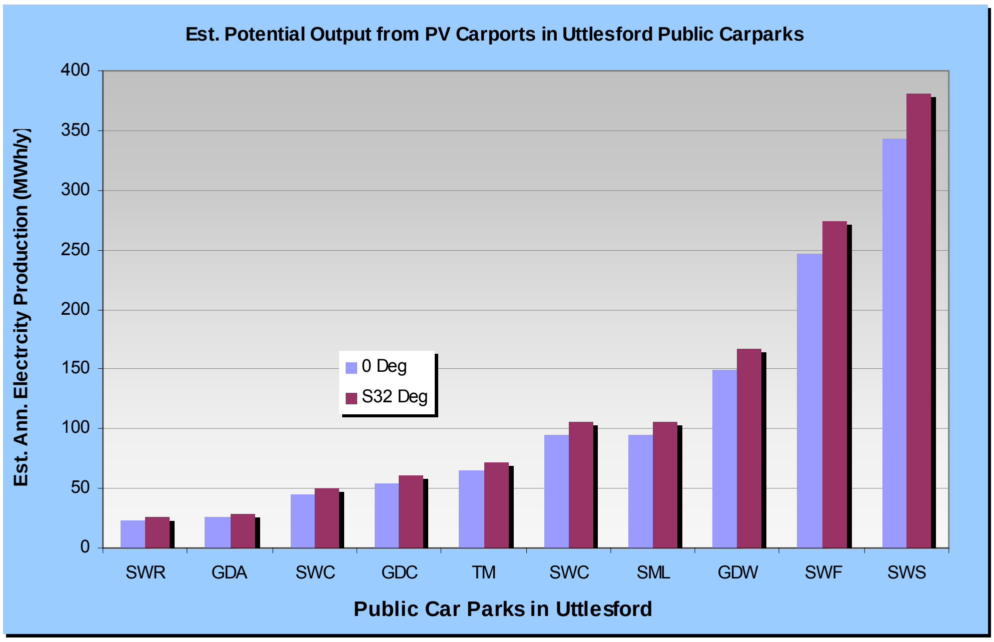

Figure 2-61: Ball-Park estimates of the potential electrical outputs for PV Carport Solar Power Stations for 10 public car parks in Uttlesford.

From **Figure 2-61**, it can be seen that the ball park estimates indicate annnual electricity productions range from **23 MWh/y** (Rose and Crown car park) to **343 MWh/y** (Swan Meadow car park) for the 0 degree tilt arrays and **26 MWh/y** (Rose and Crown car park) to **381 MWh/y** (Swan Meadow car park) for the south facing 32 degree optiumim tilt arrays. The total aggregated electricity productions from the PV Carport power stations at the ten car parks are estimated as **1,140 MWh/y** (0 Deg) and **1,260 MWh/y** (S32 Deg). At the rate of 4.7MWh/y, this would provide electricity needs of **240** to **270 households**.

Using these estimates the abated CO_2 was calculated on the same basis as the BIPV/BAPV arrays and shown in **Figure 2-62**.

[52] It has been assumed that all of the car parking spaces are surface parking. If there is a multi-storey parking proportions then these assumptions will overestimate the potential.

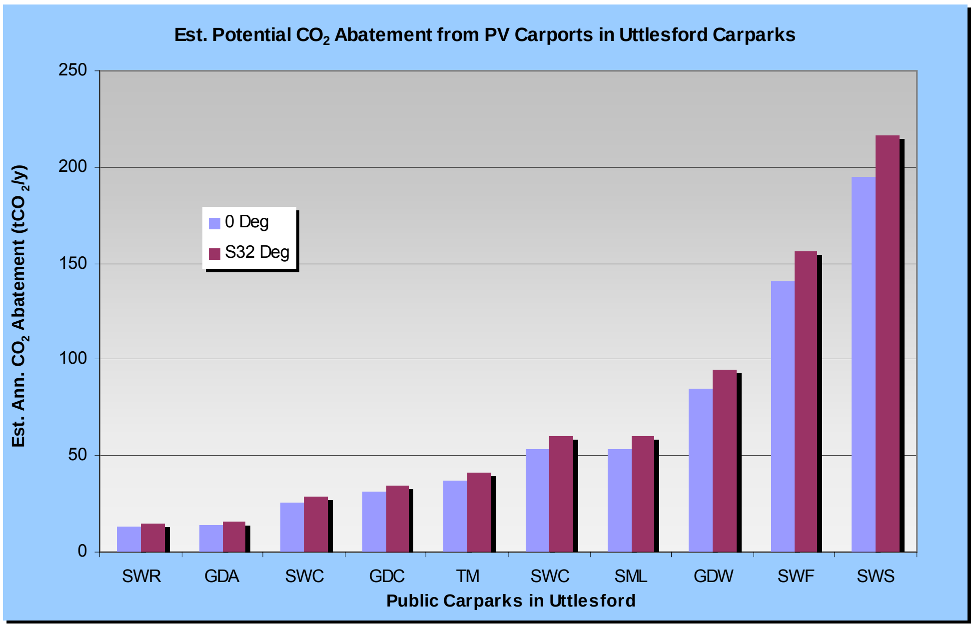

Figure 2-62: Ball-Park estimates of the potential CO_2 abatements from electrical output for PV Carport Solar Power Stations for 10 public car parks in Uttlesford

From **Figure 2-62**, it can be seen that the ball-park estimates indicate annnual CO_2 abatements ranging from **13 tonnes/y** (Rose and Crown car park) to **190 tonnes/y** (Swan Meadow car park) for the 0 degree tilt arrays and **15 tonnes/y** (Rose and Crown car park) to **216 tonnes/y** (Swan Meadow car park) for the south facing 32 degree optiumim tilt arrays. The total aggregated CO_2 emissions abated are estimated as **640 tonnes/y** (0 Deg) and **720 tonnes/y** (S32 Deg)[53].

These estimimates assume that the PV arrays located on the car parkng areas to be free from shading, so if they are likely to be affected by shading from trees or other objects then the estimates of electricity outputs and CO_2 abatemnents will need to be adjusted accordingly.

Rainwater could also be captured and used to reduce water consumption and also to reduce surfacewater run off from these car parks.

[53] If the CO_2 abatements were calculated on the same basis as CO_2 abatement from wind farms, the aggregated emissions abated would then be around **980 tonnes/y** (0 Deg) and **1,000 tonnes/y** (S32 Deg). If the electricity outputs w ere used to charge electric vehicles, the abated CO_2 emissions would be higher still.

2.3.16.4 PV Conclusions

On the assumption that the housing stock in Uttlesford has a distribution similar to Cambridge as to the suitability for utilising solar energy, ball park estimates of the annual electricity production from residential BIPV and/or BAPV arrays (depending on the size of arrays) could be up to around **35** to **49 GWh/y** (assuming 60 to 70% of Uttlesford households). This would be equivalent to the current average electricity needs of **26** to **30% of the households** in Uttlesford (assuming UK average of 4.7MWh/y per household). The estimates from these outputs would abate around **20,000** to **24,000 tonnes of CO_2/y**.

These estimates do not take account of any losses due to overshadowing however, so would need to be adjusted to take account of that if the risk of shadowing is high. That may be partially accounted for by assuming only 60 to 70% of the households in the estimates.

If annual average household electricity consumption was able to be reduced substantially (but also realistically) by more extensive usage of low energy lamps and appliances combined with reduced usage then the proportion of Uttlesford households that could be supplied with residential BIPV/BAPV would be increased proportionately.

It would be possible to increase the sizes of a proportion of the BIPV/BAPV arrays particularly on properties with large houses and gardens using ground-mounted/pergola-mounted/pole-mounted/carport-mounted arrays as well as building mounted systems.

If incorporated into the roofs of new buildings the extra cost of BIPV can be reduced considerably, particularly for housing associations or developers installing large numbers of array.

The current economics of PV systems can also be improved by the encouragement of Solar Clubs as mentioned in the section on solar water heating. Such clubs could act as a bulk-buying club[54], which are able to reduce the capital cost of the components. They may also be able to negotiate more appealing electricity tariffs by clubbing together. Solar Clubs can also provide independent advice together with practical guidance and training options.

Also mentioned in the solar water heating section is another potential approach which is the encouragement of *Solar Street Associations* which could combine the attributes of the Solar Clubs but have the additional benefits of common location, bulk purchasing, combined electricity tariffs, mutual support, awareness raising and - where appropriate - scope for larger scale systems or group systems and large scale grant funding. Such solar streets could also consider additional solar PV systems for the street such as solar powered car parking bays for EV/PHEVs, solar street lighting, way marking and solar power bus shelters and the like.

As well as BIPV/BAPV another potentially promising application is to use PV over open spaces used for other purposes such as car parks. To assess the potential for generating CO_2 free electricity from such situations, the potential output from PV-Carport solar power stations at the On-Airport car parking at Stansted Airport and on ten town centre car parks were estimated.

For the Stansted Airport systems, the estimated annual electricity production could be of the order of **23** to **26 GWh/y** - equivalent to **4,800** to **5,500 households** average electricity needs (or **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**. If these estimates of CO_2 abatements were calculated in the same way as for wind farms, the CO_2 abatement would then be between 20,150 and 22,300 tonnes/y and if the electricity was used to recharge electric vehicles or PHEVs the CO_2 abatement would greater still.

The PV Carports for the ten town centre car parks considered were estimated to be able to generate **1,100** to **1,200 MWh/y** and abate around **640 tonnes/y** to **720 tonnes/y** (or **980** to

[54] Energy Service Companies (ESCOs) could potentially also include PV systems or PV leasing arrangements as part of the measures offered.

1,000 tonnes of CO_2 per year if on the same basis as wind farms around) 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.

It is more cost effective to incorporate BIPV into the roofs of new houses so it is important to encourage new houses to include BIPV. If this is not possible for economic reasons at the time of construction, builders should be encouraged to build houses with appropriate orientation and roof pitch to facilitate a PV retrofit in the future.

There should be some caution when totalling Uttlesford solar contributions from solar water heating and domestic roof top PV as they may be competing for the same space[55]. This is more likely to be a problem with the roofs of existing houses, as the roofs on new houses could be designed to accommodate both solar water heating collectors and PV modules.

If developers can be persuaded of the benefits of BIPV and the growing market opportunities from selling houses with predicted low electricity bills, then there could be a much-increased proportion of new houses with this feature. It could be achieved with only a small increment on the purchase price of a house. There is at least one large UK house builder that has successfully built and promoting spec houses with built in PV roofs.

Likewise if housing associations can be persuaded of the lifecycle benefits of incorporating BIPV and providing houses with scope for reducing their electricity bills then there could be scope for many more PV houses. Several UK housing associations are involved in evaluating BIPV and at least one has worked out that it is economically feasible to incorporate BIPV into their new projects and in their programme of renovation work.

It is also worth remembering that whilst BIPV is a relatively expensive building component, it is the only building component that has the potential to generate an income or to virtually eliminate future electricity bills. Compared to investing in a car (which loses money over its lifetime and incurs regular financial outlay for petrol, repair and maintenance), investing in PV seems to be a good financial deal.

It should also be considered that, whilst the current price of electricity is relatively low, in the not too distant future the possibility is that the bulk price of electricity generated from fossil fuels or nuclear stations will be obliged to reflect the full cost (direct plus externalities[56]). The Climate Change Levy and the Emissions Trading Scheme could be seen as the first steps in this direction, and it seems reasonable to assume that the scale of their impact is likely to increase.

There are grants available toward the capital costs of BIPV for householders, local authorities, housing associations and builders for residential buildings. There are also a number of larger scale grants available for non-domestic buildings. The main grant available is from the *Low Carbon Buildings Programme* though they have been extremely popular and there is strong competition for available funds. There is uncertainty as to how long the grants will remain available, but if one assumes that government support for low/zero carbon technologies is to grow, then there is likely to be some support into the future.

This support could be sufficient, together with the relatively low cost of loans and the impact of the CCL to stimulate a much larger uptake of PV within Uttlesford.

[55] Altechnica (and others) are researching a bespoke solar electric+heat system that utilises the same collection area to generate electricity and useful heat that promises to avoid the conflict over available solar collection areas.
[56] The research programmes on energy externalities are suggesting that the indirect costs of fossil fuel and nuclear electricity are at least equal to the direct costs and are probably 2 to 3 times higher (Hill etal., 1992).

2.4 Solar Energy Recommendations

The solar energy resource in Uttlesford is large, but there are a number of barriers to exploiting this resource, not least the historically lower costs of conventional sources of energy. Also, because it is an energy resource directly linked to buildings, building owners and builders need to be persuaded of the importance of utilising the resource not just for themselves, but also as part of their own commitment to reducing CO_2 emissions.

Solar energy has not been very well promoted to date and there is significant ignorance about its most appropriate uses on the part of both the general public and practitioners such as architects, builders, plumbers and electricians. Addressing this will help to increase the uptake of solar energy technologies and enable them to make an important contribution to the supply and saving of energy plus reduce CO_2 emissions in Uttlesford.

A major part of the use of solar energy technology (both solar water heating and solar electricity) will be in the domestic sector so if it is to be utilised significantly, it will be necessary to promote the benefits.

In the case of PV, one of the largest impacts is likely to be for non-domestic buildings so developers, owners, managers and users of such buildings should be targeted and informed about the benefits of PV.

The potential for PV Parking bays/charging stations and the benefits of using EVs and PHEVs should be promoted.

The potential benefits of using solar energy from car parks or other appropriate open spaces by the use of PV-Carport style Solar Power Stations should be promoted as these could make a useful contribution to reducing the CO_2 emissions in Uttlesford and potentially also be used to charge EVs or PHEVs to reduce transport emission impacts. The potential for using such systems at Stansted Airport car parks should be promoted.

Solar energy also has a particular seasonal benefit for parts of the tourist/summer leisure industry where the biggest demand tends to be in the summer months when the most solar energy is also available. This sector should therefore be targeted to incorporate solar energy measures.

Developers involved in major developments in Uttlesford should be encouraged to include a range of solar measures such as effective passive solar, active solar, natural daylighting and photovoltaics. The benefits of Super Passive Solar and Earth Sheltered Passive Solar buildings should also be promoted to developers.

Strong consideration should be given to requiring new buildings to exploit solar energy in order to offset the extra energy provision that will have to be provided for them.

Uttlesford could offer discounts on the community charge as a means of stimulating wider uptake of solar energy technologies and features (plus super insulation measures and energy efficient appliances) on buildings. Perhaps a levy could be raised on those new buildings which do not have these features or measures.

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