Winbush Properties Ltd

163 Iverson Road

West Hampstead

Energy Statement

Submission

Author: Donald Sinclair

Date: 9th December 2011

Evans House, 107 Marsh Road,
Pinner, Middlesex, HA 5 5PA
Tel: 020 8429 6760
email: info@hodkinsonconsultancy.com
hodkinsonconsultancy.com

Energy Statement

Energy Statement in support of the Planning Application for the Residential Development at 163 Iverson Road, West Hampstead, by Winbush Properties Ltd.

This report has been undertaken by Donald Sinclair of Richard Hodkinson Consultancy.

Schedule of Issue

Version	Date	Reason for Issue	Issued By	Approved By
v.1	08.12.2011	Draft	Donald Sinclair	
v.2	09.12.2011	Submission	Donald Sinclair	Stephen McGregor

Table of Contents

1. Introduction

1.1. This Energy Statement has been prepared by Richard Hodkinson Consultancy (RHC), a specialist innovation, sustainability and energy consultancy, in support of the planning application for the proposed development on 163 Iverson Road, West Hampstead.

1.2. The formulation of the energy strategy for the proposed development takes into account several important concerns and priorities. These include:

a) To achieve the maximum viable reduction in total CO_2 emissions through the application of the London Plan and Camden Energy Hierarchies with an affordable and deliverable strategy.
b) To minimise the negative impact of the proposed development on both the local and wider climate.
c) To achieve the highest viable levels of the Code for Sustainable Homes (Level 4).
d) To minimise to the lowest possible extent emissions of pollutants such as nitrogen oxides and particulate matter, thereby minimising the effects on local air quality. This is of particular concern in the Borough of Camden which has been declared an Air Quality Management Area.

1.3. This statement first establishes a baseline assessment of the energy demands and associated CO_2 emissions for the development based on current Building Regulations (2010). The report will then follow The London Plan Energy Hierarchy approach of ***Be Lean***, ***Be Clean*** and ***Be Green*** to enable the maximum viable reductions in regulated and total CO_2 emissions over the baseline.

2. Development Overview

2.1. The proposed development will provide 36 dwellings of mixed tenure in a building. There will be a mix of Studio, 1, 2 and bed flats and also 2 bed houses.

2.2. Whilst the site is not within the West Hampstead Growth Area, residential development is encouraged.

2.3. The site is currently occupied by a warehouse. Pre-Application advice from Camden states that there is no objection to the demolition of the warehouse in conservation terms.

2.4. The proposed development is bounded by Iverson Road to the south and a railway line to the north.

2.5. Further details of the development and an assessment of the wider sustainability issues are contained within the Sustainability Statement.

3. Planning Policies and Project Requirements

3.1. National planning policy requirements relevant to this energy statement are given in the Government's Planning Policy Statement 22; Renewable Energy:

> *"Local planning authorities and developers should consider the opportunity for incorporating renewable energy projects in all new developments."*

3.2. The Draft National Planning Policy Framework states:

> *"The Government's objective is that planning should fully support the transition to a low carbon economy in a changing climate...To achieve this objective, the planning system should aim to:*
>
> - *Secure, consistent with the Government's published objectives, radical reductions in greenhouse gas emissions, through appropriate location and layout of new development...and the delivery of renewable and low-carbon infrastructure."*

3.3. Furthermore it states that:

> *"When determining planning applications, local planning authorities should apply the presumption in favour of sustainable development."*

3.4. The London Plan (2011) provides regional guidance. Policy 5.2 requires that:

> *"Development proposals should make the fullest contribution to minimising carbon dioxide emissions in accordance with the following energy hierarchy:*
>
> 1. *Be lean: use less energy*
> 2. *Be clean: supply energy efficiently*
> 3. *Be green: use renewable energy*

3.5. The London Plan (Policy 5.2) requires that major developments achieve a 25% improvement over the Building Regulations (2010) Target Emission Rate (TER). This target refers only to the regulated emissions associated with space heating, hot water and fixed electrical equipment.

3.6. Policy 5.6: Decentralised Energy, in Development Proposals states:

> *"Development proposals should evaluate the feasibility of Combined Heat and Power (CHP) systems, and where a new CHP system is appropriate also examine opportunities to extend the system beyond the site boundary to adjacent sites."*

3.7. Policy 5.7: Renewable Energy, states that:

> *"Within the framework of the energy hierarchy, major development proposals should provide a reduction in expected carbon dioxide emissions through the use of on-site renewable energy generation, where feasible."*

3.8. An informative to Policy 5.7 seeks for a 20% reduction in total CO_2 emissions to be achieved through renewable energy technologies, unless such provision is not feasible.

3.9. Policy 5.9: Overheating and Cooling, states

> *"Major development proposals should reduce potential overheating and reliance on air conditioning systems and demonstrate this in accordance with the following cooling hierarchy:*
>
> 1. *minimise internal heat generation through energy efficient design*
> 2. *reduce the amount of heat entering a building in summer through orientation, shading, albedo, fenestration, insulation and green roofs and walls*
> 3. *manage heat within the building though exposed internal thermal mass and high ceilings*
> 4. *passive ventilation*
> 5. *mechanical ventilation*
> 6. *active cooling systems"*

3.10. Local guidance is provided by the Camden Development Policies. Policy DP22: Promoting Sustainable Design and Construction states:

> *"The Council will promote and measure sustainable design and construction by:*

> *c) expecting new build housing to meet Code for Sustainable Homes Level 3 by 2010 and Code Level 4 by 2013 and encouraging Code Level 6 (zero carbon) by 2016.*
>
> *The Council will require development to be resilient to climate change by ensuring schemes include appropriate climate change adaptation measures such as:*
>
> *e) Summer shading and planting*
>
> *i) reducing air pollution"*

3.11. Pre-Application advice from Camden states that the development should demonstrate that Code Level 4 is to be achieved.

3.12. Furthermore Policy CS13: Tackling Climate Change through promoting higher environmental standards states:

> *"**Reducing the effects of and adapting to climate change**: The Council will require all developments to take measures to minimise the effects of, and adapt to, climate change and encourage all development to meet the highest feasible environmental standards that are financially viable during construction and occupation by:*
>
> *c) minimising carbon emission from the redevelopment, construction and occupation of buildings by implementing, in order, all elements of the following energy hierarchy:*
>
> *1. ensuring developments use less energy*
>
> *2. making use of energy from efficient sources, such as King's Cross, Gower Street, Bloomsbury and proposed Euston Road decentralised energy networks*
>
> *3. generating renewable energy on-site*
>
> *d) ensuring buildings and spaces are designed to cope with, and minimise the effects of, climate change*
>
> *The Council will have regard to the cost of installing measures to tackle climate change as well as the cumulative future costs of delaying reductions in carbon dioxide emissions.*
>
> *Local Energy generation: The Council will promote local energy generation and networks by:*

f) Working with our partners and developers to implement local energy netwrosk in the parts of Camden most likely to support them, i.e. in the vicinity of:

- *Housing estates with community heating or the potential for community heating and other uses with large heating loads*
- *The growth areas of King's Cross; Euston; Tottenham Court Road; West Hampstead Interchange"*

4. Building Regulations (2010) Baseline

4.1. This statement first establishes a baseline assessment of the energy demands and associated CO_2 emissions for the Development based on current Building Regulations (2010). The report will then follow The London Plan Energy Hierarchy approach of ***Be Lean***, ***Be Clean*** and ***Be Green*** to enable the maximum viable reductions in regulated and total CO_2 emissions over the baseline.

4.2. The estimated annual energy demand for the proposed Development has been calculated using Standard Assessment Procedure (SAP 2009) methodology. SAP calculates the regulated energy demands associated with hot water, space heating and fixed electrical items. The unregulated energy demands for appliances and cooking are taken from RHC practice benchmarks, which are drawn from analysis of NHER total energy demand calculations.

4.3. Calculations have been performed on representative dwelling types.

Building Regulations (2010) Baseline

4.4. The Building Regulations compliant baseline case provides that the building just meets the Target Emissions Rate (TER). Table 1 shows the Building Regulations (2010) compliant regulated and total CO_2 emissions for the development. These are shown in greater detail in Appendix B which summarises the SAP calculations.

Table 1: Building Regulations (2010) Baseline

	Regulated CO_2 (kg/yr)	Total CO_2 (kg/yr)
2010 Baseline	40,820	63,090

5. *Be Lean*: Energy Efficiency Measures

5.1. The following energy efficiency measures illustrate a possible route to ensuring that the proposed development meets Building Regulations (2010) with energy efficiency measures alone.

Insulation Standards

5.2. The buildings will incorporate enhanced insulation in the building envelope (walls, roofs, floors and glazing) to achieve average U-values better than those required by Part L (2010) Building Regulations. These are likely to include:

- Low E glazing with a U-Value of 1.3.
- External Wall U-Values will be improved to 0.2 (likely to require 350mm wall).
- Party walls to be fully insulated and effectively sealed to achieve an effective U-Value of zero.
- Ground Floor U-Values will be improved to 0.15.
- Roof U-Values will be improved to 0.15

Space Heating and Hot Water

5.3. The space heating requirement of the development will be reduced by the fabric measures detailed above.

5.4. It is intended to take advantage of solar gain where practicable, to reduce the space heating demands of the dwellings. This has to be balanced with the need to minimise the risk of summer overheating. As discussed below, the acoustic consultant has advised that windows on elevations facing the railway should be closed. As this restricts the benefits of cooling through natural ventilation, other measures (solar control glazing) are required, thereby limiting the benefits that can be achieved in reducing space heating demand through winter solar gains.

5.5. Orientation will be taken into account in the layout of the development, with dwellings designed to take advantage of solar gains where possible. Where practicable, the internal layout of the dwellings will be such that the living areas will be designed to face south and therefore benefit from a greater amount of solar gain than the bedrooms which do not have the same heating requirement and can be located where there is less solar gain.

5.6. High efficiency (SEDBUK 'A' rated) condensing boilers will be installed. Appropriate controls, including time and temperature zone control in all dwellings will maximise energy efficiency in operation. Where hot water cylinders are installed these will be low heat loss.

Limiting the Risk of Summer Overheating

5.7. It is not proposed to provide any mechanical cooling to the dwellings on the proposed development. It is proposed to reduce the need for active cooling as far as possible through the application of the London Plan cooling hierarchy (Policy 5.9). This will be achieved through the specification of non-mechanical measures such as good thermal insulation and air tightness and, where appropriate, solar control glazing will be installed to reduce solar gains.

5.8. The site is bounded to the north by a railway line. The acoustic consultant (Aulos Acoustics[1]) has advised that the general result of their survey indicates that the envelope will need to be sealed day and night (i.e. windows closed) on elevations with a full or partial view of the railway. Aulos have also advised that the elevation overlooking Iverson Road should be satisfactory during the day with openable windows, with the bedrooms potentially requiring windows to be closed at night.

5.9. The above mentioned acoustic conditions and requirements place restrictions on the strategies available to minimise the risk of summer overheating. A conventional strategy to minimise overheating would involve the use of openable windows throughout to enable cross-ventilation and convective-ventilation as well as might purging. As this is not possible on all elevations, alternative measures are required.

5.10. The design takes account of the need to minimise the risk of overheating through the presence of inset windows on the balconies, which serve to reduce internal heat gains by providing summer shading. When the sun is lower in the sky in the winter, heat gains will reduce the space heating demand.

5.11. It is therefore intended to specify solar control glazing to limit the heat gain through the windows and to provide enhanced mechanical ventilation to the affected dwellings. An initial overheating assessment has determined that the following measures are likely to be required: -

- Glazing with a g-value less than 0.45

[1] See Acoustic Report, submitted with this Application, for full details.

- Ventilation able to provide up to 2 air changes per hour. This can be either with Centralised extract systems or Mechanical Ventilation and Heat Recovery (MVHR)

5.12. Additionally green walls will be included. These measures facilitate localised cooling through evapotranspiration – energy which would otherwise heat the local atmosphere is instead used evaporating water, thus helping to reduce the urban heat island effect.

5.13. Open-able windows will be installed in all dwellings to give residents the choice to open the windows, or not. However, these will not be required to reach an acceptable risk of summer overheating.

Ventilation and Air Tightness

5.14. The dwellings will be naturally ventilated, with low specific fan power centralised extract systems installed.

5.15. Air tightness standards will conform to Approved Document Part L accredited details. These details incorporate an improvement over Building Regulation (2010) requirements by reducing air leakage loss and convective bypass of insulation. An improvement of design air permeability rate from $10m^3/hm^2$ to less than $6m^3/hm^2$ will further reduce space heating requirements.

Thermal Bridging

5.16. In well insulated buildings, as much as 30% of heat loss can occur through thermal bridges, which occur when highly conductive elements (e.g. metals) in the wall construction enable a low resistance escape route for heat. It is proposed that the development will meet Accredited Construction Details for thermal bridges[2].

Lighting and Appliances

5.17. 100% of internal light fittings will be dedicated for the installation of energy efficient lighting. External lighting will also be low energy lighting and controlled through PIR sensors, or daylight cut-off devices. Kitchen and other pre-installed appliances will be A or A+ rated for energy efficiency.

[2] http://www.planningportal.gov.uk/uploads/br/accredconbk.pdf

5.18. It is difficult to design and construct dwellings to reduce the unregulated electricity demands, because this is almost entirely dependent on the occupant of a dwelling and can vary substantially. However, the Applicant is committed to ensuring that all efforts are made to enable the residents to minimise their unregulated electricity consumption. Advice will be provided to all occupants in the form of a Home User Guide on how to minimise electricity consumption. This includes advice on purchasing low-energy devices as well as ensuring that they are used efficiently.

CO_2 Emissions Following *Be Lean* Measures

5.19. The impact of the above measures on the proposed development is shown in Table 2, below, which details the regulated and total CO_2 emissions of the development. It can be seen that the energy efficiency measures detailed above enable Building Regulations (2010) to be met through energy efficiency measures alone. The 20% target reduction in total CO_2 emissions for the London Plan is also shown.

Table 2: *Be Lean* Energy Efficiency Measures

	Regulated CO_2 (kg/yr)	Total CO_2 (kg/yr)
Space Heating	12,230	12,230
Hot Water	17,460	17,460
Fixed Electrical	11,110	11,110
Appliances and Cooking	-	22,270
Total	**40,800**	**63,070**
Reduction Achieved	**0.0%**	**0.0%**
London Plan 25% Reduction Required	**10,190**	-
London Plan 20% Target	**-**	12,610

5. *Be Clean*: Combined Heat and Power

5.1. In line with Policy 5.6 of the London Plan, the feasibility of decentralised heating networks as a ***Be Clean*** measure has been evaluated.

5.2. The inclusion of decentralised heating has been investigated in terms of appropriateness to the proposed development, and, to be in line with our priorities for this energy strategy, whether decentralised heating is the best technology to provide the greatest reductions in CO_2 emissions and minimisation of pollutants with an affordable and deliverable strategy.

5.3. Whilst CHP would enable reductions in CO_2 emissions, there are a number of reasons why it is not considered appropriate for this development.

5.4. Firstly, CHP is most suited to developments where there is a diversity of energy uses which produce a continuous heat demand, thus allowing electricity to be generated for extended periods. This is not the case for this solely residential scheme, where the space heating demands have been significantly reduced with high levels of energy efficiency. The result is that as the engine would not be required for extended periods it would not be producing the expected levels of electricity.

5.5. The provision of a CHP engine, plant room and heat distribution network is a highly capital intensive strategy, particularly for a small development. Furthermore, CHP has considerable long-term running costs and would increase the energy bills of the occupants over what they would pay with energy from the grid. Furthermore, there are no external providers of district heating within a reasonable distance of the development that would enable a cost-effective communal heating system to be developed.

5.6. Thirdly, CHP engines have high emissions of oxides of nitrogen (NO_x). These are around 1,000mg/kWh, even with a catalyst to reduce emissions. NO_x is associated with damage to lung function and acidification/eutrophication of habitats. As such, CHP has a harmful effect on the local environment and air quality and should therefore be avoided.

5.7. It has therefore been concluded that a CHP engine is not a viable strategy for this development and will therefore not be specified.

6. *Be Green*: Renewable Energy Technologies

6.1. The final part of the London Plan Energy Hierarchy is ***Be Green***. In line with London Plan Policy 5.2, the specification of energy efficiency and renewable energy measures should achieve a reduction in regulated CO_2 emission of 25% over Building Regulations (2010) unless such provision is not feasible. This is also required to achieve the mandatory energy requirements of Code Level 4. Table 2, above, shows the CO_2 reduction still required after energy efficiency to be 10,190 kg/yr.

6.2. Further details on the renewable energy technologies discussed in this section can be found in Appendix A. Appendix C provides a feasibility study table of the available technologies.

Biomass Boiler

6.3. Biomass boilers generate heat on a renewable basis as they are run on biomass fuel which is carbon neutral. A biomass boiler would require a central Energy Centre and heat distribution network and would therefore be liable to the same high capital and running costs noted for CHP.

6.4. Whilst technically feasible, a biomass boiler is not appropriate for this development for the same reasons as a CHP engine is not.

Solar Thermal Panels

6.5. Solar Thermal Heating Systems contribute to the hot water demand of a dwelling or building. Due to the seasonal availability of heat, solar thermal panels should be scaled to provide no more than 1/2 of the hot water load.

6.6. Solar thermal panels are a technically viable strategy, although it is unlikely that they would enable sufficient CO_2 reductions for policy compliance without additional technologies also being specified. Furthermore, pipe-runs from the roof top panels to the lower storey dwellings would be troublesome.

6.7. It has therefore been concluded that PV panels represent a more appropriate technology for this development.

Ground and Air Source Heat Pumps (ASHPs and GSHPs)

6.8. Heat Pumps upgrade energy from the ground or air and utilise it for space heating and hot water.

6.9. Heat Pumps are able to provide substantial reductions in energy. However, GSHPs require costly ground excavation works to bury the coils – boreholes would be required for the proposed development due to the high space requirements of ground coils. Air Source Heat Pumps are a more economic alternative to GSHPs as they do not require ground works. However, the performance of ASHPs is substantially lower than for GSHPs are therefore the reductions in CO_2 are correspondingly low. Whilst reducing energy significantly, heat pumps replace gas as the heating fuel with electricity, which is more carbon intensive. The result of this is that heat pumps do not enable sufficient reductions of CO_2 emissions for London Plan compliance. Electricity is also substantially more expensive than gas, so fuel bills are not reduced by GSHPs as much as by other technologies. Whilst

ASHPs are cheaper to install they have a lower performance and provide only limited reductions in total CO_2 emissions. As such, heat pumps would not enable Planning Policy compliance.

6.10. It has therefore been concluded that heat pumps are not a viable technology for the proposed development.

Wind Turbines

6.11. Small scale roof-top wind turbines are unlikely to be a viable technology for this development due to its urban location where wind speeds are low and conditions are turbulent. These conditions reduce the generating potential of wind turbines to levels which are not viable. Detailed assessment of wind conditions at the development site over the course of a year would be required to determine the technical viability of wind turbines.

6.12. It has therefore been concluded that PV panels represent a more appropriate technology for the proposed development.

Proposed Technology: Photovoltaic (PV) Panels

6.13. Unlike solar thermal panels, PV panels are not constrained by the hot water demand of the dwellings. PV panels are good at enabling substantial reductions in CO_2 emissions as a result.

6.14. It has been concluded that PV panels represent the most viable renewable energy technology for the proposed development. They are technically and economically viable for the development and enable the most substantial reductions in CO_2 emissions.

6.15. PV panels would be installed on the roofs of the flats and houses and oriented to face as close to south as possible at ~30^o from the horizontal to maximise efficiency.

6.16. It has been calculated that 22.4kWp of PV panels are required to meet the 25% reduction in regulated CO_2 emissions over Building Regulations (2010). Depending on the efficiency of the panels selected, this equates to $170m^2$ of panels. To allow spacing between rows of panels to prevent overshadowing and to enable access, $170m^2$ of panels requires ~$340m^2$ of roofspace. Each house will require 1.1kWp of PV panels each, with the rest installed as a communal system for the flats. It is not economically viable to provide additional PV panels.

6.17. The submitted architectural drawings provide an illustrative roof PV layout.

6.18. Full SAP calculations for each dwelling will be undertaken at the detailed design stage and will refine the PV requirement to ensure that all dwellings meet the mandatory energy requirements of Code Level 4 (25% reduction in regulated CO_2 emissions over 2010 Regulations).

6.19. To ensure that the PV panels are eligible for Feed-in-Tariffs, the selected product and installer will be Microgeneration Certification Scheme (MCS) certified.

6.20. The PV calculation is attached as Appendix D.

Renewable Energy Generation

6.21. Table 3, below, shows that the proposed PV panels will reduce the regulated and total CO_2 emissions of the development by 25% and 16% respectively. This meets the requirements of London Plan Policy 5.2 and the mandatory energy requirements of Code Level 4.

Table 3: *Be Green* Renewable Energy Generation

	Regulated CO_2 (kg/yr)	Total CO_2 (kg/yr)
Be Lean	40,800	63,070
Emission Reduction: PV Panels	10,190	10,190
Reduction Achieved	**25%**	**16%**

6. Summary

6.1. The Energy Strategy for the development has been formulated using the London Plan and Camden Energy Hierarchies.

6.2. The proposed ***Be Lean*** energy efficiency measures will enable the development to meet the Building Regulations (2010) baseline through energy efficiency measures alone. This represents a very high level of sustainable design and construction.

6.3. An initial assessment of the summer overheating risk has been undertaken. Due to the acoustic conditions present on the site, the windows on some elevations have been considered to be closed for this risk assessment. Solar control glazing and enhanced ventilation are required to minimise the overheating risk.

6.4. The feasibility of Combined Heat and Power (CHP) engine as a ***Be Clean*** measure has been studied. It has been concluded that CHP is not technically and economically suitable for a development of this scale.

6.5. It is proposed to install 22.4kWp of PV panels across the development, with a proportion on the houses and flats.

6.6. The combination of energy efficiency measures and solar PV panels enables the regulated CO_2 emissions of the development to be reduced by 25% over Building Regulations (2010). This meets the requirements of London Plan Policy 5.2 and the mandatory energy requirements of Code Level 4.

6.7. The summary table, below, shows that the regulated and total CO_2 emissions of the development have been reduced by 25% and 16% respectively over a Building Regulations (2010) baseline.

Summary Table				
	Regulated CO_2 (kg/yr)		**Total CO_2 (kg/yr)**	
	Gas	**Electricity**	**Gas**	**Electricity**
Building Regulations (2010) Baseline	40,820		63,090	
Be Lean	29,690	11,110	29,690	33,380
Be Green	29,690	920	29,690	23,190
Reduction Achieved	**25%**		**16%**	

Appendices

A) Low Carbon and Renewable Energy Technologies

B) Summary of Energy Calculations

C) Feasibility of Low Carbon and Renewable Energy Technologies

D) PV Calculation

Appendix A:

Low Carbon and Renewable Energy Technologies

Introduction

- This Appendix is intended to provide the background information for the low carbon and renewable energy technologies that have been considered in the formulation of this Energy Statement.

- The information provided here forms the basis for the project specific technical selection of low carbon/renewable energy technologies contained in the main section of this Energy Statement.

Combined Heat and Power (CHP)

- CHP is a form of decentralised energy generation that generally uses gas to generate electricity for local consumption, reducing the need for grid electricity and its associated high CO_2 emissions. As the CHP system is close to the point of energy demand, it is possible to use the heat that is generated during the electricity generation process. As both the electricity and heat from the generator is used, the efficiency of the system is increased above that of a conventional power plant where the heat is not utilised. However, the overall efficiency of ~80% is still lower than the ~90% efficiency of a heat only gas boiler.
- Where there are high thermal loads, CHP can be used within district heating networks to supply the required heat.
- **Performance and Calculation Methodology: -** Most commonly sized on the heat load of a development, not the electrical load. This prevents an over-generation of heat.
  - Require a high and relatively constant heat demand to be viable.
  - CHP engines are best suited to providing the base heating load of a development (~year round hot water demand) with conventional gas boilers responding to the peak heating demand (~winter space heating). CHP engines are not able to effectively respond to peaks in demand.
  - In general, CHP engines have an electrical efficiency of ~30% and a thermal efficiency of ~45%.
  - Electricity produced by the CHP engine displaces grid electricity which is given a carbon intensity of 0.529 kg per kWh.
- **Capital Cost: -** High in comparison to biomass boilers.
  - Relative cost reduces as the size of engine increases.
- **Running Costs/Savings: -** CHP engines often struggle to provide cost-effective energy to dwellings on residential schemes.
  - Running costs and maintenance are higher than for domestic gas boilers.
  - Needs Private Wire supply for economic case to be positive.
- **Land Use Issues and Space Required: -** CHP engines require a plant room, and possibly an energy centre for large residential developments.
  - CHP engines require a flue to effectively disperse pollutants. The height of the chimney required is dependent on the size of the engine installed.
  - Heat network issues.

- **Operational Impacts/Issues: -** Required to be run by Energy Services Company (ESCo) who are unenthusiastic about getting involved in small – medium scale schemes.
  - Issues with rights to dig up roads for district heating networks.
  - Emissions of nitrous oxides – ~1000mg/kWh – 20 times higher than for a gas boiler.
- **Embodied Energy: -** Comparable to that of a conventional gas boiler.
- **Funding Opportunities: -** Tax relief for businesses under the Enhanced Capital Allowances scheme.
- **Reductions in Energy Achievable: -** Can provide some reductions in effective primary energy, but when distribution losses and other local losses are included more fuel is required.
- **Reductions in CO_2 Achievable: -** Can provide greater reductions in CO_2 than energy, aided by the emissions factor of grid displaced electricity of 0.529 kg CO_2/kWh.
- **Advantages: -** Good reductions in overall primary energy and CO_2 emissions.
- **Disadvantages: -** More expensive and greater NO_x emissions than a biomass boiler.
  - Often do not supply energy cost-effectively in comparison to the market.
  - Requires Private Wire network to maximise cost effectiveness.

Combined Cooling Heat and Power (CCHP)

- CCHP is a CHP system which additionally has the facility to transform heat into energy for cooling. This is done with an absorption chiller which utilises a heat source to provide the energy needed to drive a cooling system. As absorption chillers are far less efficient than conventional coolers (CoP of 0.7 compared to >4) they are generally only used where there is a current excess generation of heat. New CHP systems are generally sized to provide the year round base heating load only.
- For this reason it is generally not suitable for new CHP systems to include cooling.
- Where there are high thermal loads, CCHP can be used within district heating and cooling networks to supply the required heat and coolth.
- **Performance and Calculation Methodology: -** Most commonly sized on the heat load of a development, not the electrical load. This prevents an over-generation of heat.
  - Require a high and relatively constant heat and cooling demand to be viable.
  - CCHP systems are best suited to providing the base loads of a development with conventional gas boilers and chillers responding to the peak demands. CCHP systems are not able to effectively respond to peaks in demand.
  - In general, CHP engines have an electrical efficiency of ~30% and a thermal efficiency of ~45%.
  - Absorption chillers have a CoP of ~0.7.

- Electricity produced by the CHP engine displaces grid electricity which is given a carbon intensity of 0.529 kg per kWh.

- **Capital Cost: -** High in comparison to biomass boilers and increased further by inclusion of absorption chiller.
  - Relative cost reduces as the size of engine increases.
- **Running Costs/Savings: -** CHP engines often struggle to provide cost-effective energy to dwellings on residential schemes.
  - Running costs and maintenance are higher than for domestic gas boilers.
  - Needs Private Wire supply for economic case to be positive.
- **Land Use Issues and Space Required: -** CHP engines require a plant room, and possibly an energy centre for large residential developments.
  - CHP engines require a flue to effectively disperse pollutants. The height of the chimney required is dependent on the size of the engine installed. Additionally the absorption chiller requires either a cooling tower or dry cooler bed for heat rejection purposes.
  - Heat network issues.
- **Operational Impacts/Issues: -** Required to be run by an ESCo who are unenthusiastic about getting involved in small – medium scale schemes.
  - Issues with rights to dig up roads for heat networks.
  - Emissions of nitrous oxides – ~1000mg/kWh – 20 times higher than for gas boilers.
- **Embodied Energy: -** Comparable to conventional gas boilers.
- **Funding Opportunities: -** Tax relief for businesses under Enhanced Capital Allowance scheme.
- **Reductions in Energy Achievable: -** Can provide some reductions in effective primary energy, but when distribution and other local losses are included, more fuel is required.
- **Reductions in CO_2 Achievable: -** Can provide greater reductions in CO_2 than energy, aided by the emissions factor of grid displaced electricity of 0.529 kg CO_2/kWh.
- **Advantages: -** Good reductions in overall primary energy and CO_2 emissions.
- **Disadvantages: -** More expensive and greater emissions of NO_x than biomass.
  - Often do not supply energy cost-effectively in comparison to the market.
  - Requires Private Wire network to maximise cost effectiveness.

Biomass Boilers

- Biomass boilers generate heat on a renewable basis as they are run on biomass fuel which is carbon neutral. Fuel is generally wood chip or wood pellets. Wood pellets are slightly more expensive than wood chips but have a significantly higher calorific value and enable greater automation of the system.

- Can be used with district heating networks or as individual boilers on a house-by-house basis.
- **Performance and Calculation Methodology: -**
  - Biomass boilers are best suited to providing the base heating load of a development (~year round hot water demand) with conventional gas boilers responding to the peak heating demand (~winter space heating).
  - Operate with an efficiency of 87-91%.
  - Small models available.
  - Conflicts with CHP they are both best suited to providing the base heating load of a development. As such they should not be installed in tandem unless surplus hot water capacity is available. Special control measures would be required in this case.
- **Capital Cost: -** Low in comparison to CHP.
  - More suitable to smaller developments than CHP as installed cost is lower.
- **Running Costs/Savings: -** Biomass fuel is more expensive than gas and as such heat being provided to dwellings is generally more expensive than the market.
- **Land Use Issues and Space Required: -** Biomass boilers require a plant room and possibly separate energy centre for large residential developments.
  - Require a flue to effectively disperse pollutants. The height of the chimney required is dependent on the size of the boiler installed.
  - Fuel store will be required. This should be maximised to reduce fuel delivery frequency.
  - Space must be available for delivery vehicle to park close to plant room.
  - Heat network issues.
- **Operational Impacts/Issues: -** Normally run on biomass, but can also work with biogas.
  - Require some operational support and maintenance.
  - Fuel deliveries required.
  - Boiler and fuel store must be sited in proximity to space for delivery vehicle to park.
  - Issues with rights to dig up roads, etc (for heat networks).
  - Emissions of nitrous oxides – ~80-100mg/kWh.
- **Embodied Energy: -** Comparable to conventional gas boiler.
- **Funding Opportunities: -** The Bio-energy Capital Grants Scheme offers grants of up to 40% of the difference between the installed cost of biomass boiler and the cost of the fossil fuel alternative to the industrial, commercial and community sectors.

- **Reductions in Energy Achievable: -** No reduction in energy demand, but energy generated from a renewable fuel. Significant long term running costs (fuel).
- **Reductions in CO_2 Achievable: -** Can provide significant reductions in CO_2, but generally limited by the hot water load (base heating load).
- **Advantages: -** Reductions in CO_2 at low installed cost.
- **Disadvantages: -** High long-term running costs.
    - Often do not supply energy cost-effectively in comparison to gas boilers.

Solar Thermal Panels

- Solar Thermal Heating Systems contribute to the hot water demand of a dwelling or building. Water or glycol (heat transfer fluid) is circulated to roof level where it is heated using solar energy before being returned to a thermal store in the plant room where heat is exchanged with water from the conventional system. Due to the seasonal availability of heat, solar thermal panels should be scaled to provide no more than 1/2 of the hot water load.
- Can also be used to provide energy for space heating in highly insulated dwellings.
- There are two types of solar thermal panel: evacuated tube collectors and flat plate collectors.
- **Performance and Calculation Methodology: -**
    - Evacuated Tube Collectors: ~60% efficiency.
    - Flat Plate Collectors: ~50% efficiency.
    - SAP Table H2 used for solar irradiation at different angles.
    - Operate best on south facing roofs angled at 30-45^0 and free of shading, or on flat roofs on frames. East/West facing panels suffer a loss in performance of 15-20% depending on the angle of installation.
    - Flat plate collectors cannot be installed horizontally as this would prevent operation of the water pump. Must therefore be angled and separated to avoid overshadowing each other.
    - SAP limits benefit to a ~12-14% reduction in regulated CO_2 over baseline.
- **Capital Cost: -** Typically £2,500 per 4m^2 plus installation. Costs higher for evacuated tubes than flat plate collectors.
- **Running Costs/Savings: -** Reduce reliance on gas and therefore reduce costs.
    - Payback period of ~20 years per dwelling.
- **Land Use Issues and Space Required: -** Installed on roof so no impact on land use.
    - Due to amount of roof space required and distance from tank to panels, less suitable for dense developments of relatively high rise flats.

- Within permitted development rights unless in a conservation area where they must not be visible from the public highways.
- Dormer and Velux windows may conflict if energy/CO_2 reduction required is large.

- **Operational Impacts/Issues: -** Biggest reductions achieved by people who operate their hot water system with consideration of the panels.
- **Embodied Energy: -** Carbon payback is ~2 years.
- **Funding Opportunities: -** none
- **Reductions in Energy Achievable: -** Reduce primary energy demand by more per standard panel area than solar PV panels.
- **Reductions in CO_2 Achievable: -** Comparable to solar PV per m^2.
- **Advantages: -** Virtually free fuel, low maintenance and reductions in energy/CO_2.
- **Disadvantages: -** Benefits limited to maximum ~50% of hot water load.

Solar Photovoltaic (PV) Panels

- Solar PV panels generate electricity by harnessing the power of the sun. They convert solar radiation into electricity which can be used on site or exported to the grid in times of excess generation.
- **Performance and Calculation Methodology: -**
  - The best PV panels operate with an efficiency approaching 20%. ~7m^2 of these high performance panels will produce 1kWp of electricity.
  - Operate best on south facing roofs angled at 30-45^0 or on flat roofs on frames. Panels orientated east/west suffer from a loss in performance of 15-20% depending on the angle of installation.
  - Must be free of any potential shading.
  - Cannot be installed horizontally as would prevent self-cleaning. Must therefore be angled and separated to avoid overshadowing each other.
  - Electricity produced displaces grid electricity which has a carbon intensity of 0.529 kg CO_2 per kWh.
- **Capital Cost: -** ~£3,500 – £4,500 per kWp depending on performance of panels.
- **Running Costs/Savings: -** Reduce reliance on grid electricity and therefore reduce running costs.
  - At current electricity prices, payback period of ~60-70 years per dwelling.
  - Feed-in tariff and Renewables Obligation Certificates (ROCs) payments required for maximum financial benefit.
- **Land Use Issues and Space Required: -** Installed on roof so no impact on land use.

  - Due to amount of roof space required are less suitable for dense developments of relatively high rise flats.
  - Within permitted development rights unless in a conservation area where they must not be visible from the public highways.
  - Dormer and Velux windows may conflict if energy/CO_2 reduction required is large.
- **Operational Impacts/Issues: -** Proportionately large arrays may need electrical infrastructure upgrade.
  - Virtually maintenance free and panels are self cleaning at angles in excess of 10 degrees.
- **Embodied Energy: -** Carbon payback of 2-5 years.
- **Funding Opportunities: -** Financier utilising Feed-in-Tariffs.
- **Reductions in Energy Achievable: -** Reduce energy demand by less per m^2 than solar thermal panels.
- **Reductions in CO_2 Achievable: -** Provide greater percentage reductions in CO_2 than energy. Comparable to solar thermal per square metre.
- **Advantages: -** Virtually free fuel, very low maintenance and good reductions in CO_2.
- **Disadvantages: -** More expensive than solar thermal.
  - Slightly greater loss in performance than solar thermal panels when orientated away from south.

Ground Source Heat Pumps (GSHPs)

- Ground Source Heat Pumps work in much the same way as a refrigerator, converting low grade heat from a large 'reservoir' into higher temperature heat for input in a smaller space. Electricity drives the pump which circulates a fluid (water/antifreeze mix or refrigerant) through a closed loop of underground pipe. This fluid absorbs the solar energy that is stored in the earth (which in the UK remains at a near constant temperature of 12^{o}C throughout the year) and carries it to a pump. A compressor in the heat pump upgrades the temperature of the fluid which can then be used for space heating and hot water.
- **Performance and Calculation Methodology: -** System requires electricity to drive the pump. Therefore displaces gas heating with electric, which has a higher carbon intensity (gas: 0.198; electricity: 0.517).
  - As they are upgrading heat energy from the earth, GSHPs operate at 'efficiencies' in excess of 350%. This is limited in SAP unless Appendix Q rated model used.
  - Due to the lower temperature of the output of GSHPs compared to traditional gas boilers, GSHPs work best in well insulated buildings and with underfloor heating. They can,

however, also be installed with oversized radiators, albeit with a consequent reduction in performance

- **Capital Cost: -** ~£7,500 per house. Additional costs if underfloor heating is to be installed.
- **Running Costs/Savings: -** Electricity more expensive than gas, thus fuel costs not reduced as much as energy is reduced.
  - Payback period of ~20 years per dwelling.
- **Land Use Issues and Space Required: -** Require extensive ground works to bury the coils that extract the low grade heat from the earth. They therefore require a large area for horizontal burial (40-100m long trench) or a vertical bore (50-100m) which is considerably more expensive but can be used where space is limited.
  - Must be sized correctly to prevent freezing of the ground during winter and consequent shutdown of the system.
  - May require planning permission for engineering works. Once buried, there is no external evidence of the GSHPs.
- **Operational Impacts/Issues: -** Work best in well insulated houses.
  - Need immersion for hot water.
  - Highly reliable and require virtually no maintenance.
  - Problems if ground bore fails.
- **Embodied Energy: -** Low, but as gas is being replaced with the more carbon intensive electricity, carbon payback is slowed. Carbon payback depends on CoP.
- **Funding Opportunities: -** none.
- **Reductions in Energy Achievable: -** Reduce energy demand by less per m^2 than solar thermal panels.
- **Reductions in CO_2 Achievable: -** Provide greater %age reductions in CO_2 than energy. Comparable to solar thermal (esp. in SAP).
- **Advantages: -** Large reductions in Energy. Currently receives benefit from SAP of an electrical baseline rather than gas.
- **Disadvantages: -** Small reduction in CO_2. CoP limited in SAP. Only small cost savings.

Air Source Heat Pumps (ASHPs)

- Air Source Heat Pumps work in much the same way as a refrigerator, converting low grade heat from a large 'reservoir' into higher temperature heat for input into a smaller space. Electricity drives the pump which extracts heat from the air as it flows over the coils in the heat pump unit. A compressor in the heat pump upgrades the temperature of the extracted energy which can then be used for space heating and hot water.

- Generally ASHPs are air-to-water devices but can also be air-to-air.
- **Performance and Calculation Methodology: -** System requires electricity to drive the pump. Therefore displaces gas heating with electric, which has a higher carbon intensity (gas: 0.198; electricity: 0.517).
  - Performance defined by the Coefficient of Performance (CoP) which is a measure of electricity input to heat output. However, the concept of a CoP must be treated with caution as it is an instantaneous measurement and does not take account of varying external conditions throughout the year.
  - As they are upgrading heat energy from the air, ASHPs operate at 'efficiencies' in excess of 250%. This is limited in SAP unless an Appendix Q rated model is used.
  - British winter conditions (low temperatures and high humidity) lead to freezing of external unit. Reverse cycling defrosts the ASHP, but can substantially reduce performance when it is most needed. Performance under these conditions varies considerably between models. Vital that ASHP that has been proven in British winter conditions is installed.
  - Due to the lower temperature of the output of ASHPs compared to traditional gas boilers, ASHPs work best in well insulated buildings and with underfloor heating. They can, however, also be installed with oversized radiators, albeit with a consequent reduction in performance.
- **Capital Cost: -** ~£2,000 per house.
- **Running Costs/Savings: -** Electricity more expensive than gas, thus fuel costs not reduced as much as energy is reduced.
  - Payback period of ~10 years per dwelling.
- **Land Use Issues and Space Required: -** No need for external ground works, only a heat pump unit for the air to pass through.
  - Minimal external visual evidence.
- **Operational Impacts/Issues: -** Work best in well insulated houses.
  - Unit must be sized correctly for each dwelling.
  - Vital that ASHP model selected has been proven to maintain performance at the low temperature and high humidity conditions of the British winter.
  - May need immersion for hot water.
  - Highly reliable and require virtually no maintenance.
- **Embodied Energy: -** Low. Carbon payback longer than for GSHPs as the CoP is lower.

- **Funding Opportunities: -** none
- **Reductions in Energy Achievable: -** Large reductions in energy demand. Less so than GSHPs.
- **Reductions in CO_2 Achievable: -** Provide smaller percentage reductions in CO_2 than energy. Less than GSHPs.
- **Advantages: -** Large reductions in Energy. Currently receives benefit from SAP of an electrical fuel factor rather than a gas baseline.
- **Disadvantages: -** Small reduction in CO_2. CoP limited in SAP. Only small cost savings.

Wind Power

- Wind energy installations can range from small domestic turbines (1kW) to large commercial turbines (140m tall, 2MW). There are also different designs and styles (horizontal or vertical axis; 1 blade to multiple blades) to suit the location. They generate clean electricity that can be provided for use on-site, or sold directly to the local electricity network
- **Performance and Calculation Methodology: -** Power generated is proportional to the cube of the wind speed. Therefore, wind speed is critical.
  - Horizontal axis turbines require >~6m/s to operate effectively and vertical axis turbines require >~4.5m/s. The rated power of a turbine is often for wind speeds double these figures.
  - Wind speeds for area from BERR's Wind Speed Database.
  - Electricity produced displaces grid electricity which has a carbon intensity of 0.568 kg/kWh.
- **Capital Cost: -** ~£1,000 per kW. Smaller models are more expensive per kW.
  - Vertical axis turbines more expensive than horizontal.
- **Running Costs/Savings: -** Reduce reliance on grid electricity and therefore reduce costs.
  - Payback period of ~15-20 years per dwelling.
  - Feed-in tariff and ROC payments required for maximum financial benefit.
- **Land Use Issues and Space Required: -** Smaller models (<6kW) can be roof mounted.
  - Must be higher than surrounding structures/trees.
  - Planning permission required.
- **Operational Impacts/Issues: -** Urban environments generally have low wind speeds and high turbulence which reduce the effectiveness of turbines.
  - Vertical axis turbines have a lower performance than horizontal axis turbines but work better in urban environments.

- Annual services required.
- Turbines rated in excess of 5kW may require the network to be strengthened and arrangements to be made with the local Distribution Network Operator and electricity supplier.
- Noise.

- **Embodied Energy: -** Carbon payback is ~1 year for most turbines.
- **Funding Opportunities: -** Financier utilising Feed-in-Tariffs.
- **Reductions in Energy Achievable: -** Significant reduction in reliance on grid electricity.
- **Reductions in CO_2 Achievable: -** Good. Greater reduction in CO_2 than PV for same investment.
- **Advantages: -** Virtually free fuel; reductions in CO_2.
- **Disadvantages: -** Expensive, although cheaper than PV for same return.
  - Lack of suitable sites.
  - Maintenance costs.
  - Often not building integrated.

Hydro Power

- Hydro power harnesses the energy of falling water, converting the potential or kinetic energy of water into electricity through use of a hydro turbine. Micro hydro schemes (<100kW) tend to be 'run-of-river' developments, taking the flow of the river that is available at any given time and not relying on a reservoir of stored water. They generate clean electricity that can be provided for use on-site, or sold directly to the local electricity network.
- **Performance and Calculation Methodology: -**
  - Flow rates at particular sites from National River Flow Archive held by Centre for Ecology and Hydrology.
  - Electricity produced displaces grid electricity which has a carbon intensity of 0.568 kg/kWh.
- **Capital Cost: -** £3,000 - £5,000 per kW.
  - Particularly cost effective on sites of old water mills where much of the infrastructure is in place.
- **Running Costs/Savings: -** Reduce reliance on grid electricity and therefore reduce costs.
  - Payback period of ~10-15 years per dwelling
  - Feed-in tariff and ROC payments required for maximum financial benefit.
- **Land Use Issues and Space Required: -** Require suitable water resource.

  - Visual intrusion of scheme.
  - Special requirements where river populated by migrating species of fish.
  - Planning permission will require various consents and licences including an Environmental Statement and Abstraction Licence.
- **Operational Impacts/Issues: -** Routine inspections and annual service required.
  - Automatic cleaners should be installed to prevent intake of rubbish.
- **Embodied Energy: -** Carbon payback for small schemes of ~1 year.
- **Funding Opportunities: -** Financier utilising Feed-in-Tariffs.
- **Reductions in Energy Achievable: -** significant reduction in reliance on grid electricity.
- **Reductions in CO_2 Achievable: -** High.
- **Advantages: -** Virtually free fuel, reductions in CO_2.
- **Disadvantages: -** Expensive, but good payback period.
  - Lack of suitable sites.
  - Planning obstructions.

Appendix B: Summary of SAP Energy Calculations

SAP Sample Dwelling Calculations Outputs												
	Sample	Average		Energy Demand (kWh/yr)				Regulated CO2 (kg/m2/yr)				FEE
Unit Type	Unit Type	Area (m2)		Space Heating	Hot Water	Fixed Electric	Unregulated Electric	TER	DER	Improvement		(kWh/m2/yr)
Small Flats	Top Floor	52.6		1,805	1,956	484	1,017	18.89	18.92	-0.2%		41.0
Large Flats	Mid Floor	77.8		1,323	2,549	605	1,211	13.89	13.87	0.1%		26.6
Houses		116.0		4,911	2,740	786	1,493	16.57	16.56	0.1%		48.4
Area Weighted Average								**14.90**	**14.89**	**0.1%**		

Site Energy Demand						
Unit Type	Average	No.	Energy Demand (kWh/yr)			
	Area (m2)	Units	Space Heating	Hot Water	Fixed Electric	Unregulated Electric
Small Flats	52.6	7	12,632	13,690	3,391	7,120
Large Flats	77.8	26	34,389	66,269	15,737	31,474
Houses	116.0	3	14,732	8,221	2,357	4,478
Total		**36**	**61,752**	**88,180**	**21,484**	**43,072**
Regulated Total			**171,416**			
Total			**214,488**			

Site CO2 Emissions						
Unit Type	Average	No.	CO2 Emissions (kg/yr)			
	Area (m2)	Units	Space Heating	Hot Water	Fixed Electric	Unregulated Electric
Small Flats	52.6	7	2,501	2,711	1,753	3,681
Large Flats	77.8	26	6,809	13,121	8,136	16,272
Houses	116.0	3	2,917	1,628	1,219	2,315
Total		**36**	**12,227**	**17,460**	**11,107**	**22,268**
Regulated Total			**40,794**			
Total			**63,062**			

Appendix C: Low Carbon and Renewable Energy Technologies Feasibility Table

Feasibility Study Table									
Technology	**Sufficient Energy Generated?**	**Payback**	**Land Use Issues**	**Local Planning Requirements**	**Noise**	**Carbon Payback**	**Available Grants**	**Feasible?**	**Reason not Feasible or Selected**
Combined Heat & Power (CHP)	Yes	Medium	Air quality in residential area	None	In Plant Room	Yes	Tax Relief - ECA	No	Development too small for community heating to be viable
Biomass	Yes	None	Air quality in residential area	Encouraged for large scale developments	In Plant Room	Yes	Bio-energy Capital Grants Scheme	No	Development too small for community heating to be viable
Solar Thermal	No	High	Sufficient roof space required	Encouraged	None	~2 years	none	No	Not preferred
Solar Photovoltaic (PV)	**Yes**	**Very High**	**Sufficient roof space required**	**Encouraged**	**None**	**2-5 years**	**none**	**Yes**	**Selected**
Ground Source Heat Pumps (GSHPs)	No	High	Requires large area for coils or borehole	Encouraged	None	Low	none	No	Not preferred
Air Source Heat Pumps (ASHPs)	No	Very High	Visual intrusion of external units	None	Low	Low	none	No	Not preferred
Wind Power	No	Low	Urban Area - low and turbulent wind; Visual impact	Encouraged for large scale developments	Yes	~1 year	none	No	Wind speeds in area unlikley to be sufficient
Hydro Power	No	Medium	Requires suitable water resource; Visual impact	None	Low	~1 year	none	No	No River

richard HODKINSON consultancy

Appendix D: PV Calculation

Renewable Energy Generation	
CO2 Reduction Required	10,190
Aspect	South
Angle	30
PV Required (kWp)	**22.4**
Panel Area Required (m2)	**168**
Total CO2 Reduction	**16%**
Cost @ £3250 per kWp (£)	**72,900**

1kWp (m2)	7.5

SAP Table H2					
	Horizontal	**30**	**45**	**60**	**Vertical**
North	961	730	640	500	371
Northwest	961	785	686	597	440
West	961	913	854	776	582
Southwest	961	1027	997	927	705
South	961	1073	1054	989	746
Southeast	961	1027	997	927	705
East	961	913	854	776	582
Northeast	961	785	686	597	440

PV Output (kWh/yr) for 1kWp				
Horizontal	**30**	**45**	**60**	**Vertical**
769	584	512	400	297
769	628	549	478	352
769	730	683	621	466
769	822	798	742	564
769	858	843	791	597
769	822	798	742	564
769	730	683	621	466
769	628	549	478	352

Overshading Factor		None/V. Little	**1.0**
	% Sky Blocked	**Overshading Factor**	
Heavy	>80%		0.5
Significant	>60%-80%		0.65
Modest	20%-60%		0.8
None/V. Little	<20%		1

	CO2 for 1kWp				
	Horizontal	**30**	**45**	**60**	**Vertical**
North	407	309	271	212	157
Northwest	407	332	290	253	186
West	407	386	361	328	246
Southwest	407	435	422	392	298
South	407	454	446	419	316
Southeast	407	435	422	392	298
East	407	386	361	328	246
Northeast	407	332	290	253	186

richard HODKINSON consultancy