1 Technical Annex 1 F – Evaluation of renewable technologies

Alternative energy technologies use local generation techniques to reduce the energy consumed via the national grid and gas supply network. There are continual developments in this market, in terms of technology, economy, public perception and government policy; and there may be many changes in the next ten years that could influence the viability of their use. This report considers the technologies that are available and feasible now; they are made based on present day prices and experience of their application within the UK.

Having considered methods for the reduction of energy consumption this section considers how the remaining carbon dioxide emissions can be reduced through the introduction of on-site renewable energy generation to provide both heat and power to the development. The alternative energy technologies considered include low and zero carbon options applicable to a scheme of this scale and location.

Several constraints have informed the renewable options for the development. The first constraint is the location and limitations of the site in conjunction with the planning and design requirements of the development and community. Secondly the market cost and availability of renewable energy technologies. The final consideration is the density and phasing of the development and the viability of a community heat and power scheme.

1 F.1 Wind

Wind Turbines are well known as a source of renewable energy. The best location for a wind turbine is in an exposed site with high average wind speeds, and with the potential for linking to the National Grid. Smaller turbines can be located in many areas, but need good exposure to the wind to be economically viable (Edwards, 1999). Recently, however, a range of very small turbines aimed at roof top use have come to be used in domestic applications and are seen as a viable way of providing a proportion of a households power needs (Taylor, 2001). At present large wind turbines are the most efficient and cost-effective method of generating renewable power within the UK.

The main benefits of local wind power are:

- Provide power all the year round, at varying levels;
- Attract a Renewable Obligation Certificate (ROC) for each unit of power generated
- Visibly show a commitment to environmental issues
- Generate a large amount of publicity.

The main concerns raised over wind turbines are that they (Boyle, 2004):

- Intrude on the visual landscape
- Can be noisy if not well designed
- Affect radar systems
- Can cause electromagnetic interference affecting radio signals

Proposed Development

The potential for using wind turbines is an issue of scale, and deciding what is appropriate and cost-effective. The two extremes of scale are the use of a large, circa 2MW, wind turbine, to a series of small, circa 1.5kW, turbines on the roof of high-rise properties.

Large scale wind energy has the potential for community ownership, high electrical yields and is commercially viable. However, any proposal for a wind turbine must consider the impact on the local landscape. A desktop study performed by TNEI consultants outlines some important points that will need further investigation in the form of a detailed feasibility study and noise assessment. The proximity of 3 civil aerodromes require consultation with the Civil Aviation Authority (CAA), Ministry of Defence (MoD) and National Air Traffic Services (NATS). Current noise legislation is designed to protect residential areas. As a general rule, wind turbine proposals that lie within excess of 400m of a residential area are likely to be viewed positively. The suggested turbine location is approx. 350m from the nearest residential property, and therefore will require a background noise survey. Measurements are required under a variety of different wind speed and direction conditions and different temperature and rainfall conditions. As a rule of thumb, average (median) wind speeds exceeding 6 ms-1 are usually considered viable for wind energy. The DTI wind tool specifies an average wind speed of 6.4 ms-1 (at 45m above ground level) for the kilometre square in which the site sits. This tool does not take local topography or surface roughness into account. A better indication of wind speed can be gained from BREVe2 software, which takes into account the surface roughness of the local area. This model predicts a median wind speed of 6.6 ms-1 at 45m above ground level and a wind speed of 7.4 ms-1 at 80m above ground level. However, this does not take into account very local obstructions such adjacent trees and buildings such as the stadium, and therefore real time wind monitoring is essential. The site is within 5km of two local nature reserves, and two registered parks and gardens. TNEI consider it would be prudent to consult with English Heritage, Natural England, the RSPB and the local Wildlife Trust, and do not anticipate any problems.

Due to the nearest residential properties being around 350m away from the proposed location of the wind turbine, TNEI have recommended that due to noise constraints, the largest wind turbine that would be permitted on the site is around 250kW. This would only give an energy saving of around 1% of the total site energy requirement. If a turbine of this capacity is installed, then a further 9% of the site's energy would need to be met by other renewable sources.

Small scale wind turbines could be utilised for way-finding, public art or educational purposes while making a minor contribution to the reduction of carbon dioxide emissions. Urban wind typically has high levels of turbulence and low wind speeds. Small-scale wind turbines are therefore considered an expensive and unproven means of producing electricity and reducing CO_2. Integration of wind turbines requires early commitment to enable the structural and architectural ramifications to be resolved. A significant amount of risk is involved when dealing with urban wind speeds and this option is not recommended as an efficient means of meeting the energy targets.

1 F.2 Solar Photovoltaics (PV)

Solar photovoltaic panels convert direct and diffuse energy from the sun into electrical energy (Boyle, 2004).The panels can be easily integrated into roof spaces and facades or can be free standing to provide a renewable source of power that can be used directly or exported to the grid. Optimum annual output is achieved through installation on south facing elevations but near south, vertical walls and flat roofs can be used. PV panels can also be designed to make an architectural statement. There are a variety of panels available; framed modules, roof slates or glazing materials which can be used as direct alternatives to conventional building materials.

Benefits

- Direct generation of high value electricity to be fed straight to the user
- Each kWh will attract a Renewable Obligation Certificate (ROC)
- Provide shading to building that can reduce over-heating
- Clear statement of environmental commitment

Disadvantages

- The cost of solar PV panels is very high,
- The power is generated at times of low load and any excess power will only receive a low purchase price from the national grid.

Although the cost is high, this can be reduced to some extent by integration into the building fabric and from obtaining funding from external sources. In general Solar PV panels do not provide a great amount of useful energy for the cost of provision, being around 8 times less cost-effective than a small wind turbine.

<u>Proposed Development</u>

Solar PV would make a visible statement but has high capital costs for a small energy contribution. At this stage in the development it is not possible to know the availability of south facing roof or façade areas. It could also be considered for individual homes to contribute towards the requirements of the Code for Sustainabile Homes level 3. Typically an area of 14m2 would provide approximately half of annual domestic electrical demand with capital cost of about £8,400 per property. The affect of the orientation of individual houses on the output would require further investigation.

Solar PV can be economical for low demand remote applications, such as signage, bus shelter lighting and street lighting. Use of solar PV for these applications will be reviewed as the design develops.

If solar PV were to be installed, it would be recommended that it be as an addition to other renewable technologies, to form a part of a mix of energy technologies for the site.

1 F.3 Solar Hot Water Heating

Solar thermal collectors absorb direct solar radiation and transfer it to circulating water, which exchanges the heat obtained with a hot water store. These collectors operate most effectively during the summer when there is maximum sunshine, which conversely, is when heat demand is at a minimum. They are therefore commonly sized to meet summer hot water demands. If combined with thermal storage or heat pumps the performance of solar collectors can be improved, but these systems are more complex and expensive.

Benefits:

- ‘Free’ energy from the sun
- Visual sign of energy commitment
- Can provide useful shading
- Low technology

Disadvantages

- Require space at high level that could be used as e.g. roof garden
- Additional service connections to reach hot water system
- May not match the aesthetics of buildings
- Can make CHP/biomass district heating system less effective by reducing base heat load

Solar water collectors have many of the same solar access constraints as Solar PV but are not as affected by shading. Optimum annual output is achieved on south facing elevations but near south, vertical walls and flat roofs can be used. Evacuated tube collectors can be optimised by adjusting the solar angle enabling them to be vertically mounted which creates opportunities for architectural integration. It is best suited to residential and commercial properties and should be designed to minimise pipe runs. Like Solar PV, solar hot water makes a visible statement but does require increased maintenance and capital expenditure.

Proposed Development

Integration of solar hot water into individual homes would be the most appropriate means of utilising solar hot water as shared systems can become overly complex. Typically an area of $5m^2$ is required per property to provide approximately 60% of hot water demand with an associated cost of about £5,000 per property. The affect of the orientation of individual houses on the output would require further investigation. This is an alternative means of helping to achieve CSH level 3 if indeed this is a requirement at the design stage.

1 F.4 Biomass

Biomass is a generic term for both liquid biofuels, such as biodiesel or bioethanol, and solid biofuels, such as woodchips and pellets. In this strategy biomass will refer to woodchips and pellets.

Using biomass fuels in modern efficient heating systems is a well-established technique. The boilers used are computer controlled for optimum efficiency and are easy to maintain and operate. Woodchips or pellets are delivered on a regular basis into a fuel store and then automatically fed into the boiler when demanded.

Benefits:

- Carbon neutral
- Cost savings based on present day prices
- Sustainable management of local woodland

- Benefits to local economy
- Establishment of reliable supply chain

Disadvantages:

- Additional capital cost of the boiler
- Additonal need for fuel store, fuel transfer machinery and regular fuel deliveries via lorry
- Additional space requirement for boiler and fuel store

Proposed Development

A range of options are available for the use of biomass on the site ranging from supply of heating and hot water for the dwellings to a full site wide district heating system to meet the baseload for the development. A 2MW biomass boiler could provide all of the heating and hot water requirements of the residential and supermarket, providing 9% of the whole site's energy requirement. The same size boiler connected to a district heating system to meet the baseload for the all of the area to the south of Cherryfield Drive would provide 24% of the energy requirements for the whole site since it would be running at full capacity for a greater number of hours. However, it is important to note that there is a significant cost associated with the installation of a district heating network, estimated to be in the region of £2,000,000.

1 F.5 Biomass CHP

Combined Heat and Power (CHP, also cogeneration) is the generation of useful heat and electricity where a turbine or engine is connected to a dynamo to produce electricity while the exhaust heat is used to produce steam and hot water. Capturing the resultant heat from the generation of electricity is a more efficient technology than using large-scale power stations and gas boilers for power and hot water, however CHP is not considered to be a renewable energy source unless fed with a renewable fuel.

Renewable fuels are:

- Hydrogen produced through electrolysis of water via a renewable source of power (solar, wind, wave, etc.). Future hydrogen grids are being discussed but are yet to be applied.
- Bioethanol and biodiesel fuels which are being promoted as transport fuels in the UK. Due to the lack of availability in the UK, but high demand for transport fuels, these are being imported from areas such as Brazil, West Africa and Indonesia. We do not recommend these as a stationary fuel in the long term due to long-term price, availability and sustainability concerns.
- Biogas from the anaerobic digestion of organic waste. This process involves the storage and digestion of materials such as organic municipal solid waste, food processing waste, agricultural silage and human effluent. This process is the ultimate approach to local waste treatment, turning waste products into useful energy and fertiliser resources. However, there are few examples of this in the UK and the scale of technology required to provide sufficient biogas would be more appropriate in a rural location than in the outskirts of Liverpool.

- Biomass in the form of woodchips as a result of sustainable forestry management and timber processing industries is readily available in the UK. These sources can be supplemented by locally growing Short Rotation Coppice (Energy Crops) such as Willow and Poplar. In countries such as Austria, Germany, Denmark and Sweden biomass woodchip provides a substantial amount of heating and power needs. Biomass can be used in small domestic boilers but is more commonly used in district heating schemes, sometimes using CHP technology.

Biomass boilers are a renewable energy source for heating and, using locally sourced biomass, can provide substantial carbon savings. Even greater carbon savings are possible if a biomass CHP system could be used, by providing renewable and efficient power and a source of hot water from the one system.

The technology options for biomass CHP are:

- Steam (Carnot cycle)
- Organic Rankine Cycle
- Gasification

The Carnot cycle is the most common approach to biomass CHP, relying on traditional technologies in the form of direct combustion heating water-tube steam boilers generating high-pressure steam that is passed through a steam turbine. The heat to power ratio of this system is approximately 5 to 1 and the scale of system is usually large. Traditional waste incineration and coal-fired combustion relies on this technology.

The Organic Rankine Cycle uses a heating fluid such as a thermal oil to transfer heat to a steam generator which feeds the steam into a turbine or engine or to a Stirling engine. An example of an ORC has been developed by Talbotts in the UK.

Biomass gasification relies on the thermal degradation of biomass woodchip into gas in the absence of air. The gasification process is a proven concept and is similar to the process of producing towns gas from coal, however past attempts to apply it for small-scale woodchip gas production have not been as successful as hoped.

There are biomass CHP systems in use in Europe but there is minimal operating data available and most of the schemes in operation are in the order of 500kWe and up. While CHP itself is well established, the use of biofuels in CHP schemes presents technical challenges which are being addressed. While there are other technologies under investigation, there are two systems which are currently viable, gasification and direct combustion. Gasification is the conversion of the combustible part in the biofuel into gases (hydrogen, CO, methane, CO_2 and nitrogen) and char by combusting the fuel via a restricted flow of oxygen. The majority of these systems use woodchips as their fuel supply.

Proposed Development

Biomass CHP is still viewed as an unproven technology in the UK, however, the planned installation of several Biomass CHP systems will encourage the reassessment of the viability of this technology in the near future. A district heating scheme would serve to 'future proof' the development for the provision of new renewable technologies such as this.

1 F.6 Ground Source Heat Pumps

Ground Source Heat Pump is an established technology and can be installed in horizontal trenches or vertical boreholes. Heat pumps upgrade low value energy with the use of electrical power via the refrigeration cycle (Rawlings, R.H.D, 1999). In the case of a closed Ground Source Heat Pump (GSHP) system a water-based solution is pumped through pipes drilled 60 to 100 metres into the ground using the relative warm ground temperature in the winter to provide heating at 40˚C to the property. To do this they will require sufficient free underground area. It is not advised to drill the ground loops underneath the building construction, and usually they are positioned within an adjacent car park.

A closed loop system typically provides 20kW of heating for every 100 metre borehole; with each borehole placed 2 metres apart, so to provide a large amount of heating a substantial free area would be required for the ground loops. GSHP systems operate with a performance efficiency ranging from 300% to 500% depending on the output temperature (ETSU, 2004), due to the use of free energy from the ground. Each property would require roughly one borehole to provide its heating needs.

Alternatively an open-loop system could be used, pending the availability of a large underground aquifer beneath the site. In this case the aquifer would be used as a huge thermal store, balancing the heating demands of the winter with cooling demands of the summer. For maximum efficiency and to meet the requirements of the Environment Agency, the site annual cooling demand should be matched as near as possible to the annual heat demand. This would require any additional heating or cooling to be provided by an alternative system such as gas fired boilers or electrically power chillers.

A heat pump system would be able to supply cooling at temperatures as low as 6^{o}C and heating at temperatures up to 45^{o}C (Rawlings, 1999). This would require the use of low-temperature/high-volume heating systems throughout the development, typically in the form of underfloor circuits. This places a restriction on the future design of heating and cooling systems. Another barrier is the reliance on electrical power to provide heating; this may be an issue in the long-term as electricity prices are predicted to rise.

<u>Proposed Development</u>

Closed loop ground source heat pump systems to provide large CO_2 savings are not feasible on this site due to the relatively high building density on the site, and lack of suitably large area for installation of shallow pipework.

Open loop ground source heat pump systems that abstract water from the aquifer below and then re-inject it would be capable of providing large CO2 savings. A GSHP would be capable of supplying in excess of the 10% renewables obligation, if it were to provide the space heating, cooling and possibly chilling to the supermarket and retail units on the south of the site.

The system would circulate ground water at a stable temperature at around 10ºC. In the summer, heat would be rejected to the ground via injection boreholes, and in the winter this heat would be withdrawn from the ground and upgraded via reversible heat pumps to provide space heating at low temperature.

We have estimated that such a system would reduce the energy demand of the site by around 16%, in turn reducing site CO2 emissions by around 8%. Such a heat pump system would have a total capacity of around 4.5MW and would require 18 boreholes, 9 for abstraction and 9 for injection to be drilled around the site.

It is essential that the aquifer is subject to further analysis to establish its suitability for abstraction. Further analysis and approval from the Environment Agency is also necessary.

1 F.7 Energy from Waste

Waste management strategies for buildings should be tailored to the amount and composition of waste that will be generated. If energy from waste is to be incorporated to a building project, the amount and composition of residual waste, i.e. after recycling or composting, needs to be estimated.

The following is a list of potential energy from waste technologies, with a brief description of each that could treat waste generated at the proposed development:

- Anaerobic digestion (AD) - Bacterial digestion of wet waste, typically food, green or human wastes, in absence of oxygen. Under such conditions, the organic waste fraction is transformed into biogas composed by 60% methane and 40% carbon dioxide and minor parts of sulphur and other compounds. The bio-gas can be used to fuel gas engine generators or CHP units and the solid and liquid by-products can be used as fertilisers. This process is commonly used as part of sewage treatment process.
- Mass burn incineration - Direct combustion of waste to raise steam for electricity generation and reduce volume of waste to landfill. It is widely used and there are many plants in operation all around the world. Highly contentious in terms of opposition from environmental campaigners and local residents Needs extensive air pollution prevention equipment. Capable of handling most feedstocks.
- Gasification/pyrolysis - Also known as 'advanced thermal treatment'. Based on heating of separated non-recyclable waste in partial or total absence of oxygen (gasification and pyrolysis respectively). Gives off a 'syngas' which can be cleaned and used to fuel gas engine CHP units. Leaves a residue which can be landfilled or can be hazardous waste depending on specific process. There are many variants of this technology which is relatively common in Germany and Japan. Suited to dry feedstock with high calorific value.
- Plasma arc gasification - Other innovative energy from waste technology that lags behind the previous is plasma arc gasification. However, it is commercially unproven. There is some experience though in using it aboard cruises and military ships and there are a few pilot commercial plants operating on municipal solid waste. Because of this, plasma arc technology is not considered any further.

A review of existing reports on the various forms of energy from waste showed that each technology is better suited to a type of waste and that it appears to be a lower limit in the quantities of waste that they require to operate economically as summarised in the next table:

Technology	Minimum throughput (tonnes per annum)	Suitable fuel
Anaerobic digestion	5,000	Organic waste
Gasification/Pyrolysis	30,000	Homogeneous pre-processed waste, e.g. refuse

		derived fuel
Incineration	60,000	Almost every type of fuel is suitable

According to chapter 13 of this report, there will be around 4,000 tonnes per annum of waste generated, approximately 25% of which will be organic waste. The quantities expected of any of the waste streams or their combinations are very low for any commercial energy from waste facility.

Proposed Development:

Energy from waste is not be considered further for the proposed development alone. Nonetheless, as part of a sustainable waste management strategy, reducing the amount of waste produced and enabling recycling and/or composting should be encouraged. Recycling could be promoted by involving the community with campaigns and providing them with the necessary equipment, e.g. separated bins, appropriate collection services, etc. Home composting systems, or a communal in-vessel system if there is space in the development, could also be proposed.