Renewable Energy Technologies Impact Assessment

Introduction

This paper was produced by D.A.R.E. for the South Devon AONB Partnership to compare and contrast the impacts across a range of renewable energy technologies. This work arises from an action in the AONB Management Plan which commits the Partnership to adopting a supportive position on the development of renewable energy and identify the technologies appropriate to the sensitive landscape of the AONB. D.A.R.E would like to thank South Devon AONB for permitting this matrix to be allowed into the public arena

Background

It is now widely accepted that burning fossil fuels contributes to greenhouse gas emissions and global climate change, and that their use must be significantly decreased in the short to medium term. Fossil fuels are also a finite resource and evidence suggests demand is about to exceed supply leading to progressive shortages in the near future.

There are growing calls for the UK to build a second round of nuclear power stations but no mention is made that Uranium Oxide, like fossil fuels, is also a finite resource. Uranium Oxide exists in abundance throughout the earth's crust but at very low density, so low that it will take more energy to recover than it contains. The World's known reserves of economically recoverable Uranium is estimated at less than 4 million tonnes, and at current rates of use there is about 50 years worth of supply. Climate change is a global phenomenon; going nuclear may reduce the UK's CO_2 emissions but will do little to mitigate global greenhouse gas emissions unless the World transfers to nuclear power on a large scale, in which case the Uranium could run out before the oil does! Also, if Climate Change scientists are right and sea levels rise by 10's of meters over the next few hundred years, then all our existing nuclear power stations, which are at sea level, will become inundated. Whilst the Uranium fuel itself will be removed, the reactor core will be too dangerous to move. Since the radioactive half-life of Uranium is about 1000 years, there will either have to be an extensive (expensive) programme to make the old reactors safe or our seas will be polluted. Some believe nuclear fusion holds the promise of unlimited cheap energy; so far fusion energy has eluded science. If fusion ever becomes reality, by its nature it will be a 'centralised' energy source. Going nuclear will divert resources that could be used for renewables now, and retain corporate control over our energy supplies.

Accepting that neither the *'business-as-usual'* approach nor the nuclear option are sustainable, and that however much demand is reduced by 'contraction' or 'energy efficiency', there will always be a need for a supply of heat and power. The only long-term sustainable solution lies in the development of non-polluting renewable energy.

The world needs to develop a strategy to determine the best mix of energy sources to produce a secure and sufficient supply of affordable, non-polluting energy. The matrix below compares the various renewable energy and conventional technologies across a range of impacts. What becomes clear is that every technology has some impact; the choice is which impacts are acceptable.

Energy policy context

Accepting that the continued use of fossil fuels is not sustainable both from an environmental and resource perspective and that using nuclear fuel is not sustainable either, adopting Renewable Energy is the only sustainable alternative. However this will involve building a completely new infrastructure that will take time. The UK government, in a White Paper on Energy, has set out a rolling programme for the uptake of renewables. The programme sets two forms of targets; 1) a reduction in carbon emissions based on 1990 levels of carbon. And 2) for a % of our electricity energy needs to be generated by renewables.

With regard to the first target, the UK is more or less on target. This is being achieved by a combination of adopting energy efficiency measures but more importantly by reducing our use of coal

and oil and changing to gas, which burns more cleanly. Whilst this has been a successful policy in the short term it does mean our finite supply of gas will be used up more quickly and unless renewable technologies are installed at an adequate rate, continuity of supply after the gas runs out is far from assured.
With regard to installing renewable technologies, the UK is nowhere near on target. The first target is to produce 10% of our electricity needs by 2010. In the case of Devon this amounts to installing 151 MW of renewable capacity. At the time of report (November 2005) the level stands at 63 MW. The government is currently in consultation to set the 2020 renewable targets.
Given that the South West, facing the Atlantic Ocean as it does, is blessed with both good wind and wave energy regimes, a lot more needs to be done.

DARE
The Devon Association for Renewable Energy is a ‘not for profit’ company whose aim is to promote the generation and use of renewable energy in Devon. DARE achieves this by working with Local Authorities at Regional, County and District level, Community groups, Developers of new build and individuals to offer impartial advice on renewable energy technologies. DARE has successfully undertaken a number of micro-hydro assessment surveys, facilitated several large community projects and is currently engaged with four AONB areas delivering renewable energy scoping studies.

The impacts matrix
The attached table summarises the impacts and viability of a range of energy technologies.

Comment by technology

Photovoltaics (PV)
Visual - can be integrated into the roof structure and be colour matched with the roof become almost indistinguishable from the roofing tiles – hence low impact. On the other hand PV can be retrofitted to a roof and stand proud of and possibly be a different colour from the roofing slates and hence stand out, but because PV is fixed (stationary) in this instance is classified as M. Once installed there is no traffic issue. If installed on a domestic property it is unlikely there will be any transmission lines issue. There is no noise, smoke or smell. Being modular PV panels can be fitted in any size array. The output is always electricity. Because the manufacturing process is complex PV remains an expensive technology, although there is a belief that costs are being maintained artificially high due to vested interested in the oil industry. The primary raw material is silicon, which is plentiful, but there may be some concern over other rare metals used in the process. Further research and development continues and steady improvement in output and costs may be expected. There is hope that a completely new solar cell based on ‘Die-sensitised cells’ will emerge in the near future.

Solar hot water (SHW)
Visual - much like PV can be integrated into a roof structure but more likely to be retrofitted to a roof so stand proud of the surface. There are two main types; flat plate which as the name suggests comprises a glazed large flat plate of black material with water pipes attached to the rear surface, and evacuated tube consisting of a row of cylindrical glass tubes and a header tank. Hence low to medium visual impact. Once fitted there is no traffic issue. There is no transmission, noise, smoke or smell issue. Scale - generally between 2 and 4 sq metres in size. The output is always hot water. A well established technology with a good supply chain: costs are very competitive. There is little environmental problem.

Solar hot air (SHA)
This is a relatively new technology – Similar to a flat plate solar hot water heater, a roof mounted glazed panel containing a black absorber surface is connected to air pipes. A small fan draws air from the house interior, passes it through the solar absorber, where it is heated and then passes back into the house. The system is often coupled with a heat recovery ventilation unit to allow stale moist air to leave the building whilst pre-heating fresh incoming air.
Visual - again similar to solar hot water. Once fitted there is no traffic issue. There is no transmission, noise, smoke or smell issue. Scale - generally between 2 and 4 sq metres in size. The output is hot

air and also hot water. A new technology so costs have yet to settle down. There is little environmental problem.

Wind 1.3MW

Visual - the 1.3MW wind turbine is the 'second generation' industry standard. Standing 65m to hub height with blades of 45m, the blade tip can reach 110 m above ground. There can be no question that this size of wind turbine is highly visible particularly since to be economic they need to stand in a good wind stream (average wind speed at hub height 7.5m/s), which normally means on hilltops or high ground. In certain light conditions 'blade flicker' can produce a stroboscopic effect: this is well understood and wind farm designers can programme individual turbines to 'switch off' if the problem is likely to occur. Once installed there are no traffic, transmission, smoke or smell issues. Noise was a concern with 'first generation' turbines. Noise used to emanate from two sources; gearboxes and blade tips. Second generation turbines either have no gearboxes or better engineered (quieter) gearboxes and blade rotational speeds have been reduced to eliminate tip noise. As each blade sweeps passed the tower, occasionally a "whooshing" sound may be heard in certain directions from the blade. In higher wind speeds the sound of the wind in the trees drowns out any turbine noise and rarely is noise a problem more than 400m from the tower. There is a suggestion that 'infrasound' (low frequency sound – below the threshold of human hearing) is a problem. Research to date suggests that this is not a problem, but investigations are ongoing. The output is always electricity. The economics are good. They can pay back, in energy terms, their cost of manufacture in about 6 months. In environmental terms they are benign; cattle and sheep graze right up to the base of them, birds do not fly into them. Electronic - there is a possibility that radio, TV and or radar signals could get reflected from the rotating blades causing some interference.

It is worth mentioning that 'third generation' wind turbines have been tested and are soon due to become the new industry standard. At 2.75MW they produce more than double the amount of power although the blades are only about 10m longer. The hub height is raised by about 10m giving an overall height of 130m to blade tip. Early results suggest the 2.75MW turbines operate economically in lower average wind speeds (6.5m/s) so offer the opportunity to site them in less 'landscape sensitive' areas. Also because the wind blows more often at lower speeds (it has to blow at 6.5m/s before it can blow at 7.5m/s) the larger turbines generate for a greater period of time each year so produce proportionally more energy.

The first 'fourth-generation' turbine (5MW) has been constructed (2005) and is just starting a test programme.

Despite vocal opposition from a few, at the present time large wind turbines are the only technology that is 'market ready' and offer the best opportunity to generate cost effective, pollution free energy quickly.

Wind 6kW

Visual - this size of turbine is most frequently used for small off-grid sites, typically on a 9m tower with a blade diameter of 5m. Once installed there is no traffic, transmission, smoke or smell issues. Noise may be an issue, as generally smaller turbines rotate at higher speeds so generating tip noise. Also being closer to the ground the noise may be louder close to. However since this size of turbine is generally chosen for remote sites the only people likely to be disturbed are the owners themselves. The economics are less attractive than larger turbines (costs about £25,000).

Wind – 72W

Visual - at 1 m in diameter and on a 9m tower, the visual impact is minimal. Similar comments as the 6kW apply. Several manufacturers are about to launch 1kW size wind turbine designs intended to be roof or chimneystack mounted. Private dwellings are the target market. One manufacturer is marketing a wind device that will simply plug into a standard 13amp three pin socket and will offset mains electricity by driving the meter backwards. There may be concerns about noise vibration within the building to which the appliance is attached. At 1 kW they will be about 1.5 – 2m in diameter and if installed in an urban setting would be visible to neighbours.

Micro-hydro

By its nature any micro-hydro installation is likely to be a valley bottom. Visual intrusion is likely to be minimal; any turbine house would be small (about the size of a domestic garage) and could be screened. Transmission – a grid connection power line is possible depending on the circumstance. Once installed there are no traffic, smoke or smell issues. Noise may be an issue but appropriate sound insulation should mitigate this. Scale - given the topography of the landscape and the rainfall for the South Hams it is unlikely there will be any large hydro schemes. A number of smaller schemes is more likely. Economics - micro-hydro costs are very site specific. A new site may require civil engineering works that will add to the cost. Renovating an old mill site can be a very cost effective option. Micro-hydro is capital intensive initially but if well designed will offer many years (70+) of operation. Pay-back should be possible in under 10 years. The output can be either electricity or mechanical. Mechanical can be used to power a heat pump (see section on heat pumps to follow). Other impacts – micro-hydro can have environmental impacts but all negative impacts can be mitigated (fish ladders, fish protection screens). Micro-hydro can have a number of positive environmental benefits (water aeration improves oxygen levels, trash racks screen out floating debris, and leats can provide new aquatic habitats).

Tidal

Visual - tidal can be located either at sea or in tidal estuaries. It can take the form of a marine current turbine on the ocean floor (no visual impact at all) or be mounted on a pile the top of which is visible above sea level but out at sea (minimal visual impact), or in the form of a barrage across an estuary through which the tide flows (highly visible). Transmission - for 'at sea' installations, an undersea cable will need to be laid. Once ashore, the power is likely to be connected into the grid system so overhead power lines are likely. Similar applies to barrages. Once installed there should be no traffic, smoke, smell, or noise issues. Scale & economics - tide mills used to be part of the pre-Industrial Revolution landscape so can be done at small scale. However given the technical nature and difficult installation requirements of larger installations, tidal power is likely to be very large scale to be economic. Environment - large scale tidal installations will have an environmental impact – how that impact may be mitigated is not clear as yet.

Wave

Visual – wave-power installations can be located either at sea or on the shoreline. They can be either on the surface (visible) or seabed (not visible). Currently there are 22 designs for potential devices. It is likely that many designs will prove uneconomic or not robust enough to make it to market. Transmission - for 'at sea' installations, an undersea cable will need to be laid. Once ashore, the power is likely to be connected into the grid system so overhead power lines are likely. Similar applies to barrages. Once installed there should be no traffic, smoke, smell, or noise issues. Scale & economics - wave technology is new, however given the technical nature and difficult installation requirements of larger installations wave power is likely to be very large scale to be economic. Environment - large scale wave installations will have an environmental impact – how that impact may be mitigated is not clear as yet.

Miscanthus energy crop

Visual - Miscanthus (Elephant Grass) can grow up to 3m in height. Once planted the rhizomes can remain in the ground indefinitely (20 years +). Typically planted in February/March the crop grows steadily through the growing season to reach maximum height by late summer. During the autumn the chlorophyll is re-absorbed into the roots and the colour changes from green to pale buff. The crop remains standing all winter and continues to dry out on the stalk. The crop is harvested once a year in February/March and can be cut with conventional grass cutting (silage) farm machinery. Once harvested the plant re-grows from the roots. The crop is visible but may be considered as part of the agricultural landscape. Transmission is not an issue. Traffic – 'on farm' use is likely to generate less traffic than normal farming practice. Some crops require many tractor movements (ploughing, harrowing, seeding, spraying, harvesting) but, once planted, Miscanthus requires only a single pass (1*) to harvest each year. However if used in a large bio-powered power station there may be many lorry movements converging at the power station to deliver the required amount of feedstock. Smoke could be an issue at a power station, but modern combustion technology and clean air legislation should mean there is no problem. Smell shouldn't be an issue. Noise - there will be some farm machinery noise in the field once a year. There may be noise from lorry movements close to a power station. Scale - at present, scale is dictated by economics. Large scale offers economies of scale so is more viable. However smaller combustion plant is now available so can be smaller scale. Economics - Miscanthus has a number of other uses (animal bedding, fibre boards) some of which are more remunerative than growing as an energy crop. However Miscanthus could be used more than once in a 'circular' process ie first as animal bedding then as a feedstock for anaerobic digestion to produce methane (see later). Environment - being a rhizome, Miscanthus does not spread (escape) in an uncontrolled manner. It binds the soil so mitigates soil erosion. Because the crop is harvested once the year it provides good ground cover for wildlife (ground nesting birds can remain undisturbed at nesting time). The rhizome network provides good support for tractors when they do need to access the land. Miscanthus can provide a buffer crop as part of an integrated catchment management programme.

Short Rotation Coppice energy crop (SRC)

Visual - short rotation coppice (usually a Willow cultivar) can grow to 4 – 5 m in height. Once planted the crop takes 3 – 4 years to grow to first harvest and is then harvested on a 3 year rotation. The crop usually remains in the ground for about 15 years then may need lifting and replanting with another crop to avoid soil depletion. Because the crop grows over a three-year period the visual impact is that of a semi-permanent scrub woodland. Traffic – once established the crop is harvested on a three year rotation so tractor movements are one to three years (1:3*). If the output is used to fire a biomass power station there would be lorry movements close to the station. Transmission lines are likely. Noise –traffic movement near power station, otherwise minimal. Smell & Smoke – not an issue. Scale – It is unlikely that any one farm will have the land area available to develop a completely viable system. It is more likely that a number of farms within a locality will each grow some SRC and supply a central power station. Therefore there is likely to be a large number of small patches of SRC across the landscape. Economics - difficult to assess at this time: needs a co-ordinated approach to put growing and using infrastructure in place. Other impacts – there may be some concern that the 'Rust' resistant strains of SRC cultivars used may hybridise with natural willow populations altering the natural willow.

Oil Seed Rape energy crop (OSR)

Visual - OSR is an 'annual' plant sown and harvested within a single year. Its visual impact is therefore part of the 'patchwork' of diversity of cropping within the agricultural landscape. However when in flower the crop is a bright (highly visible) yellow. It is a matter of opinion whether this is visually acceptable. Transmission – at present OSR is harvested and transported away from farms for processing elsewhere so transmission lines are not an issue. However research is underway to establish whether 'on farm' processing can 'add value' to the crop. If successful the processed product may either be sold as a liquid fuel (diesel replacement) from the farm gate or used to power a CHP plant on site, the power and heat being distributed locally. So transmission lines may be a possibility in the future. Traffic - at present confined to tractor movements on the land to plough, sow, fertilise, spray and harvest the crop plus lorries to remove crop for processing. Noise & smell - other than noise of vehicle movements not an issue. Scale – generally individual farms confine planting as part of a crop rotation scheme so may be a few acres to tens of acres. Economics – as an energy crop at present marginal. Crop needs several passes with tractor. Hence research to improve return on crop so may be more economic in future. As a 'second use' crop (waste vegetable oil) the economics are good. Environment - there are three concerns. 1) Genetically modified varieties may be cross-pollinating with pure strains. 2) OSR pollen may contribute to hay fever and asthmatic conditions. 3) The crop seeds freely and 'escapes', and rogue plants re-appear the following season. Roadside verges and watercourse banks appear to be offering a mechanism to spread rogue self-seeding plants.

Wood fuels

Visual – Woodlands fall into two categories; naturally established woodlands of native tree species and man made plantations, frequently of a single species established as a commercial crop. Generally the former is seen as enhancing the appearance of the countryside and the latter is of questionable appearance. Transmission – woodfuel may be used to co-fire an existing fossil fuel power station, but in this instance all the transmission infrastructure already exists. More likely woodfuel will be used to supply heat so transmission lines are not relevant. Traffic – Where a commercial timber crop is harvested there may be a number of lorry movements removing the crop. However it generally takes many years for a crop to reach maturity so traffic movements will be confined to a concentrated activity over a short time period. In established woodlands there may be more frequent but low level traffic movements by local woodsmen. Noise – logging frequently requires the use of chainsaws and tractors to remove timber from deep within the wood. However this activity tends to be sporadic. Smell – not usually an issue. Smoke – not generally a problem, some waste timber may be burned on site but is frequently left on site to rot or provide habitat for insects etc. Scale – natural woodlands and commercial plantations may vary in size. Economics – The whole purpose of commercial plantations is economic gain. Historically many natural woodlands have not been seen as economically viable and have, as a consequence, been left unmanaged. With the growing awareness that timber is a 'carbon neutral' energy source, many people are buying wood stoves so the economics may be seen as improving. Environment – Apart from the issues associated with growing large areas of single species plantations, there are few concerns.

Anaerobic Digestion (AD)

Background - all organic material rots, being broken down by enzymes, bacteria and fungi to release nutrients for reuse in nature. Where organic material is broken down in an oxygen free environment, methane (CH_4) a very clean burning gas suitable as a petrol/diesel replacement, is produced. (Burning methane releases CO_2 on a one for one molecule basis, but CO_2 is 21 times less injurious than methane). Visual – the visual impact is directly proportional to scale. AD plant can be small and located within existing buildings so have no visual impact at all. Conversely can be large scale with dedicated plants and so will be visible. Transmission – depends on end use; being a gas it can be compressed into tanks and taken away by road. Could be used on site to power a CHP plant so there could be local transmission lines. Traffic – there may be traffic movements bringing feedstock to and removing processed feedstock from the plant. Noise – only usual associated with traffic movements. Smell – a possibility due to fact feedstock is of organic nature so rotting may be in process. Animal slurries and municipal waste can smell so does need to be regulated. Smoke – not an issue. Scale – can vary from very small to very large. Economics – research continues to enable the process to be economically viable in an increasing variety of systems and situations. Other impacts – there are potential serious issues associated with dangerous pathogens and heavy metals being released so robust control is necessary. However there is scope for significant environmental benefit by using AD. Independent monitored tests indicate that AD reduces the count of Faecal Streptococci from 1.3 million bacilli/gram to less than 5/gram. (an infective dose of Faecal Streptococci is about 100 bacilli per gram). Some suggest AD could be used to convert all animal slurries, food waste and municipal waste into energy, giving a valuable soil conditioner and possible fibreboard material and a liquid fertiliser.

Heat Pumps

Heat pumps are mechanical devices that absorb heat from a large low grade heat source and deliver a smaller quantity of high grade heat. The low temperature heat source can be; air, water or the ground. Here we discuss ground-sourced heat pumps (GSHP) as these are the most likely installation.

Visual - by their nature GSHP are underground (either vertical borehole or horizontal trenches) so once installed are not visible at all. Transmission – the energy output is heat which is usually used within the building where it is captured so no transmission lines. Traffic – once installed no traffic. Noise, smell and smoke are not an issue. Scale – can be any size. Economics – high initial capital cost but low running costs so long term benefit.

Fuels Cells

Fuel cells are an energy conversion technology. One of the issues with renewable energy is that being reliant on natural flows of energy they are intermittent in nature, sometimes being abundant and other times being insufficient to meet demand. When energy is surplus to demand it may be converted to hydrogen gas and stored. When demand exceeds supply the hydrogen can be passed through a fuel cell to generate electricity.

Visual - fuel cells may be used to power motor vehicles of the future or may be land based to help regulate fluctuations in demand in the grid. In the case of vehicular use there will be no visual impact other than the vehicles themselves. For land-based applications, fuel cells are likely to be enclosed in a building. Transmission – if used for vehicle motive power – no issue. However where used to overcome issues of 'interuptibility' of other renewable energy sources there may be transmission lines. Traffic – no different from other traffic problems. Noise, Smell, Smoke are not an issue. Scale – if used in a land-based scheme could be large. Economics – high initial capital cost but low running costs so long term benefit. Environment – some types of fuel cell may contain rare elements so there may be some issues but because this is a technology in development it is not possible at this time to say which type of fuel cell will come to dominate the market so quantify the problem. It is more likely that there may be issues associated with the primary generation energy to produce the hydrogen. If energy generation moves towards renewables this should not be an issue.

Passive

Passive solar gain is not a renewable energy technology as such but is included here for completeness. The concept relates the orientation of buildings to maximise the gains that can be achieved by using solar energy direct. Areas of south facing glazing admit sunlight to reduce the need to light and heat building interiors. Care must be taken with design to avoid overheating in summer and avoid the need to use energy to cool the building.

Energy Efficiency

Again not a renewable energy technology but methods of reducing energy demand whilst maintaining the same utility. The more obvious methods are to insulate buildings to reduce the heat leakage. Replacing older heating boilers with modern high efficiency boilers. Replacing refrigerators and other white goods with grade 'A' (or better). Replacing tungsten light bulbs with compact fluorescent tubes or L.E.D's.

The technologies describe below are the conventional energy generation methods and are included for comparison.

Biomass Power Stations (large scale)

Visual – Depending on size, like conventional power stations they are likely to be highly visible. Transmission – will be connected to the National Grid. Traffic – the feedstock (miscanthus, short rotation coppice) will need to be grown in the surrounding countryside and transported to the site. It will become increasingly uneconomic to transport more than 10 – 15 kilometres. Noise – associated with industrial nature of process. Smell – possible but unlikely in a well-managed plant. Smoke – possible but unlikely provided combustion well managed. Scale – Likely to be medium to large scale for economies of scale to operate. Economics – will need to balance cost of feedstock transport against value of energy produced both in finance and environmental costs. Environment – short term impact whilst building – possible longer term impact due to transport needs.

Coal

Visual - coal mines may be either 'open cast' or deep mine. Open cast are highly visible. Deep mine is also visible because of associated pit head works and slag heaps. Power stations are highly visible with cooling towers, chimneys, electricity sub stations etc. Transmission – National Grid across the country. Traffic – generally power stations are built close by to minimise traffic but due to large quantity transport is often by train. Noise – associated with industrial nature of process. Smell – sulphurous smells from combustion. Smoke – from power station chimneys. Scale – generally very large scale. Economics - clearly viable as this is still a significant means of energy generation. Environment – huge environmental impacts due to release of greenhouse gas emissions, coal mine head gear, open cast mines, spoil tips, sulphur emissions.

Gas

Visual - generally gas is transmitted by underground pipelines and is not visible. Power stations using gas as their fuel are generally smaller than coal fired because gas can be easily transported so power stations can be local to where the energy is to be used. Transmission – power lines may be an issue as with other power stations grid connected. Traffic is less of a problem because the fuel is brought in by pipeline. Noise - is less of a problem due to reduced vehicle movements. Smell – is not normally an issue. Smoke – gas is clean burning so not normally an issue. Scale - can be a small stand alone back up facility or a large grid connected power station. Economics - clearly viable as this is now the most significant means of energy generation in the UK. Environment – although gas burns more cleanly so the emissions are reduced, it is still a fossil fuel and releases carbon dioxide so there remains a significant environmental impact.

Oil

Visual - impacts range from huge oil refineries to small domestic oil tanks. Transmission – can be used for large power stations connected to the national grid with associated power lines; or can be used independently at domestic scale for heating purposes with no transmission lines. Traffic – usually transported by road tanker and/or used as a road transport fuel so massive traffic implications. Noise – that associated with industrial plant. Smell – can give off sulphurous fumes. Smoke – not usually an issue but diesel engines can give off particulates. Scale – can be any from domestic heating to power stations. Economics – oil price is the basic unit by which other energy uses is measured (millions of tonnes of oil equivalent (Mtoe)). Oil is the 'primer mover' for the energy requirements of the world and it is concern about oil depletion and supply limitations that may well see an increase in price of oil. Any significant increase in oil price could make other, currently less economic technologies as listed above, become more economically viable. Environment – it is concern about the greenhouse gas effect of carbon emissions from burning oil that is the major concern. Sulphur emissions, oil spills.

Nuclear

Visual - whilst Uranium Oxide is ubiquitous, it is only worth mining in a few locations around the world so from a UK perspective there is no visual issue with mining. Nuclear power stations are large-scale industrial plants with associated sub-stations and power transmission lines. Once a nuclear power station has been commissioned traffic movements are usually confined to staff going to and from work. Generally noise, smell and smoke are not an issue. Scale – by their nature they are large scale. Economics – originally marketed as supplying energy so cheaply it wouldn't need to be metered, this has proved not to be the case, no account having been taken of the huge costs associated with de-commissioning. Economics continue to be a concern with large government loans to keep the operating companies in business. Environment - there are several serious concerns about the environment: 1) Whilst not using water cooling towers, nuclear power stations are invariably located close to water for cooling purposes. Vast quantities of warm water are released into the local environment altering the natural flora and fauna. 2) To gain access to large quantities of water nuclear power stations are invariable located at or near sea level and may be vulnerable to sea level rise. 3) The process produces radioactive waste (Uranium 235, Uranium 238 and Plutonium). In some instances the half-life is millions of years. No one knows what the long-term environmental implications are.

Combined heat and power (CHP)

Whether used as transport fuel, gas or oil for heating or as electricity, 89% of all the energy used in the UK comes from fossils fuels and a further 8% comes from nuclear fuels. In all cases the primary energy given off is heat. In the case of electricity generation the heat from the primary fuel is used to boil water to create the steam to power the turbines. It is inherent in the nature of heat engines that only a third of the heat can be converted into electricity. Because heat degrades quickly, unless there is a demand for the waste heat close to the power station, the waste heat has to be vented to atmosphere in cooling towers. The UK has a centralised structure of power stations and National Grid to distribute the power to the end users, about two thirds of the energy used to generate electricity is wasted. CHP is a de-centralised system of power generation on a smaller scale and local to where the power is needed. This means both the heat and the power can be used so eliminating the waste. The technology is much the same as used with centralised generation but CHP allows for a more efficient use. It is now possible to replace a domestic central heating boiler with a micro CHP boiler in which gas is used to power a small engine that generates electricity and the heat that would otherwise be wasted is used to heat the home.

Conclusions

There can be no doubt that how we generate our energy will change radically over the next 45 years or so. Today fossil fuels play, and in the short to medium term will continue to play, a vital role in meeting our energy needs. But by 2050 fossil fuels are likely to be in such short supply, market forces will mean their cost will be prohibitive - we are already beginning to see this happen. Also by 2050 that there will be a better understanding about the limitations of nuclear energy, although it is quite likely in the short term, political expediency may dictate that a small number of second-generation nuclear stations will be built. Ultimately the only inexhaustible source of primary energy is the sun. The sun delivers to planet Earth enough energy in one hour to supply the entire world's energy needs for a year. However most of that energy is very diffuse so it is more realistic, and safer, to assume that only the more intensive natural energy streams will be economic to exploit.

Because natural energy streams are diffuse and intermittent no one technology can deliver all our energy needs; this means a portfolio of strategies will be needed to ensure a sufficient and affordable supply. Since we cannot ignore the economic realities of life it is likely the more cost effective solutions will be adopted first.

In practice this means we must maximise the benefits of adopting energy efficiency measures. Once we have reduced our energy demand then renewable technologies will come into their own. Solar hot water heating and onshore large-scale wind turbines are already cost effective and installations are seen in increasing numbers. It will take time to get a renewable infrastructure in place, so there will be a transitional period where both fossil fuel, nuclear and renewable technologies co-exist. As the cost of conventional fuels rise so energy prices will progressively cross successive thresholds at which individual renewable technologies will become cost competitive. It is difficult to forecast the timetable with any accuracy.

The biggest single barrier to the uptake of renewables is cost. The oil industry is fully aware of this but it is highly unlikely they will announce a 'countdown' to the expiry of oil as this will trigger a premature mass exodus to other energy sources - oil left in the ground is valueless. More likely the oil industry will seek to assure us that oil reserves are plentiful until the last minute. Decision makers will need to be aware of the politics of oil pricing to ensure they do not caught unaware by the end of the 'oil age'. The reality is the oil industry is already diversifying into renewables. This is a classic case of; 'We hear what you say, but see what you do.' On the other hand decision makers should not rush to adopt expensive renewable technologies ahead of time, as this will impose an undue economic burden on their community. A sensible strategy will be to progressively adopt the 'best available technology' as each technology crosses an economic threshold.

Onshore large-scale wind turbines are economic today but are undoubtedly conspicuous features in any landscape so if their uptake is to be avoided, positive leadership must be shown to encourage other, less visually intrusive renewable technologies such as: building integrated solar hot water, PV and developing micro-wind turbines; micro-hydro, local waste to energy facilities such as anaerobic digestion of organic wastes to power CHP systems and district heating systems; and the growing of energy crops.

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