Whitelands Farm Bicester

Proposed Hotel and Restaurant Development

Feasibility Study for Low or Zero Carbon Technologies

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1.0 Introduction

This feasibility study has been prepared on behalf of Dynamic Design in order to determine the most appropriate options for the integration of Low or Zero Carbon technologies at the proposed development at Whitelands Farm, Bicester.

The significance of Low or Zero Carbon Technologies (LZC) is becoming ever greater as we aim to reduce the strain on natural resources along with minimising our negative effect on the environment. LZC Technologies work to the most efficient level and achieve the greatest cost effectiveness when used in conjunction with all other aspects of energy efficient design and should not be seen as an alternative to designing in this way.

The proposed development, which comprises an 80-bed hotel and adjacent restaurant, must achieve a BREEAM rating of Very Good. There is no mandatory maximum EPC CO2 Index required to achieve this rating, therefore the feasibility study has been commissioned with a view to establishing the most appropriate LZC system(s) for the development within sensible cost constraints (costs are not included in this study). The technologies that are to be considered include:

1. Solar thermal.
2. Photovoltaics.
3. Wind turbines.
4. Small Scale Hydroelectric Power.
5. Biomass.
6. Gas Combined Heat and Power.
7. Ground Source Heat Pump.
8. Air Source Heat Pump.

This report reviews the following areas for each of the technologies;

1. Energy generated by each renewable technology.
2. Payback periods
3. Land-use requirements of the technology
4. Local planning requirements and impact of the technology
5. Noise issues
6. Whole-life cost and life-cycle impact of the technology in terms of carbon emissions
7. Available grants
8. Whether the technology is appropriate for the site and energy demands of the development.
9. Reasons for excluding the technology.

1.1 Development

The development in question consists of two separate structures, comprising an 80-bedroom hotel and adjacent restaurant.

The site is situated on lands at Whitelands Farm, Bicester, and in constrained by the location of existing roads, there being little area of the site that is not given over to buildings or car parking.

As there is the availability of mains gas on the site all of the comparisons within this study take this as the primary fuel.

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2.0 Solar Systems

The first issue when determining the feasibility of any solar system, whether it be Photovoltaic (discussed later) or Solar Water Heating, is orientation. The proposed hotel has a flat roof which could allow any orientation of solar technologies. The restaurant has mostly flat roof with some pitched roof at the rear.

2.1 Solar Thermal Systems

Of all the LZC technologies Solar Thermal is the most widely used domestically mainly due to both demand for hot water and reliability. However, these systems are not as often found in commercial buildings as other options exist for hot water production. Solar thermal systems come in two main types which include flat plate heat transfer systems and evacuated tube systems. Solar Thermal systems work by pre-heating the water in the HWC (usually via a secondary coil in the HWC) which may then require top-up, say from the primary heating system boiler or dedicated hot water boiler, at certain times of the year.

Flat plate systems consist of a dark coloured plate enclosed in an insulated box with a layer of glass or plastic covering. The plate also has a particular coating to ensure the system has a high level of absorption and low levels emission. A collector of this type would typically yield an energy capture of between 380-450kWh per m^2 per year.

Evacuated tube systems on the other hand consist of glass vacuum tubes with metal strip connectors. These tubes have very low levels of heat loss and tend to outperform the flat plate type collectors in areas of low irradiance. This mainly is due to the evacuated tube collectors having the capability to be able to utilise solar irradiance from a variety of angles and not just on the plane. A system of this type would typically yield between 500-550kWh per m^2 per year. Solar Thermal systems are usually sized based on the estimated hot water load over the year, with care taken not to oversize for winter (or undersize for summer).

In this case, direct gas-fired water heaters are proposed for both parts of the development. It would have been possible to produce at least some of the hot water via the proposed air-source heat pump which will provide heating and cooling. However, the efficiency of the heat pump would be reduced in this case. Solar hot water might therefore be considered subject to cost constraints.

Table 1: Solar Thermal

Energy Generated	Annual hot water energy demand per building: unknown at present Potential contribution from Solar system: N/K
Payback Period	Simple payback periods for a solar thermal system would be in the range of 7-15 years.
Land Use	There will be no land use issues with this technology as the system could be accommodated on the roof of either or both buildings
Local Planning Issues	No planning issues would arise with regards to this technology on the site in question.
Noise	This system will have no impact on noise
Whole life cost / life cycle impact in terms of carbon emissions	Payback in terms of carbon emissions would be around 2 years (excluding transport).
Any available grants	The RHI (renewable heat incentive) scheme may improve the economics of the system (Note recent suspension of this scheme)
Energy appropriate to the site and energy demand of the development.	Energy appropriate to the demands of site
Reasons to exclude technology.	Cost constraints – significant capital investment required to make meaningful contribution to hot water

2.2 Photovoltaic

As with Solar thermal the first issue as discussed in the previous section is that ideally a South facing orientation with a 30-40^{o} inclination would be required. Once again the flat roof areas would allow any orientation of panels.

Photovoltaic (PV) cells are made from a semi-conducting material, normally silicon. When exposed to light an electric field is created across its layers (two or more layers of silicon) which in turn stimulate the flow of electricity. This generated electricity can then be used to power lights and appliances in the building or exported back into the grid.

Even in areas such as the UK and Ireland we can benefit from the use of PV cells as the cells only require daylight to work and not intense levels of sunshine. On average in the UK around 1000kWh of solar energy falls annually on each m^2 of un-shaded surface. This may seem high but typically PV systems only have an efficiency of 12% with the best range of the highest expense reaching a peak of around 17%.

Unlike most other forms of LZC technologies PV is not used to complement fossil fuels and is completely independent of price fluctuations which occur within this market. A system can be sized to meet a proportion of estimated loads at a given time, with export potential taken into account,

However, on a cost-effectiveness basis PV panels are still hard to justify at present.

Table 2: PV

Energy Generated	Annual energy generated (10kWp system): ca 100000kWh
Payback Period	Simple payback periods for a PV system would be in the range of 30+ years.
Land Use	There would be no land use issues with this technology as the system could be accommodated on the roof of either or both buildings
Local Planning Issues	No planning issues would arise with regards to this technology on the site in question.
Noise	This system will have no impact on noise
Whole life cost / life cycle impact in terms of carbon emissions	Payback in terms of carbon emissions is ca 6 years (does not include transport of the system).
Any available grants	The FIT (feed in tariff) scheme for both electricity used on site and electricity fed back to the grid.
Energy appropriate to the site and energy demand of the development.	This energy is appropriate to the demands of the site as useful energy from the system can be used on site or exported directly to the grid.
Reasons to exclude technology.	Capital cost

3.0 Wind Energy

There are various ways that wind energy can be used. Mainly either stand-alone or grid linked wind turbines are used in the UK. Stand-alone turbines will not have any connection to the grid and in extreme cases can be the sole supply to the building in question. In this case some form of battery back-up would be required in order to bridge the gaps between lulls in wind resources. Batteries are usually sized to cope with a couple of days with no wind however in extended periods without resources non-essential electricity usage may have to be reduced in order to prolong the lifespan of the battery reserves. Due to the high initial cost of batteries and the intermittent reliability of wind as a resource, this style of wind turbine is usually less favoured unless an extremely remote location dictates otherwise.

Grid connected turbines on the other hand are useful as the grid can be used for a back-up to the turbine when wind resources are not at an adequate level. Additionally, the grid can be used for exporting the excess power produced during times of high wind. This option is also quite costly due to the price of the interfacing equipment required. The introduction of the Feed-in Tariff would help improve the economics of the installation.

Even though the UK has one of the best wind profiles and therefore renewable energy sources across Europe, for many reasons, which include location, planning, aesthetics and safety, most urban locations can be ruled out. On the site in question there is no obvious position for a wind turbine at a safe and appropriate distance from the buildings Along with this there are many planning issues that would be apparent when discussing the possibility of a turbine with a hub height in excess of 10 (normally required in order to achieve economic viability in UK). For these reasons a wind turbine is not recommended. If planning permission were likely to be favourable, a detailed wind resource assessment would need to be carried out in any case.

Table 3: Wind Turbine

Energy Generated	Would depend of size of unit (planning issue) Potential contribution from system: N/K
Payback Period	Simple payback periods for a wind turbine, depending on size, would be in the range of 7-15 years.
Land Use	Issue regarding accommodation of turbine on site allowing for separation from buildings/roadways.
Local Planning Issues	Planning issues would arise with regards to this technology on the site in question.
Noise	This system will have considerable impact on noise given the constraints of the site
Whole life cost / life cycle impact in terms of carbon emissions	Payback in terms of carbon emissions would be around 2 years (excluding transport).
Any available grants	The FIT scheme would improve the economics of the system
Energy appropriate to the site and energy demand of the development.	Energy appropriate to the demands of site though electricity demands fairly modest
Reasons to exclude technology.	Site constraints, planning issues, noise.

4.0 Small Scale Hydro-electric Power

“Small-scale hydro” would normally refer to systems of 100kW or less. These systems reply on a source of natural running water close to where the potential user would be located. Where this geography allows such power to be utilised, these small-scale turbines can provide impressive amounts of energy (although the system efficiency on a small scale is usually only around 50%) and have favourable payback periods and savings compared with other LZC technologies. Payback periods for such a system could range from between 10-12 years.

There are many advantages of hydro power on a small scale which would include either being independent of the grid (where hydro-power is a consistent reliable resource) or exporting to the grid and financially reaping the benefits. In the case of the site in question there is no water course suitable for the introduction of small-scale hydro-power.

Table 4: Hydro

Energy Generated	Not viable – no suitable resource
Payback Period	Simple payback periods for a hydro plant, depending on size, would be in the range of 7-15 years.
Land Use	Not viable – no suitable resource
Local Planning Issues	Not viable – no suitable resource
Noise	This system would have little impact on noise if a resource were available on site
Whole life cost / life cycle impact in terms of carbon emissions	Payback in terms of carbon emissions would be around 2 years.
Any available grants	The FIT scheme would improve the economics of the system
Energy appropriate to the site and energy demand of the development.	Energy appropriate to the demands of site though electricity demands fairly modest
Reasons to exclude technology.	Not viable – no suitable resource

5.0 Biomass

Biomass refers to any form of non-fossil organic matter which may be made up of wood, crops or grasses. Burning any form of biomass for heating is seen as a low or zero carbon fuel as the carbon absorbed during the life span of the plant is equated to the amount produced on its combustion (with a small amount of carbon assumed from processing and transportation). Therefore, as long as new plants replace those used for fuel, biomass is seen to be a sustainable source of fuel.

The main issue that is raised when first discussing the possibility of the inclusion of biomass is storage. A relatively large storage area close to where the fuel will be used is required in order to simplify conveyer belt feeding systems or make manual feeding easier. In a development such as the one in question, which includes a large hotel and restaurant, considerable space would be required for storage of the fuel and to accommodate the boiler itself. Wood pellets would be the preferred fuel type as logs would require a manual feeding system and wood chip, although a little cheaper, can be more problematic.

Biomass payback periods will vary depending on the fuel used and efficiencies of the system (which range between 20-90%) as well as fuel/boiler type displaced. Biomass boilers have no added noise issues compared with conventional fuels such as oil or gas. However, the additional initial cost over the standard heating system along with the added maintenance issues would be prohibitive and maintenance issues would probably preclude the option for biomass.

Table 5: Biomass

Energy Generated	Required boiler size not yet assessed
Payback Period	Simple payback periods for a biomass plant, without grant-aiding would be around 10-15 years.
Land Use	Some requirement for fuel storage
Local Planning Issues	No planning issues should arise
Noise	This system would have little impact on noise compared to other thermal boiler systems
Whole life cost / life cycle impact in terms of carbon emissions	Payback in terms of carbon emissions would be around 4 years.
Any available grants	The RHI scheme would improve the economics of the system (Note recent suspension of this scheme)
Energy appropriate to the site and energy demand of the development.	Energy appropriate to the demands of site though other means of providing outputs more efficiently and at lower capital cost
Reasons to exclude technology.	Space and maintenance requirement

6.0 Combined Heat and Power

Combined Heat and Power (CHP), sometimes known as co-generation, is already well-established in the commercial sector.

The viability of CHP depends upon the load matching between heat and electricity. The space heating demand for the buildings should be low, though there will be a constant hot water demand. Electricity loads would also be relatively low, comprising only heating and hot water system pumps, lighting (mostly LED or fluorescent) and small power, with the restaurant kitchen/back of house areas being the only other significant loads.

A full CHP feasibility study would need to be carried out which is beyond the scope of this study. Therefore CHP is not recommended in this case.

Table 6: CHP

Energy Generated	Required boiler size not yet assessed
Payback Period	Simple payback periods for a CHP plant would be around 10 years.
Land Use	Physical size of engine (though can serve as back-up generator if suitably configured)
Local Planning Issues	No planning issues should arise
Noise	This system would have some impact on noise compared to thermal boiler systems
Whole life cost / life cycle impact in terms of carbon emissions	Payback in terms of carbon emissions would be around 5 years.
Any available grants	The RHI (Note suspension of this scheme) and FIT schemes would improve the economics of the system
Energy appropriate to the site and energy demand of the development.	Energy appropriate to the demands of site though other means of providing outputs more efficiently and at lower capital cost
Reasons to exclude technology.	Needs full feasibility study before recommending

7.0 Geothermal (Ground Source Heat Pumps)

Ground Source Heat Pumps (GSHP) utilise the latent energy stored in the ground to either heat or cool a building, depending on the time of the year. The earth's surface acts as a large heat sink which collects energy from solar radiation. In the U.K and Ireland the average ground temperature remains at between 10-12^{o}C all year round.

A GSHP is comprised of 3 main parts which include the ground loop, heat pump and distribution system. A ground loop can either be horizontally laid in a trench or vertically in a bore-hole set-up where restrictions in land are present. The system is then filled with a mixture of water and anti-freeze. The heat pump works somewhat like a standard fridge (reversing the process) with an evaporator, compressor and a condenser which uses the refrigeration process to transfer the heat from the ground at a low temperature, into a hot water tank at a higher temperature. Finally, the distribution system is normally under-floor heating, as GSHP are best suited to such a low flow-temperature system. Alternatively, a radiator system could be used.

Efficiencies of such a system would depend on the Coefficient of Performance (COP – an expression of efficiency) of the heat pump used, along with some other factors including system controls. On the site in question there is adequate land for ground arrays, either beneath car-parking areas, or planted areas. Alternatively, a number of boreholes might be sunk. However, a detailed ground survey would be needed before the feasibility of either approach could be confirmed.

Heat Pumps can also be used for cooling loads, allowing heating or cooling in different parts of the building. This can be especially useful in buildings such as the hotel where rooms face in different orientations.

Heat pumps can also provide hot water, though in this case are best used in a pre-heat capacity (which maintains higher CoP) with top-up heat (say via a high-efficiency gas water heater) nearer to point of use.

Table 7: GSHP

Energy Generated	Depends on estimated loads and CoP of system
Payback Period	Simple payback periods for a GSHP, without grant-aiding would be around 20 years.
Land Use	Requirement for ground array or bore hole
Local Planning Issues	No planning issues should arise
Noise	This system would have no impact on noise
Whole life cost / life cycle impact in terms of carbon emissions	Payback in terms of carbon emissions would be around 3 years.
Any available grants	The RHI scheme would improve the economics of the system (Note recent suspension of this scheme)
Energy appropriate to the site and energy demand of the development.	Energy appropriate to the demands of site
Reasons to exclude technology.	Uncertainty re underlying geology. A detailed ground survey would be required.

8.0 Air Source Heat Pumps (ASHP)

Air source heat pumps work in a similar way as Ground source heat pumps as the name suggests but instead of using latent heat from the ground as their energy source heat from the air is used. ASHP's can be used to provide heating during the winter months and then the cycle can be reversed to provide cooling during the summer.

There are two main types of ASHP - air-to-air and air-to-water systems. Air-to-air systems are most common and are utilised in most cases along with fan assisted units to take heat energy from the air outside and pump it inside. Air-to-water systems can be used in two main ways: either to heat the water directly within the HWC to aid either solar or a more conventional heating system-based means of water heating; or to be used in a hydrauliic heat distribution system within a building through either radiators or an under-floor heating system.

There are 3 main parts to an ASHP: the evaporator coil, which absorbs heat from the outside air; the compressor, which pumps the refrigerant through the heat pump and compresses it to the temperature needed for the heat distribution circuit; and the heat exchanger that transfers the heat from the refrigerant to either the air or water.

Seasonal efficiencies of an ASHP can vary widely as they depend upon the temperature of the supply air, which coming from outside has many variations due to the UK climate. GSHP's normally have better seasonal efficiencies than ASHP's for this reason as the latent heat from the ground is normally more constant throughout the year in addition to having a higher mean during the winter months than that of outside air which can vary not only seasonally but daily.

Noise also may be a factor when proposing to use an ASHP as the fan and compressor can be loud whilst in operation. Units should thus be situated away from the hotel rooms.

However, an air source heat pump is simpler to install and incurs lower capital costs than a ground source heat pump (which would also require a ground survey) and therefore is recommended here. Hot water, however, is to be provided via direct-fired gas water heaters to avoid lowering the efficiency of the ASHP.

Table 8: ASHP

Energy Generated	Depends on estimated loads and CoP of system
Payback Period	Simple payback periods for a ASHP, without grant-aiding would be around 10 years.
Land Use	No issues
Local Planning Issues	No planning issues should arise
Noise	Some impact on noise if units located close to rooms
Whole life cost / life cycle impact in terms of carbon emissions	Payback in terms of carbon emissions would be around 3 years.
Any available grants	The RHI scheme would improve the economics of the system (Note recent suspension of this scheme)
Energy appropriate to the site and energy demand of the development.	Energy appropriate to the demands of site
Reasons to exclude technology.	None – recommended means of providing heating and cooling

9.0 Conclusions and Recommendations

Although in order to achieve BREEAM Very Good there is no maximum permissible EPC CO2 Index, Low and Zero Carbon Technologies are seen as part of environmentally and sociably responsible design. After initial discussions with the engineers the choice of LZC technologies was reduced significantly with the most viable proposals being Air Source Heat Pump system, Solar Thermal or Solar PV system.

PV is still expensive and payback periods are long (though the FIT will improve these) while Solar Thermal would also require significant capital investment to have a meaningful impact on hot water loads, especially for the hotel.

Therefore an air source heat pump was chosen to provide heating and cooling on the development for reasons of low capital cost, low level of maintenance and straight-forward installation.

The table below gives an overview of what has been described in this report.

Table 9: Conclusions

Technology	Recommendations
Solar Thermal	No – High capital cost required to make significant impact on hot water provision
PV	No - Technically feasible though long economic payback periods.
Wind Energy	No - Planning issues along with space restrictions on the site are detrimental to the possible use of this technology.
Hydro Power	No – no suitable water course is located close to the site.
Biomass	No - Restrictions on space mean area large enough to facilitate a self-fed community Biomass system. Maintenance issues
CHP	No - Requires detailed feasibility study
GSHP	No – Uncertainty re ground conditions
ASHP	Yes – low capital cost and maintenance and ease of installation

CO_2 reduction calculations

This assessment is based on an SBEM assessment carried out on a similar hotel and restaurant development for the same client using similar fabric and services specifications.

Brewer's Fayre Restaurant

Carbon Reduction on Building Regulations Target Levels

The SBEM BER was 68.9 kg CO2/m² pa compared with a TER of 111.5 kg CO2/m² pa. Thus the design achieved a 38% reduction on the TER.

Proportion of Energy from Low/Zero Carbon Technologies

Heating represents 2% of total energy and cooling 22%. Both heating and cooling are to be provided via an air source heat pump which is classified as Low /Zero Carbon (LZC). Thus 24% of total energy is to be provided via LZC.

Premier Inn Hotel

Carbon Reduction on Building Regulations Target Levels

The SBEM BER was 56.5 kg CO2/m² pa compared with a TER of 72.7 kg CO2/m² pa. Thus the design achieved a 22% reduction on the TER.

Proportion of Energy from Low/Zero Carbon Technologies

Heating represents 3% of total energy and cooling 12%. Both heating and cooling are to be provided via an air source heat pump which is classified as Low /Zero Carbon (LZC). Thus 15% of total energy is to be provided via LZC.

Assumptions

Building Fabric U-values (Standard Whitbread spec);

Walls 0.15 W/m^2K

Roof 0.1 W/m^2K

Floor 0.15 W/m^2K

Windows 0.7 W/m^2K

Building Services

Air Source Heat Pump for heating and cooling – CoP 4.5 (heat recovery in bedrooms)

Ventilation provided via heating/cooling system with additional extract in kitchens/WCs

Hot Water Services from dedicated gas-fired hot water boiler 98% seasonal efficiency

Lighting via LEDs or T5 equivalent fluorescent fittings