

## 8 SUSTAINABLE ENERGY PRODUCTION AND EMISSION REDUCTION

### **Chapter summary**

***Quarry restoration provides a range of opportunities for sustainable energy production and carbon emission reduction along with the potential for growth of 'carbon neutral' bio-energy crops.***

### **8.1 Biofuels**

The UK government has an ambition to provide 60% of electricity generated in the UK from renewable energy sources by 2050. Biofuels provide a sustainable, carbon-neutral fuel to meet this requirement.

Recent studies (*Brierly et al; 2005*) have indicated that restored quarries may provide suitable locations for the growth of energy crops for harvest and combustion. The species employed are fast growing and include willow and poplar grown as short rotation coppice (SRC) and grass species such as *Miscanthus* and switch grass. A plentiful water supply is a primary requirement for high productivity, particularly for SRC. Quarry restoration design would need to be optimised to ensure an adequate water supply and easy access for harvesting machinery.

There is discussion over the degree to which integration of bio-energy crop production, biomass transportation, and power generation from energy crops should be integrated within the minerals industry. Biomass crops can be described as 'carbon-neutral' because the carbon dioxide released on combustion is absorbed during growth. Location in relation to energy production plants and transport costs are an important factor and in some cases on a purely financial assessment a subsidy is required in order for this agricultural end use to be competitive with other agricultural end uses (*Brierly et al, 2005*). Although this is site specific and in many cases the quality and area of the land restored for other agricultural purposes may not be high. The societal value of the environmental benefits may attract other financial benefits which could be added to the private financial return to the grower to represent the true economic value.

### **8.2 CO<sub>2</sub> Emissions**

Reedbeds and other peat-forming vegetation remove CO<sub>2</sub> from the atmosphere and incorporate the carbon within the plant structures and developing deposits of organic matter. Under anoxic (water-logged) conditions the vegetation does not decay to release CO<sub>2</sub> but instead forms peat. Peat forms a valuable substrate for use in the formation of wetland habitat. However, appropriate methods for the temporary storage of peat during operations prior to restoration should be considered to prevent desiccation and loss of structure in the peat. Peat forming vegetation such as fens and reedbeds can form a net carbon sink and suggestions have been made by English Nature that creation of certain habitat types could be promoted with industry for use as a CO<sub>2</sub> emission offset. This may become increasingly significant as companies (including minerals operators) strive to become carbon neutral, either in anticipation of future regulation or to meet the demands of shareholders.

### **8.3 Opportunities for sustainable water-based energy supply through quarry restoration**

Often upon completion of mineral extraction large waterbodies will be created at different elevations, supported by both groundwater and surface water inflows. A considerable amount of energy may be stored within the lakes of the system, in terms of both thermal and potential energy. It may be possible to utilise this energy within the proposed restoration schemes, which often include return to agricultural usage, wildlife habitat creation, recreational or residential usage. Of particular interest may be the use of heat pump systems to provide heating for

residential, aquaculture or agricultural (greenhouse) purposes and micro hydro-electric generation (**Figure 8.1**).

### 8.3.1 Ground source heat pumps (GSHP)

Heat pumps have only recently come to the fore in the UK, in part as a result of the increase in gas prices, but have been widely used for decades in mainland Europe and North America. A heat pump works on the reverse principle to a refrigerator, extracting heat from one medium (eg lake water) and transferring it to another, using electrical energy to drive a compressor. Heat extracted is derived from indirect solar energy. The system is reliable and highly efficient; typically the input of 1 kW of electrical energy will produce a 4 kW output of heat (coefficient of performance .COP equals 4). This makes it environmentally friendly and operating costs generally work out cheaper in comparison to other fuel types (see table below).

Fuel	Price (p) per kWh
Gas	1.8 – 2.58
Oil	2.85 – 3.125
Electricity	2.94 – 7.88
Heat pump (COP 4)	0.7 - 2

Table 8.1: Estimated energy costs

On the downside is the relatively high initial capital cost although the payback period for high energy users is relatively rapid.

A closed-loop system is generally used to collect the heat in which an antifreeze mixture is pumped through coils of pipe buried in the ground or submerged in a lake. An open-loop system, which utilises flowing water directly to the heat pump, can have even higher efficiencies (co-efficient of performance typically >5) with an associated reduction in running costs. It is these open-loop systems which seem to have great potential for use within a quarry restoration, where gravity supply will further reduce running costs.

Based on a specific heat capacity for water of 4.2 kJ/litre/°C, for every one degree fall in temperature a total of 4.2 KJ of energy are released per litre of water throughflow. Assuming a co-efficient of performance of 4 and a temperature drop in the water of say 5°C a flow rate of ~0.036 l/s is required per 1 kW (kW = kJ/s) of heat energy required.

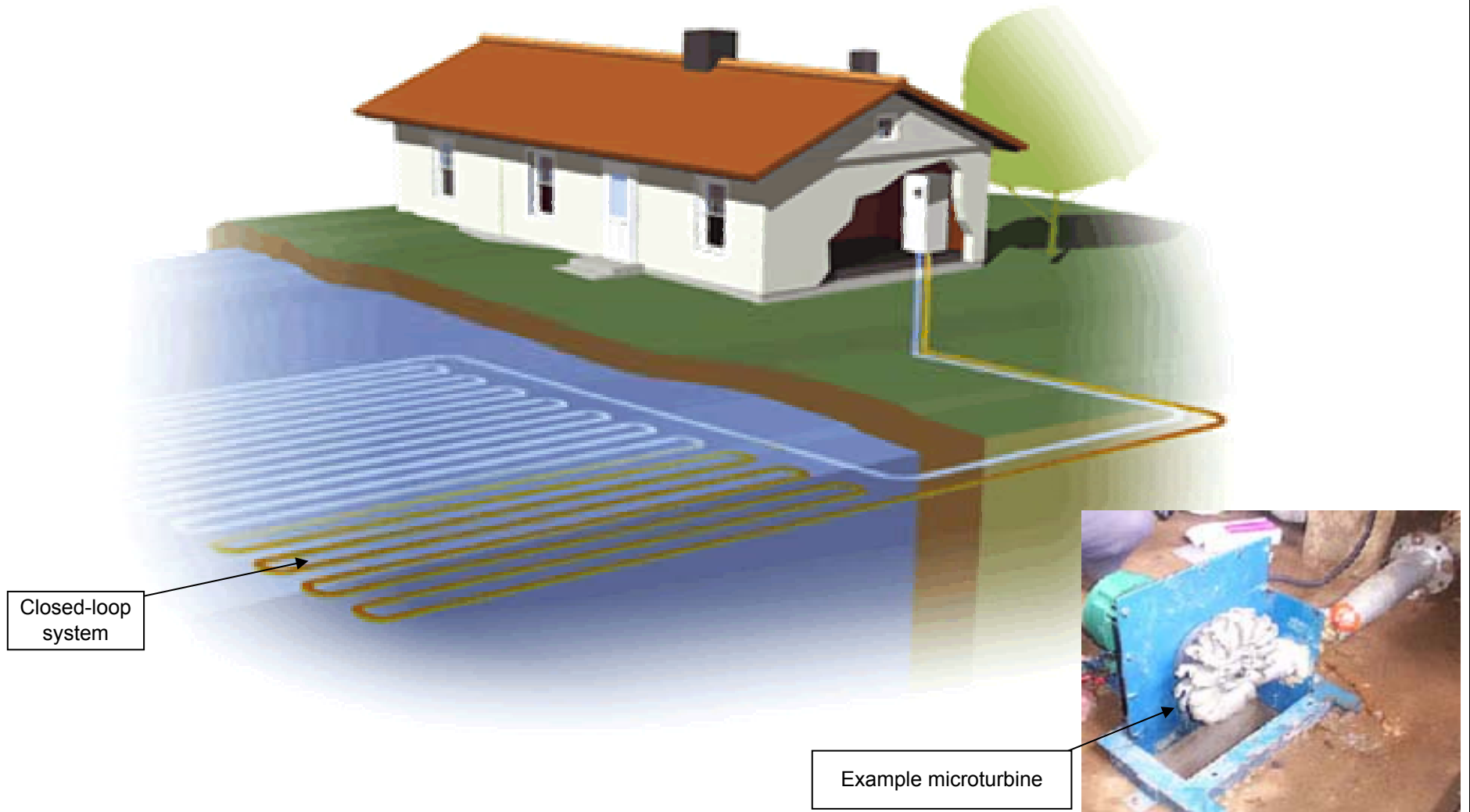
Typically hot water output temperatures are 35°C for use with under-floor heating systems, up to a maximum of 55°C, although this becomes less efficient. Potentially the heat generated may be used for space heating in residential buildings and recreational facilities including swimming pools. For some applications the system may be reversed during the summer to provide cooling (either passive or active). A typical small 2-bedroom modern house will typically require a 6 kW heat pump; this will increase with house size to in the order of 20 kW plus for larger (1,000 m<sup>2</sup>) buildings.

Serious consideration should be given to the application of heat pump technology at restored quarry sites given the large volumes of water available and the potential to use gravity transfer.

### 8.3.2 Application to aquaculture and horticulture

Following restoration landowners are often seeking a return to some form of agricultural land with an associated income although often the quality and quantity of land may be low due to the mineral extraction and waterbodies. Aquaculture and horticulture may potentially produce higher

# Heat Pumps and Hydro Power



returns than other end uses. Both may be energy intensive to provide optimum temperatures for growth.

Potentially some portion of aquaculture or greenhouse heating could be economically supplied using a ground source heat pump with supplementary heating if required via gas or oil during peak loads. As an example for a large 3.2 Ha greenhouse heating costs could amount to between £57,000 and £95,000 per year (gas 1.8 – 3 p per kWh). Should a heat pump prove feasible, operating costs could potentially reduce to between £22,000 and £64,000 (0.7-2 p per kWh) depending on the electricity tariff. The savings could make restored quarry sites very attractive for these applications.

Other agricultural applications of GSHP which have been tried successfully in North America include:

- a) Mushroom farming, which also has a considerable cooling requirement due to the heat from the breakdown of organic material
- b) Soil cooling for certain plants (eg Freesia) which require very close control of soil temperature in order for bulbs to grow properly and produce flowers
- c) Dehydration of soil to reduce the moisture content of potting soil being readied and packaged for shipment (grain drying).
- d) Cold storage facilities

### 8.3.3 Micro hydroelectric power

Micro hydro power systems which generally produce less than 100 kW are receiving more widespread interest in the UK due to improved technology and less stringent regulation of grid-connected micro hydro generators. Electricity supply companies are now obliged to buy a certain proportion of their electricity from renewable sources, such as hydro power through the Renewable Obligations scheme.

The hydro power in a stream or river can be calculated as follows:

Hydro Power (kW) = Head (m) x Flow (m<sup>3</sup>/s) x 9.81 x Efficiency  
The system efficiency for micro hydro plants is typically 50% to 60%

Various types of turbine-generator units have been developed for a wide range of heads and flows and are available in the UK at costs of less than £2,000 per kW. The electricity generated from these units may be used on site or sold to the grid under the Renewables Obligation for ~4.5 p per kWhr.

### 8.3.4 Potential for Sustainable Energy Generation at Dry Rigg

As an example, upon completion the quarry lake will represent a significant volume of water 3,480 MI held in storage and relatively isolated from surrounding groundwater and surface water features. This could provide a useful supplement when required to local water resources, although given the sparse local population it may not be required. The catchment of the lake is also relatively small limiting the available recharge. Micro energy generation (eg hydropower and heat pumps) for a small local business, eg greenhouse/aquaculture, may be considered as an option given the available head difference between the lake (224 mAOD) and the valley floor (210 mAOD). Applications might be suited that require significant inputs of energy on demand. Potential annual heating derived from a heat pump could amount to some 7,300 Mw per annum for an electrical input of 1,825 Mw.

Hydroelectric generation potential is estimated as 22.6 MW/yr (6,271 kWhrs) on the valley floor, so theoretically an application could utilise some (25,084 kWhrs) of 'free' heat energy using a heat pump powered by hydroelectricity concentrated over a desired time period.

## 8.4 The eco-park

The availability of sustainable resources may complement the creation of an ecologically friendly development or 'eco park' such as the very successful Cotswold Water Park. The use of sustainable energy will add value to the final restoration, reduce carbon emissions and potentially benefit the surrounding community. Natural water treatment (ie reedbeds), water supply, habitat development and recreation facilities may all be utilised in conjunction at the site. Sufficient land is often available for the construction of required facilities and necessary engineering works may be undertaken as part of the restoration.

The site at Scorton near the River Swale where Tarmac is still in the initial phase of sand and gravel extraction provides a potentially suitable site for such a sustainable development. Restoration proposals potentially include the creation of a series of linked waterbodies with an outfall to the Swale. The site has good potential for the use of an efficient open-loop ground source heat exchange system with minimal pumping costs due to the potential for a gravity feed. An adequate water supply is available to meet the project requirements and electricity demand may potentially be offset by micro generation on-site (hydroelectric). A flow rate of at least 75 to 100 l/s is available with a drop in head of ~7 m across the site. Peak demand is likely to be during the winter when maximum water flows are likely to occur.

The following opportunities have been identified for the application of heat pump technology at the site:

- Quarry office
- Agricultural (greenhouses & covered growth sheds, potential for the Tarmac owned farm adjacent to Scorton lake)
- Aquaculture (heated fish ponds)
- New build homes
- Potential industrial units
- Existing dwellings around the various lakes (feasibility would need to consider pumping costs, conversion costs and distance to properties from heat sources)