5.0 Energy – Low and Zero Carbon Technologies

5.1 Introduction

5.1.1 Developments need to contribute to tackling climate change by reducing carbon emissions. New buildings should approach this through the application of the energy hierarchy which provides a series of steps that should be taken to minimise the carbon emissions in an efficient and cost effective way. The energy hierarchy is set out as follows:

- Firstly, reduce the need for energy – Site layout and orientation of buildings can reduce the energy demands of buildings by maximising passive solar gain (See Section 4 – Reducing Energy Demand).
- Secondly, use energy efficiently – There are various measures that can be incorporated into the design of buildings to help save and efficiently use energy, such as thermal efficient glazed window, draught proofing, insulation, and energy efficient appliances (washing machines, light fittings etc.).
- Thirdly, use low and zero carbon energy – Developments can incorporate technologies that provide energy efficiently, such as combined heat and power, or, generate energy from sources that are continuously and sustainably available from our environment, such as solar, wind, water, geothermal and biomass.

5.1.2 This section considers the final step of the hierarchy and focuses on low and zero carbon technologies that can either be incorporated into the fabric of the building, or built within the development. Some of the technical considerations and potential constraints are identified for each of the low and zero carbon technologies. Further detailed information, including potential planning issues, can be obtained from Welsh Government practice guidance on renewable and low carbon energy[6].

5.2 Wind

Description of Technology

5.2.1 Wind energy generation uses the wind's energy to turn a rotor connected to an electrical generator. There are two types of wind turbine – horizontal axis turbines and vertical axis turbines. Whilst the majority of wind turbines are currently designed using a horizontal axis, vertical axis turbines are more common at the micro scale as they are designed to perform more efficiently

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6 *See Welsh Assembly Government. 2010. Practice Guidance – Planning Implications of Renewable and Low Carbon Energy (Cardiff, WAG), Cadw/Welsh Assembly Government. 2010. Renewable Energy and Your Historic Building. Installing Micro-Generation Systems: A Guide to Best Practice. (Cardiff, Cadw/WAG), and Welsh Government. 2012. Practice Guidance – Renewable and Low Carbon Energy in Buildings (Cardiff, WG).*

at the more turbulent wind speeds typically experienced in built-up areas.

5.2.2 Small and micro scale wind turbines can be installed with a free standing mast or fixed to a building. They are often deployed as single machines to supply power to a specific building or development. At the micro-scale, turbines range from 5W battery charging models to around 2.5kW roof top devices. Small scale turbines generally have a generating capacity range up to around 50kW. While individual large (1-3MW range) and medium (up to around 750kW) scale turbines can also be deployed as single machines, they are more often used in groups in the form of a wind farm development[7].

Constraints

5.2.3 The principal constraint for small and micro scale wind turbines is wind speed. Roof top micro turbines in particular are prone to low wind-speeds as a result of building-induced turbulence. Sites should therefore be accurately monitored as far as possible at the feasibility stage to ensure wind speeds are sufficient to allow the wind turbines to perform satisfactorily.

5.3 Solar

Description of Technology

5.3.1 Solar energy generation uses the sun's energy to provide hot water via solar thermal systems or electricity via solar photovoltaic systems. Both technologies are technically well-proven and their installation on the roofs of new and existing buildings is now commonplace.

5.3.2 **Solar thermal systems** use solar collectors, to preheat water for use in sinks, showers and other hot water applications. There are two main types of solar thermal collector: flat plate collectors which consist of an absorber plate with a transparent cover to collect the sun's heat; and evacuated tube collectors which consist of a row of glass tubes, each containing an absorber plate connected to a manifold heat exchanger. In both cases, the solar thermal collectors work in conjunction with a water tank which stores the hot water. A supplementary heating source, such as a boiler or immersion heater, is also necessary to supply hot water when there is insufficient solar energy to meet the hot water needs of the building.

5.3.3 Solar thermal collectors are usually roof mounted and are increasingly being incorporated into a new or existing roof in much the same way as roof windows. They can also be wall mounted or free standing ground structure. A typical roof-mounted collector on a domestic building would usually protrude no more than 12cm beyond the plane of the roof, be dark in colour and measure 3-5m^2 in area (see Figure 5.1).

5.3.4 A well designed solar thermal system can make a valuable contribution to the hot water demand for domestic buildings (50-60% during May-September). It is potentially the cheapest form of renewable energy for domestic buildings and is also suitable for non-domestic buildings with a high hot water demand, such as hospitals, swimming pools and industrial buildings.

Figure 5.1 Roof mounted solar thermal panels on residential dwellings at Glanmor Gardens, Dowlais.

5.3.5 **Solar photovoltaic systems** use solar cells to convert daylight into electricity which can directly power appliances, be stored in batteries, or be fed into the grid via the mains supply. Whilst there are many types of solar PV with different characteristics (crystalline cells, thin-film, hybrid), they commonly

7 *Typical scales of individual wind turbine technologies taken from Welsh Assembly Government. 2010. Practice Guidance – Planning Implications of Renewable and Low Carbon Energy (Cardiff, WAG).*

consist of a number of semiconductor cells which are interconnected to form a solar panel or module. There is considerable variation in appearance, but usually solar panels/modules are dark in colour and have low reflective properties.

5.3.6 Solar photovoltaics can either be roof mounted or free standing in modular form, or integrated into the roof or facades of buildings using technologies such as solar shingles, solar slates, solar tiles and solar glass laminates. A small scale array of panels, typically installed on a domestic property, would measure 9-18m2 in area and produce 1-2 kW peak output. Solar photovoltaics are particularly well suited to buildings that have a day time demand for electricity, such as offices, schools and shops.

Constraints

5.3.7 The main technical constraint relates to the availability of unshaded and suitably orientated roof or external wall space, both in terms of area and structural integrity. For optimum performance, solar collectors need to face due south, not be overshadowed by trees and buildings, and be inclined at an angle of 30°-40° and 20°-40° for thermal and photovoltaic collectors respectively. Whilst some flexibility may be necessary when installed on existing buildings, performance will be compromised when designed outside these criteria. The availability of space for the storage of system components, such as a water tank, may also be a constraint.

5.4 Ground, Air and Water Source Heat Pumps

Description of Technology

5.4.1 Heat pump systems extract the solar heat energy stored in the ground (ground source heat pumps), bodies of water (water source heat pumps) or air (air source heat pumps). This heat can be used for space heating, water heating, heat recovery, space cooling and dehumidification in both residential and commercial buildings.

5.4.2 Although all the heat delivered by heat pumps comes from renewable energy, a supply of electricity is required to pump the system, which may or may not come from renewable sources. A good quality installation will, however, extract significantly more useful heat energy than the electrical energy needed to operate the system. Consequently, heat pumps will usually have a much lower carbon footprint than other conventional heating systems.

5.4.3 **Ground source heat pumps** (GSHP) utilise the heat energy stored in the ground surrounding (or even under) buildings. Heat is removed from the ground at certain temperatures and passed through a heat exchanger to release it into a building at a higher temperature. A typical GSHP system consists of three main components: a heat pump (located within the building and similar in size to a large refrigerator); a ground collector loop (either pipes laid in trenches in the ground or vertical pipes within boreholes); and an interior heating or cooling distribution system. GSHP are most suited to low temperature heat distribution systems, such as under floor heating systems or low temperature radiator systems with a large surface area. These systems work best in highly insulated buildings.

5.4.4 **Air source heat pumps** (ASHP) use the outside air as a heat source for heating a building. This type of heat pump can either be directly fixed to an external wall where they look like and basically act as an air conditioning unit operating in reverse, or they can be fed into a centralised ducted warm air central heating system (see Figure 5.2). ASHPs tend to be much easier and cheaper to install than GSHP, but tend to be less efficient due to the seasonal variability of ambient air temperatures.

Figure 5.2 Air source heat pump attached to the side elevation of a house.

5.4.5 **Water source heat pumps** (WSHP) extract heat from large bodies of water or rivers with a reasonably high flow volume using a similar heat collection system to GSHPs. An abstraction licence from Natural Resources Wales is normally required.

Constraints

5.4.6 As all types of heat pump operate most efficiently at lower temperature outputs (no more than 40°C), they are not usually suited to high temperature radiator systems.

5.4.7 The use of GSHPs can be constrained by the amount of space available to accommodate trenched collector loops. While bore hole loops can overcome this issue, they are considerably more expensive and dependent on favourable geological conditions.

5.4.8 Consideration should be given to seasonal variations in ambient air temperatures when contemplating the use of ASHPs as this will influence the system's overall efficiency.

5.4.9 WSHPs can be constrained by variations in the amount of water available for abstraction. This could be due to differing groundwater levels or river flows. Any abstraction licence issued is likely to include certain conditions/restrictions which will also affect the water available for these schemes.

5.5 <u>Hydropower</u>

Description of Technology

5.5.1 Hydropower schemes harness the energy of flowing water to generate electricity. The amount of electricity generated is proportional to the volume of water and the height it falls. Hydropower is a well developed and reliable source of renewable energy, which has further potential in Wales, particularly for small scale 'run of river schemes'. A typical scheme consists of an inlet pipeline (penstock) to direct water, turbine generating equipment and housing, a 'tailrace' (channel) to return water to the watercourse and electricity transmission equipment (see Figure 5.3). An abstraction and/or impoundment licence is likely to be required from Natural Resources Wales.

Figure 5.3 Micro hydropower scheme with a 26 kW power output providing electricity to the Blaenavon World Heritage Centre. Photos include the water intake (left), turbine generator (centre) and generator building (right).

5.5.2 Small scale hydropower schemes generally relate to those generating up to 300 kW of electricity which is fed directly into the national grid. Micro hydropower schemes, typically generating up to 50 kW, can supply electricity to several homes, farms and business units.

Constraints

5.5.3 The main technological constraint relates to the need for sufficient water fall distance and flow rates throughout the year. There is also the need for adequate site access, space to accommodate the necessary equipment and a means of transmitting the electricity generated to its end user. Any abstraction and/or impoundment licence issued is likely to include certain conditions/restrictions which will also affect the water available for these schemes.

5.6 Biomass

Description of Technology

5.6.1 Biomass is a form of bio-energy typically sourced from wood fuel, energy crops or wood waste, agricultural residues and the biological component of municipal solid waste. Although biomass systems have traditionally been used to provide heat to buildings, they are increasingly being used to generate electricity or combined heat and power (see below for more information on combined heat and power).

5.6.2 Biomass systems typically comprise of the following elements: fuel delivery and storage facilities; combustion or advanced thermal processing plant with or without electricity generation plant; flue and ash extraction mechanisms; and connecting pipework.

5.6.3 Biomass systems are available at the following scales[8]:

- **Small scale** (less than 500kWth) biomass systems typically focus on the production of heat for domestic and small commercial uses. They can either comprise of a stove that provides warmth for individual rooms, or a boiler that meets the central heating and hot water needs of a building. Consideration should be given to how the flue will be accommodated within the design of a building and the amount of space available for fuel storage, particularly in relation to biomass boilers which have larger requirements.
- **Medium scale** (500kWth – 10MWth) biomass systems again tend to prioritise the production of heat for larger individual buildings and developments serving multiple buildings. Biomass combined heat and power systems which serve community facilities, schools or industrial units also tend to fall within this category. A biomass heat plant for a school would typically consist of a boiler house with a 4m by 3m footprint, a fuel bunker with similar proportions to the boiler house and a 3m to 10m high chimney. Sufficient space will also be required for fuel deliveries.
- **Large scale** (Over 10MWe) biomass systems are primarily electricity generating plants with much larger site footprints.

Constraints

5.6.4 The main technical constraints for biomass installations relate to the availability of space, particularly for the delivery and storage of fuel, and the adequate provision for a flue. The availability of suitable fuel sources, in terms of both quality and quantity, can also act as a major constraint.

5.7 Combined Heat and Power

Description of Technology

5.7.1 Combined heat and power (CHP) systems generate both electricity and useful heat that can be used for space heating and hot water. This type of system can have a much higher efficiency than thermal systems that generate electricity alone, provided that it is sized correctly to meet power and heating demands, and is located in close proximity to the heat user. Combined cooling, heat and power (CCHP), or trigeneration, systems are also available which provide additional cooling through the use of absorption chillers.

5.7.2 CHP systems can be fuelled by both renewable and non-renewable sources, such as biomass and natural gas respectively. They typically comprise of the following components: fuel delivery and storage facilities (if using solid fuel, such as biomass); boiler/turbine; connecting pipework; and a heat exchanger/heat recovery generator.

5.7.3 CHP systems can be installed at a various scales ranging from micro-CHP domestic applications to CHP systems supplying district heating to an estate of houses or whole

[8] *Typical scales of individual biomass schemes taken from Welsh Assembly Government. 2010. Practice Guidance – Planning Implications of Renewable and Low Carbon Energy (Cardiff, WAG).*

communities. Micro-CHP domestic systems primarily generate heat with some electricity generation, typically around 1 kW. They are similar in size and shape to standard domestic boilers and likewise can be wall hung or floor standing. CHP systems supplying district heating typically require their own building and need to incorporate heat distribution network infrastructure. Solid fuel based CHP plants, such as biomass, will require a larger footprint than gas fired CHP plants, due to space requirements for on-site fuel storage, processing and deliveries.

Constraints

5.7.4 The viability of CHP systems, in cost and efficiency terms, is dependant on the heat and power requirements of the end user. In particular, CHP systems supplying district heating are generally more viable with developments that include high heat users, such as leisure centres and hospitals, or those including a variety of users that spread the demand for heat over the day and week.

5.8 District Heating

Description of Technology

5.8.1 District heating (DH) is a means for delivering heat to multiple buildings from a central energy centre. It typically delivers space heating and domestic water, but can also provide cooling by means of heat driven chillers. A DH scheme can usually generate and deliver heat more efficiently than multiple individual systems.

5.8.2 The basic components of a DH scheme are an energy centre containing the heat source/s; a distribution network of insulated pipes used to deliver the heat to end users; and a hydraulic interface unit, such as heat exchangers linking each customer to the heat distribution network. DH is adaptable and the energy centre can consist of traditional gas boilers, biomass boilers, gas or biomass CHP systems, and waste heat.

5.8.3 In principle, a DH scheme can be connected to any building and can range in scale from serving a number of buildings on a single site to serving a whole community, town or city centre. They can be operated under a range of business models, which are generally referred to as energy service companies (ESCos). The end-user commonly purchases the energy from the ESCo who constructs, operates and maintains the DH network.

Constraints

5.8.4 A significant constraint to district heating is the need for a sufficient heat demand density. The heat demand density is a spatial characteristic that indicates the levels of heat required for a certain area. They are typically highest in town and city centres where high building densities are also found. Here, shorter distances are required between connected buildings and the energy centre, which reduces capital costs for the installation of pipe-work and minimises the heat distribution loss across the network.

5.8.5 A further constraint is the lack of overall size and diversity of the heat loads. DH schemes typically generate heat at a constant rate so there needs to be a continuous demand for the energy. This can be resolved by connecting the DH network to a mix of building types which have heat demands at different times.