National Assembly for **Wales**
Cynulliad Cenedlaethol **Cymru**

Renewable Energy

Abstract

This paper provides background briefing on renewable energy, the different types of technologies used to generate renewable energy and their potential application in Wales.

It also briefly outlines energy policy, the planning process, possible problems associated with connecting renewable technologies to the electricity grid and energy efficiency.

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Renewable Energy

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Note – measurement of energy

Watt (W) is a measure of instantaneous power or capacity
1 Gigawatt = 1,000 Megawatts = 1,000,000 Kilowatts = 1,000,000,000 Watts
1GW = 1,000MW = 1,000,000kW = 1,000,000,000W

Watt-hour (Wh) is total energy over time (one watt expended for period a of one hour)
1 Terawatt hour = 1,000 Gigawatt hours = 1,000,000 Megawatt hours = 1,000,000,000 Kilowatt hours = 1,000,000,000,000 Watt hours
1TWh = 1,000GWh = 1,000,000MWh = 1,000,000,000kWh = 1,000,000,000,000Wh

Cynulliad Cenedlaethol Cymru
National Assembly for Wales

Renewable Energy

1 Introduction

This paper provides some background information on the different types of renewable energy generating technologies and their potential application in Wales and the UK.

It also briefly examines energy policy and the reasons behind the drive to promote renewable energy and some of the issues associated with renewable energy, such as the planning process and connecting renewable electricity generators to the electricity grid.

In addition to examining technologies such as wind, wave, solar, biomass and hydrogen energy, the issue of energy efficiency is briefly explored.

Currently, less than three per cent of the electricity generated in Wales is from renewable sources. The UK Government has made a commitment to generate 10 per cent of the UK's electricity from renewable sources by 2010 and 20 per cent by 2020.

The Welsh Assembly Government has set a target of producing 4TWh electricity per year from renewables by 2010 and 7TWh per year by 2020. Welsh electricity production is about 33.5 TWh per year, so 4TWh is equal to just over 10 per cent of the electricity production of Wales.[1]

Production of 4TWh requires an installed capacity of about 1,500MW. There is currently 450MW installed capacity in Wales, made up of onshore wind farms, offshore wind turbines, biomass and hydro-electric generators. In total, this installed capacity generates abour 1.4TWh electricity per year. To meet the target, an extra 2.6TWh electricity per year are needed by 2010. The Welsh Assembly Government has estimated that this requires an additional installed capacity of 1,000MW. Eighty per cent of this is anticipated to come from onshore wind farms, with the remainder coming from offshore wind farms and other sources of renewable energy.[2]

2 Background

Renewable energy is a general term used to describe any source of energy that occurs naturally and is not exhaustible, such as solar power, wind power or wave power. Energy from biological sources, such as wood burned as fuel, or biodiesel made from vegetable oil, can also be described as renewable if the crop is managed sustainably.

Climate change is a major driver in the move towards increasing the use of renewable energy. Increased levels of 'greenhouse gasses' in the atmosphere lead to climate change. Greenhouse gases, when released into the atmosphere, absorb heat, keeping it close to the earth and making the temperature warmer than it would normally be. The additional warming affects the climate of the earth, potentially changing air and ocean currents, weather systems, melting snow and ice and leading to increases in sea level. These changes would have knock-on effects on habitats and species distribution. Changes in weather and temperature could affect agriculture or lead to an increase in

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[1] *Review of Energy Policy in Wales Part 1: Renewable Energy*, Economic Development Committee Report for Consultation, April 2002, National Assembly for Wales
[2] *Technical Advice Note (TAN) 8: Planning for Renewable Energy*, (2005), Welsh Assembly Government, http://www.wales.gov.uk/subiplanning/content/tans/tan08/newtan8/tan8-e.htm

extreme weather conditions (e.g. floods, storms, droughts) and associated costs to the economy.

The main greenhouse gas is carbon dioxide (CO_2)[3], released by activities such as the burning of fossil fuels (coal, oil and gas) in power stations and vehicle engines. The Earth's temperature does vary naturally and natural processes (e.g. volcano eruptions) also release CO_2, but these are not sufficient to account for the observed changes in the Earth's temperature[4].

Additional motives for increasing renewable energy use include reducing pollution from fossil fuels and increasing the security of energy supply. Within a few years, the UK will not be self-sufficient in energy generation and will have to import energy or fossil fuels.[5] Renewable energy can be generated from a range of sources. Increasing diversity of supply and the use of UK-generated renewables will reduce any over-reliance on any one source of energy or on imported fossil fuels, making the supply of electricity / energy in the UK more secure.

2.1 Renewable energy targets

The Kyoto Protocol, as part of the United Nations Framework Convention on Climate Change (UNFCCC) sets out detailed, legally binding emissions targets that signature parties must meet by cutting their greenhouse gas emissions. In total, these cuts amount to a five per cent reduction in emissions compared to a 1990 base level by 2008 – 2012. The EU's target for emission reductions is eight per cent, which it can distribute among its Member States. The UK's target in contributing to this goal is to reduce emissions by 12.5 per cent.

The EU's signing of the Kyoto Protocol boosted the importance of environmental aspects and sustainability to EU energy policy and the promotion of renewable energy is seen as being an important step in the EU reducing its reliance on energy imports. The EU is currently dependent on imports for 50 per cent of its energy requirements.[6]

In 2001 the EU adopted a *Renewable Energy Directive*[7] establishing national renewable energy targets for each Member State. The targets are not legally binding. The Directive aims to double renewables' share of energy production by 2010. Most of the increase is expected to come from biomass and wind energy production. A 2003 report by WWF states that the EU will fall at least 5 per cent short of its target to produce 22 per cent of its energy from renewable sources. The countries mainly responsible for not making the target are likely to be Italy, the UK, Greece and France[8].

2.1.1 UK Energy Policy

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[3] Other greenhouse gases include methane (CH_4), nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). All these greenhouse gases are included in the Kyoto Protocol's emission targets.

[4] *Energy white paper: Our energy future – creating a low carbon economy*, (2003), Department of Trade and Industry, TSO, http://www.dti.gov.uk/energy/whitepaper/ourenergyfuture.pdf

[5] At current levels of use, the UK will become a net importer of energy in the future. At present, the UK imports 50 per cent of the coal it uses, will be a net importer of gas by 2006 and a net importer of oil by 2010. By 2020, the UK will be dependent on imports for 75 per cent of its energy needs.

[6] *Green Paper, Towards a European Strategy for the Security of Energy Supply*, (2002), European Commission, http://www.europa.eu.int/comm/energy_transport/doc-principal/pubfinal_en.pdf

[7] *Directive 2001/77/EC of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market*, Eur-Lex website, http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32001L0077&model=guichett

[8] *EU unlikely to meet renewable energy target*, (2003), Edie weekly summary 03/10/2003, Edie website, http://www.edie.net/gf.cfm?L=left_frame.html&R=http://www.edie.net/news/Archive/7578.cfm

The *Energy White Paper*[4], published in February 2003, by the Department of Trade and Industry (DTI) is the UK Government's (including the devolved administrations) overall strategic energy policy. It covers energy production, energy efficiency, industrial and domestic energy use and transport and sets out four main goals for the coming years:

- to put the UK on a path to cut CO_2 emissions by some 60 per cent by about 2050, with real progress by 2020;
- to maintain the reliability of energy supplies;
- to promote competitive markets in the UK and beyond, helping to raise the rate of sustainable economic growth and improve productivity;
- to ensure that every home is adequately and affordably heated.

The White Paper sees increases in energy efficiency being key to reducing demand and emissions and advocates using a diversity of energy generation systems as the best way to ensure energy reliability (security of supply) in the future without relying on imports. The Government does not propose to set targets for the amount of energy to be produced by different means, but to encourage a market framework to promote diversity, whilst being cautious that no single means of production accounts for too much energy production. The White Paper recognises the problems associated with the increased use of renewable energy and of more distributed energy generation, while encouraging a broad vision of local, distributed and micro-generation of energy by 2020.

The White Paper specifically mentions nuclear energy as an 'important source of carbon free electricity', but it does not contain specific proposals for building new nuclear power stations. The possibility of new nuclear power stations at some point in the future is not, however, ruled out.

2.1.2 Welsh Energy Policy

Some aspects of energy policy are devolved and Wales is able to set different energy targets to England. Other aspects remain with the UK Government. Granting consent for large–scale energy projects (generating over 50 megawatts) remains with the UK Government, as does the power to grant certain consents for offshore energy developments (over one megawatt).

A tri-partite working group, chaired by the Office of the Secretary of State for Wales, and consisting of officials from the DTI and the Assembly Government, is exploring the implications of transferring these consenting powers to the National Assembly for Wales.[9] Discussions about the transfer of these powers, which relate to sections 36 and 37 of the *Electricity Act 1989,*[10] have been on-going for several years.

[9] Written Questions answered between 29 October and 4 November 2004, http://assembly/rop/rop/answers%20to%20written%20questions/2004/november/waq041104-e.html
[10] A copy of the *Electricity Act 1989* can be obtained from the Members' Library or on the internet at: http://www.opsi.gov.uk/acts/acts1989/Ukpga_19890029_en_1.htm
The *Electricity Act 1989 (Requirement of Consent for Offshore Wind and Water Driven Generating Stations) (England and Wales) Order 2001* sets the 1MW consenting limit for offshore power generating stations. A copy of the Order (SI 2001/ 3642), which made under section 36 of the *Electricity Act 1989,* can be obtained from the Members' Library or on the internet at: http://www.opsi.gov.uk/si/si2001/20013642.htm

The Welsh Assembly Government launched the *Energy Wales Route Map* in 2005[11], which sets out the direction for energy generation and energy efficiency in Wales for the future. The Route Map sets out current Welsh energy policy as having five main strands:

- securing 4TWh per annum of renewable electricity production by 2010 and 7TWh by 2020;
- much greater energy efficiency in all sectors, as described in *Energy Saving Wales*;[12]
- more electricity generation from cleaner, higher efficiency fossil-fuel plants;
- significant energy infrastructure improvements;
- achieving measurable carbon dioxide emission reduction targets for 2020.

The Welsh Assembly Government has indicated that it believes onshore wind will be the principal renewable technology with potential to contribute to the achievement of the 2010 target. It anticipates 800MW (approx. 80 per cent) of the additional capacity required to meet the 2010 target to come from large-scale onshore wind generation and a further 200MW (approx. 20 per cent) from other renewable energy technologies.[13]

2.2 Planning and renewable energy

Planning applications for renewable energy schemes generating less than 50MW are made to the local planning authority in the same way as any other planning application. The majority of renewable energy schemes are of this type. Applications for schemes generating over 50MW are dealt with by the DTI.

2.2.1 Schemes generating less than 50MW

The planning application will proceed like any other application for planning permission. The local planning authority will notify neighbours of the development and may advertise the application in the local press. Anyone can comment on the application, although there will be only a limited amount of time in which to send comments to the local planning office. It is important to meet any deadline or the submission may not be taken into account.

It is possible for members of the public to attend committee meetings dealing with planning applications and in many cases members of the public can speak briefly to ensure that the committee is aware of their views. Only elected members of the council can vote on the decision itself.

If planning permission is refused, an appeal can be made to the National Assembly for Wales, which will appoint an independent Planning Inspector. Any members of the public who made representations at the application stage will be informed about the appeal. The local authority will send copies of their representations to the Planning Inspectorate

[11] *Energy Wales: Route Map to a clean, low-carbon and more competitive energy future for Wales*, (2005), Welsh Assembly Government, www.wales.gov.uk/subitradeindustry/content/consultations/ewrm-ltr-e.htm
[12] *Energy Saving Wales: Energy Efficiency Action Plan: Consultation Document*, (2004), Welsh Assembly Government, http://www.wales.gov.uk/subitradeindustry/content/consultations/energy-pt1-e.pdf
http://www.wales.gov.uk/subitradeindustry/content/consultations/energy-pt2-e.pdf
[13] *Renewable Energy*, Cabinet Statement by Andrew Davies, Minister for Economic Development & Transport and Carwyn Jones, Minister for Environment, Planning & Countryside, 13 July 2004, Welsh Assembly Government website, http://www.wales.gov.uk/organicabinet/content/statements/2004/130704-renewable-energy-e.doc

and they can make additional representations, including giving evidence personally at hearings and inquiries.

2.2.2 Calling in a planning application for schemes generating less than 50MW

In exceptional circumstances, planning applications may be 'called in' to the National Assembly for Wales. Individuals that wish to ask the Assembly to consider calling in an application can do so by approaching their local authority, by writing to the Minister for Environment, Planning and Countryside, or to the Assembly Government's Planning Division.

The calling in of an application is not common. The decision to call in an application is a matter for the Minister. Once called in, the case is referred to the Planning Inspectorate (PINS) which appoints an inspector. An investigation will be carried out, which may include a public inquiry. The findings and planning inspector's recommendations are referred to the Assembly's Planning Decision Committee, who make the final decision.

2.2.3 Offshore wind energy schemes

An offshore wind farm development requires a number of consents to be granted by different departments[14]:

- Under the *Electricity Act 1989 (EA),* a consent in needed for any offshore development generating 1MW or more. In England and Wales, the DTI administers this consent procedure[15].
- *Food and Environment Protection Act 1985* (FEPA). The National Assembly for Wales has responsibility for the control of works in Welsh waters under this Act, but consideration of applications under FEPA are co-ordinated by MCEU[16], who administer applications made for Welsh waters on behalf of the National Assembly.
- *Coast Protection Act 1949* (CPA). Applications for consent are administered by the Department for Transport (DfT)
- Under the *Transport and Works Act 1992 (TWA)*. The DTI administers consents for applications in UK territorial waters adjoining England, while the National Assembly for Wales administers applications for waters adjoining Wales[17]. Consent under TWA 1992 displaces the need for consents under EA 1989 and CPA 1949.
- *Town and Country Planning Act 1990* – for onshore elements associated with an offshore development. Applications may be made under the TWA, or to the local planning authority.

[14] *Guidance Notes: Offshore Windfarm Consents Process*, DTI, January 2003, DTI website, http://www.dti.gov.uk/energy/leg_and_reg/consents/guidance.pdf
[15] In Scotland, applications are dealt with by the Scottish Executive and in Northern Ireland by the Department of Enterprise, Trade and Investment (DETI(NI))
[16] The Marine Consents and Environment Unit (MCEU) is an alliance of the Marine Environment Branch of the Department for Environment, Food and Rural Affairs (Defra) and the Ports Division of the Department of Transport. It provides a central facility for the consents process for a number of offshore developments, including wind farms, http://www.mceu.gov.uk/MCEU_LOCAL/mceu1-test-E.htm
[17] The *Transport and Works Act* does not apply in Scotland.

- Crown Estate[18] lease to build on the seabed. The Crown Estate will not grant a lease unless all the required consents have been obtained by the developer.

The DTI has established an Offshore Renewable Consents Unit (ORCU) to help with applications and provide developers with a single liaison point.

2.2.4 Technical Advice Note (TAN) 8: Planning for Renewable Energy

Technical Advice Note (TAN) 8: Planning for Renewable Energy[19] is the Welsh Assembly Government's technical guidance for planning authorities when developing Local Development Plans (LDPs) and deciding planning applications for renewable energy developments.

TAN 8 uses a strategic assessment based on the environmental, landscape, technical, security and economic constraints on the development of large-scale wind farms (>25MW) to identify a number of areas where the development of large-scale wind farms is thought to be most suitable. The assessment has identified seven strategic search areas (SSAs) capable of supporting up to 1,120MW capacity. The seven areas are Clocaenog Forest (140MW), Carno North (290MW), Newtown South (70MW), Nant-y-moch (140MW), Pontardawe (100MW), Coed Morgannwg (290MW), Brechfa Forest (90MW).

TAN 8 does not imply that wind farms can only be built within SSAs or that applications for wind farms within SSAs will be guaranteed approval. Local planning authorities should take into account all the guidance contained within TAN 8 and other Ministerial guidance when formulating development plans and making decisions on planning applications.

TAN 8 does not address the issue of offshore wind generation because it is concerned with the planning process, which does not extend to offshore planning and construction, although it does point out that onshore installations associated with offshore wind farms may need planning permission.

In terms of other renewable energy technologies, TAN 8 recognises that many technologies can be accommodated through standard planning policies on design and rural development. In general TAN 8 indicates that local authority planning policies and development plans should be supportive of renewable energy developments.

3 Wind energy

Most wind turbines comprise a three-bladed rotor, like a propeller, that is turned by the wind to produce mechanical power. A gearbox converts the slow rotation of the rotor into a faster rotation that drives a generator to produce electricity. Turbines also contain ***pitch*** and ***yaw*** mechanisms to continuously adjust the angle of the rotor blades and to turn the turbine so that it is always facing into the wind. These mechanisms help ensure that the

[18] The Crown Estate is the property of the reigning Sovereign of the United Kingdom (Her Majesty Queen Elizabeth II), but it is not her private property. It is inherited with her title. She can not sell it, neither does she receive any money from it. All money generated by the Crown Estate is paid annually to the Exchequer. The Crown Estate manages all land owned by the Crown, which includes the seabed out to the 12 nautical mile (nm) territorial limit (approximately 20km). www.crownestate.co.uk

[19] *Technical Advice Note (TAN) 8: Planning for Renewable Energy*, (2005), Welsh Assembly Government, http://www.wales.gov.uk/subiplanning/content/tans/tan08/newtan8/tan8-e.htm

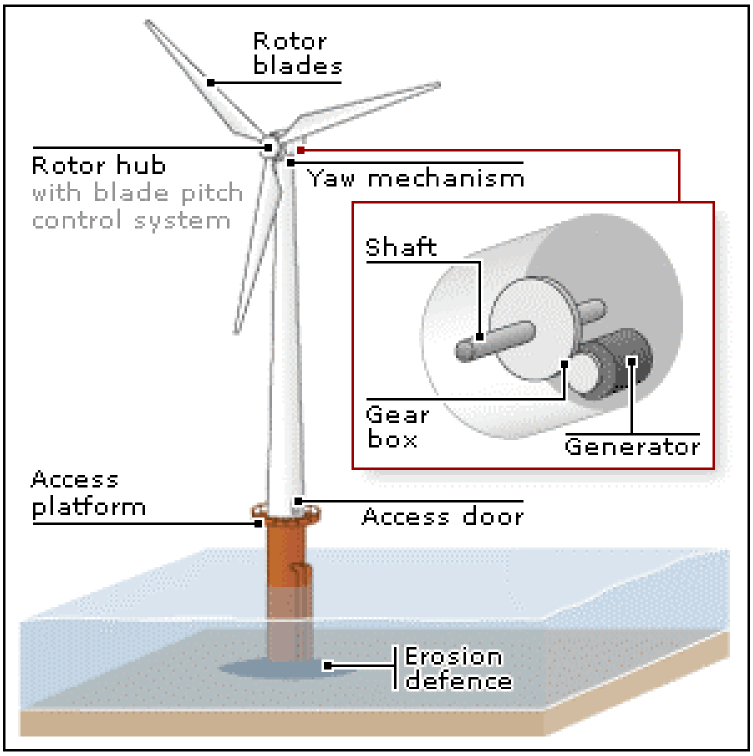
turbine captures as much wind energy as possible, while brakes and safety systems ensure that the turbine is not damaged by very high winds.[20]

Turbines start operating at wind speeds of four to five metres per second (approx. 10 miles per hour) and reach maximum power output at around 15 meters per second (approx. 33 mph). At very high wind speeds, i.e. gale force winds, (25 metres per second or over 50 mph) wind turbines shut down to prevent damage.

A single wind turbine typically produces 750kW – 1,300kW, although larger machines capable of producing over 2,500kW are available and turbines able to generate even more energy are continually being developed.[21] Wind farms comprise of a number of turbines grouped together in a relatively small area, although turbines cannot be sited too close together due to the turbulence they generate.

The ***installed capacity*** (or ***rated capacity***) of a wind turbine refers to the potential energy output it could generate if operating at maximum capacity all the time. In the UK, wind turbines turn between about 80 and 85 per cent of the time and produce about ***30 per cent*** of the amount of energy that they could theoretically produce if they were working flat out all the time. This is due to the intermittent nature and varying strengths of the wind. The amount of time individual turbines are turning and the amount of electricity they produce will depend on where they are located and the pattern of wind in the area.[22]

Figure 1 Diagram of a wind turbine



Source: BBC website[23]

[20] *Onshore wind energy*, DTI Sustainable Technology Route Maps, DTI, http://www2.dti.gov.uk/energy/renewables/publications/pdfs/technologies/tech1.pdf
[21] *Wind Force 12: a blueprint to achieve 12% of the world's electricity from wind power by 2020*, EWEA & Greenpeace, http://www.ewea.org/doc/WindForce12.pdf
[22] *The British Wind Energy Association Wind Energy FAQs,* BWEA website, www.bwea.com/ref/faq/html
[23] *Boost for offshore wind power*, (2003), BBC news website, Monday 14 July 2003, http://news.bbc.co.uk/1/hi/uk/3063433.stm

3.1 Onshore wind energy

The majority of existing wind farms are built onshore, as offshore wind farms are a relatively new development. The most favourable areas for siting onshore wind farms are hilly regions, as wind speeds are higher in these areas. Siting turbines on top of hills does, however, mean that they can be seen from some distance away.

The concrete foundation of an onshore wind turbine, to which the tower is attached, is usually flush with the ground. The turbines themselves take up very little ground space, although the wind farm could be spread across a relatively large area to allow individual turbines to be spaced far enough apart. Agriculture would be able to continue right up to the edge of the foundations of individual turbines. The life span of a turbine is about 20 – 25 years. Once they have reached the end of their life, turbines can be dismantled and the concrete foundations either re-used or removed.

3.2 Offshore wind energy

The main reasons for building offshore wind farms are the more predictable and higher average winds speeds winds found offshore. Offshore wind farms do, however, have to be able to withstand the more severe weather found at sea and are generally more expensive to build, requiring specialist construction and maintenance equipment and large lengths of new cable to be laid undersea to bring the generated electricity on to shore.

The UK offshore wind energy resource is estimated to be 100TWh per year. This figure takes current technology and practical issues into account, such as distance from shore, water depth, type of seabed and the use of some areas for other activities (e.g. fishing, dredging, etc.), meaning that turbines cannot be sited there[24].

In 1992 in the UK, nine wind turbines were erected along the Blyth harbour wall as the first step towards creating an offshore windfarm. Following this, two wind turbines were erected one kilometre off the coast of Blyth, becoming the first offshore wind farm in the UK[25].

Wales currently has one operational offshore wind farm at North Hoyle, with an installed capacity of 60MW. Consent has also been given for the development of two further offshore wind farms at Scarweather Sands (99MW) and Rhyl Flats (90MW). This gives a total offshore capacity of 249MW.[26]

3.2.1 Offshore developments outside territorial limits (beyond 12nm)

As more development takes place within territorial limits, the scope for large-scale development may be constrained by the lack of available seabed and cumulative impacts of developments may reach levels where no further development would be acceptable. The inclusion of waters beyond 12nm for development will remove these potential constraints on the expansion of the offshore wind energy industry.

New legislation is, however, needed to allow development outside territorial waters, as much of the legislation that regulates and supports wind farms in territorial waters does

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[24] *Offshore wind energy, DTI Wind Energy Fact Sheet 1*, (2001), Department of Trade and Industry, DTI website, http://www.dti.gov.uk/energy/renewables/publications/pdfs/windfs1.pdf
[25] Blyth Offshore, AMEC website, http://www.amec.com/wind/where/where_2ndlevel.asp?pageid=8035
[26] UK Wind Energy Database (UKWED), British Wind Energy Association (BWEA) website, http://www.bwea.com/ukwed

not extend beyond the 12nm limit. The existing legislation that does apply beyond territorial limits does not provide for a complete consenting process or provide developers with a satisfactory legal basis for site security. Primary legislation is necessary to build a comprehensive legal framework for wind farm development outside 12nm.

Until new legislation is brought in, it will only be possible to offer development leases for sites within territorial waters. Developers will, however, be encouraged to investigate sites beyond the boundary of territorial waters in anticipation of future legislation being enacted.

The United Nations Convention on the Law of the Sea (UNCLOS) sets out the rights of a coastal State over its territorial seas and establishes its rights over the seas beyond these limits. Whilst the UK has full sovereignty over its territorial sea, its rights over the waters beyond the 12nm boundary are more limited. UNCLOS gives a coastal State the right to establish a 200nm Exclusive Economic Zone (EEZ) around its territory, within which it can exercise sovereign rights in relation to activities such as fisheries, pollution and the production of energy from the water, currents and winds. In addition, the coastal State is given the exclusive right to construct, and to authorise and regulate the construction, operation and use of installations and structures for the production of energy from the water, currents and winds. In order to protect these installations and structures, and to ensure safe navigation, a coastal State may establish safety zones of up to 500m around such structures. In exercising these rights, a coastal State must not interfere with the rights of other States under international law; in particular, the right of freedom of navigation.

The UK has not declared an EEZ. It has, however, established an Exclusive Fisheries Zone in which it exercises EEZ fisheries rights and a pollution zone in which it exercises pollution control rights. It is the UK Government's intention to make an appropriate declaration asserting the UK's sovereign rights in accordance with UNCLOS in relation to the production of energy from the water, currents and winds in a Renewable Energy Production Zone which will extend up to 200nm.

Before the UK can exercise these rights, there must be legislation at national level that vests those rights with a competent authority (e.g. the Crown Estate) and defines the limits of the Renewable Energy Production Zone. It is possible that the *Continental Shelf Act 1964* fulfils the legislative requirements, but as there is some uncertainty surrounding this, the Government is of the view that new primary legislation is required to ensure that the UK can exercise renewable energy rights in the seas out to 200nm. It is possible that the required legislation will form part of the proposed Marine Bill, which is due to be published in draft form towards the end of 2006.

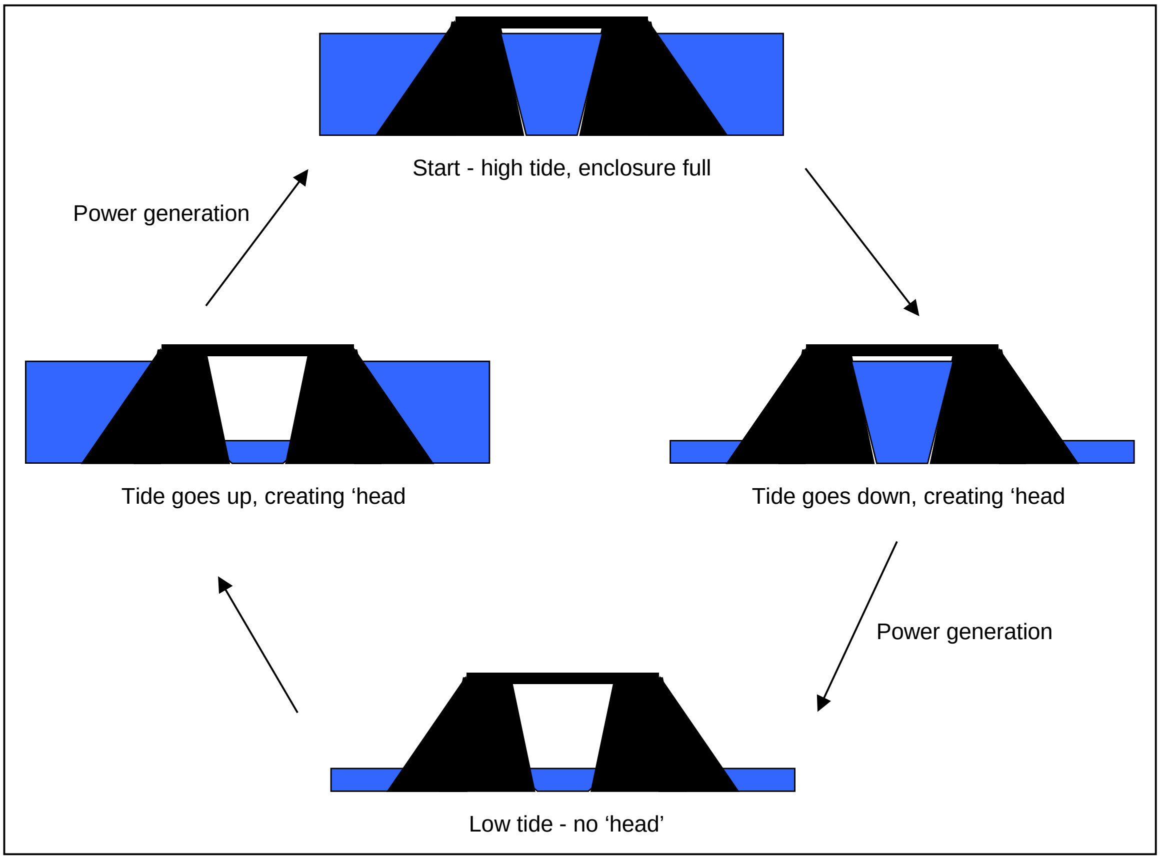
4 Tidal energy

Tidal energy can be harnessed by exploiting the natural rise and fall of the tides. Turbines can be positioned in areas where the ebb and / or flow of the tides turns the turbines, or in artificial lagoons or barrages built in tidal areas, such as estuaries. Areas with higher tidal ranges are capable of generating more electricity than areas with lower tidal ranges.

Tidal electricity generation is currently technologically feasible and proposals to build a barrage across the Severn estuary have been mooted since the 1950s. It is estimated that it would take £10 billion - £14 billion and 12 – 14 years to build a barrage across the Severn, including both environmental monitoring and construction time, but that such a development could provide five or six per cent of the UK's electricity.[27] [28] Carwyn Jones AM, Minister for Environment, Planning and Countryside has indicated that the cost of building a Severn Barrage would be about £12 billion.[29]

Tidal lagoon technology essentially encloses an area of the seabed with a wall to create lagoon. Seawater flows in and out of the lagoon through turbines as the tide rises and falls (see figure 2).

Figure 2 Schematic of a tidal lagoon



Source: Tidal Electric website[30]

[27] *Renewable energy: practicalities Volume I: report*, (2004), House of Lords Science and Technology Committee, 4th Report of Session 2003-04, HL Paper 126-I
[28] *Energy from tidal barrages technology route map*, Department of Trade and Industry, DTI website, http://www.dti.gov.uk/energy/renewables/publications/pdfs/technologies/tech8.pdf
[29] Carwyn Jones AM, Technical Advice Note 8, Environment, Planning and Countryside Committee, Wednesday 13 July 2005, http://www.wales.gov.uk/keypubrecordproceedings/content/epc-050713.htm#_c
[30] www.tidalelectric.com

Tidal lagoon schemes have been proposed off the coast in both North and South Wales by Tidal Electric[31] and the North Wales Coastal Renewability Trust (NWCRT).[32] A feasibility study carried out for Tidal Electric states that a 5km^2 lagoon in Swansea Bay could generate 187,000MWh electricity per year.[33]

Tidal stream energy can also be harnessed to generated electricity. Tidal streams are fast sea currents created by the tides, often flowing through narrow channels associated with headlands, inlets and straits, which magnify the currents. Tidal stream technology is not as established as tidal barrage / lagoon type turbines.

Stingray and Seaflow are both examples of tidal stream generators, although using different methods to generate electricity. The Stingray is a seabed-sited generator with a pivoting arm driven by hydroplanes. As tidal waves pass over the hydroplanes, the movement drives an hydraulic motor to generate electricity. Seaflow uses a rotor blade, similar to a wind turbine, but driven by the flow of water over the blades. A Stingray prototype was successfully deployed for tests in Yell Sound, Shetland in 2002,[34] while Seaflow is being tested off the coast of Lynmouth, Devon.[35]

5 Wave energy

Wave energy generators utilise the oscillating movement produced by waves and convert it into electricity using a variety of methods – oscillating columns, hinged rafts, etc. They can be deployed in either shallow or deeper waters, although the electricity-generating potential is greater offshore.[36] Total UK wave electricity generating capacity in 2003 was 0.5MW.[37]

There are a number of prototype wave energy generators in development or test around the UK, including:

- LIMPET (Land Installed Marine Powered Energy Transformer) – this is a land-based wave energy generator that harnesses the power of waves as they come in to the shore. Waves force water into a column and up, across turbines, generating electricity.[38]

- Pelamis – the prototype will be 120m long, 3.5m wide and 700 tonnes in weight. When floating on the sea, hinged joints between its articulated cylindrical sections move with the waves, powering hydraulic motors that generate electricity. Each Pelamis is designed to generate 750KW energy and several can be joined together to form a "wave farm".[39]

[31] *Turn of the tide*, (2004), Malcolm Smith, The Guardian, December 8 2004, http://society.guardian.co.uk/societyguardian/story/0,,1368188,00.html
[32] Application for North Wales Tidal Impoundment Scheme to be considered for Inclusion on Assembly's Sustainable Development Action Plan, (2004), Welsh Assembly Government website, http://www.wales.gov.uk/themessustainabledev/content/review/action-responses/nwcrt-e.htm
[33] *Feasibility Study for a Tidal Lagoon in Swansea Bay: Executive Summary*, (2004), Atkins Consultants Ltd, http://www.tidalelectric.com/Web%20Atkins%20Executive%20Summary.htm
[34] More information on Stingray can be found on the Engineering Business website at: http://www.engb.com
[35] *The Seaflow Project, Tidal Power Case Study*, DTI website, http://www.dti.gov.uk/renewables/renew_1.5.2.4.htm Marine Current Turbines Ltd. website, http://www.marineturbines.com/home.htm
[36] *Wave energy technology route map*, Department of Trade and Industry, DTI website, http://www.dti.gov.uk/energy/renewables/publications/pdfs/technologies/tech3.pdf
[37] http://www.dti.gov.uk/renewable/wave_currentuptake.html
[38] More information on LIMPET can be found on the Wavegen website at: http://www.wavegen.co.uk/what_we_offer_limpet.htm
[39] More information on Pelamis can be found on the Ocean Power Delivery website at: http://www.oceanpd.com

- Offshore Wave Energy Limited (OWEL) Wave Energy Converter (WEC) – a floating chamber that traps and compresses the air in successive wave troughs. The air is then used to drive a turbine and generate electricity. Several chambers would be jointed together to form a floating platform.[40]

- Wave Dragon – a Danish company planning to build 70MW generator off the coast of Milford Haven.[41] Wave Dragon funnels waves using a large boom so that the water flows over and into turbines to generate electricity.[42]

Waves on the ocean surface of the world have a total estimated power of 90 million GW. The UK has wave power levels that are amongst the highest in the world. The wave energy industry, like the tidal one, sees itself as having the potential of the wind industry but is currently around 10 years behind it.[43]

The Report of House of Lords Science and Technology Committee states:

> We do not believe that it is feasible for wave or tidal generation to contribute significantly to meeting the Government's 2010 target. However, there is no technological barrier to tidal barrages making a significant contribution by 2020.

Wave energy projects are mostly in the demonstration phase of development, making it difficult to accurately judge their potential contribution to renewable energy generation.[27]

6 Solar energy

Solar energy involves capturing the energy from the sun and translating it into usable energy. This can be by converting sunlight into electricity (photovoltaics or PV); passive solar energy capture (using sunlight and heat to reduce the need for artificial heat and light) or active solar heating, which uses the sun's heat to warm water for use or for heating.

TAN 8 encourages local authorities to consider design and passive solar gain when developing supplementary planning guidance and development plans as well as supporting proposals for appropriately designed solar thermal and PV installations.[2]

6.1 Photovoltaics (PV)

PV systems convert solar energy into electricity. They normally require some form of energy storage system or battery that is charged by the PV cells and can then release energy if it is needed during periods when the PV cells are not generating electricity. PV systems are particularly useful in remote areas where grid connection is problematic or costly, for example in marking meters, street lighting and remote telecommunications.

Centralised generation of electricity for the grid by means of large-scale, dedicated PV arrays is unlikely to be economically attractive in the UK for the foreseeable future. The

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[40] More information on OWEC can be found on the Offshore Wave Energy Limited website at: http://owel.co.uk
[41] *Wales waves hello to tidal power pioneer*, The Western Mail, 22 March 2004, http://icwales.icnetwork.co.uk/0100news/0200wales/tm_objectid=14076508&method=full&siteid=50082&headline=wales-waves-hello-to-tidal-power-pioneer-from-denmark-name_page.html
[42] *UK leads a wave power revolution*, McKie, R., The Observer, Sunday 21 March 2004, http://observer.guardian.co.uk/uk_news/story/0,6903,1174481,00.html
[43] DTI Renewable Energy website, http://www.dti.gov.uk/renewable/wave_currentuptake.html

greatest growth in PV is likely to be in building-integrated PV (BIPV), where PV cells can be used instead of conventional external cladding or roof elements. [44]

PV systems have high capital costs, although costs have been falling and are expected to continue to fall in the future as lower-cost PV materials are developed.

The Department of Trade and Industry (DTI) estimates that the UK market is likely to remain relatively small in the period up to 2010 but could grow substantially beyond that date and could make a significant contribution to the national energy mix by 2050 if the technology continues to develop successfully. As a result of this estimate, the UK Government's targets in relation to PV use relate mainly to reducing the costs of the technology.[44]

The House of Lords Science and Technology Committee also sees little immediate prospect for commercial generation of electricity from solar energy in the UK, but recognises its potential to contribute to renewable energy output through the use of small-scale, domestic and stand-alone applications. [27]

6.2 Passive solar energy

Solar energy can also be harnessed passively to provide heat and light without producing electricity. Passive solar energy can be captured by orientating buildings' windows in a southerly direction to capture as much natural heat and light as possible. Passive solar energy can most effectively be employed in new builds, but the amount of passive solar energy captured by existing buildings can be improved by replacing single glazed windows with double glazing. It may also be improved through the addition of a conservatory.[45]

6.3 Active solar

Active solar energy (also known as solar thermal or solar water heating) uses the sun's heat to warm water for use or for heating. collectors, usually on the roof of a building capture and store the sun's heat in water storage systems.

Solar water heating systems can provide most of the hot water needs for a UK household during the sunniest four or five months of the year and will contribute to water heating during the remainder of the year.[46]

[44] *Energy from photovoltaics technology route map*, Department of Trade and Industry, DTI website, http://www.dti.gov.uk/energy/renewables/publications/pdfs/technologies/tech5.pdf
[45] *Passive solar design technology route map*, Department of Trade and Industry, DTI website, http://www.dti.gov.uk/energy/renewables/publications/pdfs/technologies/tech6.pdf
[46] *Solar Water Heating*, Centre for Alternative Technology, http://www.cat.org.uk/information/catinfo.tmpl?command=search&db=catinfo.db&eqSKUdatarq=20020210164613

7 Bioenergy

Bioenergy is heat, electricity or movement generated from biomass. Fuels producing bioenergy are referred to as biofuels. They are derived from recently grown plants and the waste from animal husbandry and include: [47]

- agricultural and forestry residues and by-products
- energy crops
- landfill gas
- biodegradable components of municipal and business wastes.

Plants absorb carbon dioxide (CO_2) as they grow, so although biofuels release CO_2 when burned, they can be said to be carbon neutral, as long as the amount of fossil fuel used in the production of the fuel is negligible.

Products used to produce biofuel energy can be either residues / by-products of farming and forestry or energy crops, grown specifically for use as fuel. Residues from farming / forestry may be dry materials that can be burned to produce energy, or wet materials such as green agricultural wastes and farm slurry, which can be used to produce a methane-containing biogas by anaerobic digestion. Current estimates suggest that the UK availability of agricultural and forestry residues is, in practice, limited.

Energy crops grown specifically for use as fuel provide a greater potential for energy production. They include perennial plants[48] such as trees and grasses or annual crops[49] such as oilseed, cereals and plants containing sugars e.g. sugar beet.

Biomass can be used to produce a range of fuel types[50]:

- Solid fuel – includes wood chips, pellets, briquettes, or the direct combustion of raw biomass, including municipal solid waste (MSW). The plant or animal matter in MSW can be separated out, either by requiring source separation and collecting the wastes separately or by sorting the material centrally in a sorting plant or material recovery facility (MRF).[47] Burning biomass can be used to heat areas directly or to heat water to generate steam in order to power a turbine to produce electricity.

- Biogas – can be produced from the anaerobic digestion of biomass or as a by-product of landfill sites. The EU Landfill Directive will significantly impact on the production of landfill gas in the future as although it will require the installation of energy recovery on landfill sites, it will also prevent the deposition of the biodegradable waste in landfills after 2015.

- Bio-oil - produced by the pyrolysis of solid biomass. Small particles of dried woody biomass are heated very rapidly to around 900º C and break down to form a gas, a liquid fuel and a char. The gas can be used to fuel the pyrolysis process, while the bio-oil can be used to power a furnace, turbine or power a modified diesel engine.

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[47] *Energy from biofuels technology route map*, Department of Trade and Industry, DTI website, http://www.dti.gov.uk/energy/renewables/publications/pdfs/technologies/tech7.pdf
[48] A plant lasting for three seasons or more
[49] A plant that completes its entire life cycle within the space of a year
[50] British BioGen website, http://www.britishbiogen.co.uk/bioenergy/21stcenturyfuel/bionrgmoppor.html

- Bio-diesel – produced from vegetable oil crops directly or by recovering and recycling used cooking oils.

Biomass can be used in large-scale power stations to produce electricity for supply via the National Grid, or it can be used on a smaller scale, fitting into the electricity distribution network.

Co-firing of biomass with coal in conventional power stations allows continued use of existing power stations, while reducing net CO_2 emissions, as a proportion of coal is replaced by biomass. Co-firing could represent a significant proportion of the renewable energy target and a number of power stations are registered to benefit from the renewables obligation certificate by utilising co-firing. Co-firing in conventional power stations does, however, require a large amount of biomass – a 1,000MW coal fired power station operating at a five per cent co-firing level would require 200,000 tonnes wood per year. This potential level of demand for forestry residues has left existing users, such as the wood panel industry, concerned that they will be outbid for resources. Similarly, environmental groups are concerned that this level of demand will lead to an increase in cheap biomass imports, which may have originated from unsustainable sources.[51]

There are currently seven biomass electricity generating plants in the UK and a further nine under development, only one of which is located in Wales (Border Biofuels, a 15MW pyrolysis plant in Newbridge-on-Wye).[52]

There is a working assumption that, by 2010, forestry and farming will contribute up to 5TWh per year to the UK's electricity supply. To reach this target it will be necessary to use most of the available residues plus 125,000 - 175,000 hectares of energy crops (equal to 0.7 – 0.9 per cent of area currently used for agriculture in the UK).[47]

The Country Land and Business Association (CLA) and the National Farmers Union (NFU) estimate conservatively that 25 – 30 per cent of agricultural land could be used for biomass production by 2020 (approx. five million hectares). This amount of land would be able to produce nearly 200TWh electricity, which is more than 50 per cent of current energy consumption.[53]

8 Energy from waste (EfW)

The terms "energy from waste" (EfW) or "waste to energy" (WtE) encompasses all waste treatment processes that use waste to generate power and heat, while reducing the volume and weight of the waste. EfW may also be referred to as "thermal treatment". EfW includes anaerobic digestion, utilising the gas from landfill sites, incineration, gasification and pyrolysis. The different treatments produce different emissions and residues. Some people may disagree with including EfW within the context of renewable energy especially if it uses non-renewable sources such as plastics as a fuel source instead of biodegradable wastes.

[51] *Co-firing plans in the spotlight over biomass imports*, (2003), ENDS Report 342
[52] *UK biomass electricity plants*, British BioGen website, http://www.britishbiogen.co.uk/bioenergy/electricity/elecmap.htm
[53] *Guide to UK renewable energy companies 2003*, (2003), James & James (Science Publishers), London

8.1 Anaerobic digestion (AD) [54] [55] [56]

Anaerobic digestion of waste is the biological breakdown of organic waste by micro-organisms in the absence of oxygen in an enclosed container. The process requires warm conditions to take place, so some heating of the container is necessary.

AD produces a relatively stable solid residue, a liquid element and a flammable biogas composed of methane (CH_4) and carbon dioxide (CO_2), which can be used as a fuel to produce heat and / or power, some of which can be utilised in the heating of the digestion process.

Anaerobic breakdown of organic waste also takes place in landfill sites, leading to the production of landfill gas. Production and collection of biogas is, however, much more efficient from an anaerobic digester than from a landfill. In an anaerobic digester, up to 60 per cent of the waste is converted to biogas.

8.2 Incineration

Incineration involves direct combustion of waste, converting it to energy and waste ash. Incinerators generating electricity are only about 22 per cent energy efficiency, whilst those that generate combined heat and power (CHP) can be up to 75 per cent energy efficient.

Mass burn incinerators burn mixed waste on a moving grate at a rate of between 10 and 50 tonnes per hour, while fluidised bed incinerators use a chamber containing a bed of sand or other inert material which heated air flows through, thus mobilising or "fluidising" the bed. Fluidised bed incinerators are more efficient at producing energy than mass burn incinerators and operate at a lower temperature. The majority of incinerators in the UK are mass burn incinerators.

8.3 Gasification and Pyrolysis[57] [58]

Pyrolysis and gasification does not involve the direct combustion of the waste, but heats it under controlled conditions to produce a fuel.

Pyrolysis is the thermal breakdown of waste in the absence of air to produce a char, oil and syngas. The conversion of wood into charcoal is an example of pyrolysis. Gasification operates at higher temperatures than pyrolysis and breaks down hydrocarbons into a syngas in the presence of a controlled amount of oxygen. The output from pyrolysis can be fed into a gasification process.

The gases, oils and solid char from pyrolysis and gasification can not only be used as a fuel but also purified and used as a feedstock for petro-chemicals and other applications. Gasification can be used in conjunction with gas engines (and potentially gas turbines) to obtain higher a conversion efficiency than conventional fossil-fuel energy generation and to replace fossil fuels as a means of generating energy.

[54] *Anaerobic digestion*, The Wasteguide: The Stakeholders Guide to Sustainable Waste Management, the wasteguide website, http://www.wasteonline.org.uk/resources/Wasteguide/mn_wmo_biotreatment_anaerobic.html
[55] *Anaerobic digestion – Overview*, ATLAS website, http://europa.eu.int/comm/energy_transport/atlas/htmlu/adover.html
[56] Mechanical Biological Treatment website, http://www.waste-technologies.co.uk/index.html
[57] *Pyrolysis and gasification*, Juniper, Juniper website, http://www.juniper.co.uk/services/Our%20Services/P%26G.html
[58] *Pyrolysis and gasification factsheet*, Juniper, Juniper website, http://www.juniper.co.uk/services/Our%20Services/P&GFactsheet.html

Gasification and pyrolysis systems can be operated on a wider range of scales than more traditional incinerators, offering the opportunity to build local or regional facilities. They also produce lower emissions than incinerators.

9 Geothermal energy / ground pumps

Geothermal energy is the natural heat that exists in the earth. There are well-known examples of the use of geothermal energy in the form of hot water and / or steam from areas such as Iceland and New Zealand, but this form of geothermal energy use is unlikely to economically viable in Wales or the UK, as it would involve drilling to great depths to harness.

A more viable use of geothermal energy is the use of heat / ground pumps, which use the ground or a water body as a heat source and / or sink. Heat pumps work in a similar way to the cooling mechanism of a refrigerator. A long length of pipe filled with a mixture of water and antifreeze is buried in the ground (the ground loop). The fluid is pumped around the pipe and absorbs heat from the ground. An evaporator takes the heat from the ground loop and the heat is then transferred by means of a compressor and condenser to a heat distribution system e.g. underfloor heating or radiators. In hot weather, the heat pump can work the other way around, transferring heat from the building to the ground outside.[59]

Although heat pumps require energy to pump fluid around the ground loop, they can extract 2.5 – 3.5kWh heat for every 1kWh energy used to power the pump.[60]

There may be opportunities for using the water in abandoned coal mines as heat sources for heat pumps.[2]

10 Hydrogen energy & hydrogen fuel cells

The combustion of hydrogen produces only very low oxide of nitrogen (NO_x) emissions and water vapour, offering the potential for energy production and zero exhaust emissions.

Hydrogen is not considered an energy source like oil, natural gas, solar or wind, but an energy vector, like electricity, with the ability to transfer energy from one place to another[61] i.e. energy from a given source e.g. a wind turbine is used to produce hydrogen. That hydrogen is then used in a fuel cell to power a vehicle, light, etc. in the same way that a battery might.

When considering hydrogen as a fuel it is, however, important to consider the primary source of energy used to manufacture the hydrogen. If hydrogen is manufactured using electricity generated from renewable energy sources, it can be regarded as a zero-emission and sustainable option. If, however, it is manufactured from natural gas or using a fossil fuel as the energy source in its manufacture, it is less sustainable because of the carbon dioxide (CO_2) emissions associated with its production.

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[59] *Groundsource heat pumps*, (2004), Energy Saving Trust, EST Factsheet 5, http://www.est.org.uk/uploads/documents/myhome/Groundsource_o_p.pdf
[60] *Geothermal Energy*, Department of Trade and Industry, Sustainable Energy Route Maps
[61] *Liquid biofuels and renewable hydrogen to 2050, An assessment of the implications of achieving ultra-low carbon road transport*, (2004), Department for Transport, DTI website, http://www.dti.gov.uk/energy/sepn/h2bioassessment.pdf

Hydrogen can be stored either at high pressures, as a gas, or at very low temperatures, as a liquid.

10.1 Fuel cells

Fuel cells are electrochemical devices that convert the energy of a chemical reaction, typically the reaction between hydrogen and oxygen into electricity and heat. Individual fuel cells typically generate a power output of a few tens or hundreds of Watts, so cells are built up into modules known as stacks to provide a larger power output. [62]

Fuel cells offer prospects for high efficiency, low emission electricity production. They are quiet and could be used in a wide range of applications such as combined heat and power (CHP) and transport, as an alternative to the internal combustion engine. [63]

Fuel cells also offer a potential energy storage system for energy generated from renewable sources – hydrogen can be generated when electricity demand is lower than the amount generated by intermittent renewable sources (e.g. solar, wind power). The hydrogen can then be used to generate electricity when demand exceeds power generation by intermittent sources.[4]

There are a number of different types of fuel cell, at different stages of development. In general, the lower-temperature fuel cells are better suited to mobile and portable applications, whilst high-temperature fuel cells are more suited to stationary power and CHP.

Table 1 Main types of fuel cell

Fuel cell type	Electrolyte	Operating temp ºC	Applications
Solid oxide fuel cell (SOFC)	Solid ceramic (usually zirconia)	750 – 1000	CHP, distributed power generation, power generation
Intermediate temperature SOFC	Solid ceramic	600 – 800	CHP, distributed power generation
Solid polymer fuel cell (SPFC)	Sulphonic acid in a solid polymer membrane	60 – 90	Automotive, trains, marine, CHP, distributed power generation, portable power
Direct methanol fuel cell (DMFC)	Sulphonic acid in a solid polymer membrane	60 – 80	Portable power, cars
Phosphoric acid fuel cell (PAFC)	Phosphoric acid	190 – 210	CHP, distributed power generation
Alkaline fuel cell (AFC)	Solution of potassium hydroxide	50 – 200	Automotive, space
Molten carbonate fuel cell (MCFC)	Molten mixture of lithium and potassium carbonates	630 – 650	CHP, power generation

Source: *New and Renewable Energy: Prospects in the UK for the 21st Century: Supporting Analysis*

In the short- to medium-term, the hydrogen for fuel cells is expected to be produced using fossil fuels or fuels derived from fossil fuels, particularly natural gas, methanol, hydrogen, and possibly fuels derived from oil for automotive applications. In the medium to long

[62] *New and Renewable Energy: Prospects in the UK for the 21st Century: Supporting Analysis*, ETSU, ETSU R-122, Department of Trade and Industry
[63] *Fuel cells technology route map*, Department of Trade and Industry, DTI website, http://www.dti.gov.uk/energy/renewables/publications/pdfs/technologies/tech9.pdf

term, fuels derived from gasified coal and biomass would also be an option. Hydrogen derived via electricity generated by renewable energy is a prospect in the longer term.[64]

At present, global installed capacity is small, as truly commercially competitive products are not yet available. Only the PAFC has really been sold commercially for CHP and power generation applications. The majority of this capacity is in Japan and the USA. There is no installed capacity of fuel cells in the UK.[62]

Road transport contributes about one quarter of the UK's emissions of CO_2, and this proportion is expected to rise in the short term. It would be possible, to reduce total carbon emissions from road transport to very low levels, by 2050, through significant use of renewable hydrogen or biofuels.[61] It is unlikely that fuel cells will make a significant contribution to CO_2 reduction prior to 2010.[63]

Solid polymer fuel cells (SPFCs) are a strong candidate for transport applications and could be commercially competitive as a power source for fleet vehicles such as buses by 2010, but the use of fuel cells in cars presents more challenges due to space, weight and cost issues. There appears to be no fundamental reason why SPFCs could not compete in the car sector and the ultimate market size is immense. SPFCs offer the potential for range and performance to match the internal combustion engine and the development of truly commercially competitive systems appears increasingly probable. Most of the world's major car manufacturers have significant SPFC development programmes[62] – General Motors (in partnership with Shell), Toyota and Honda.[65]

There are currently two principal barriers to the development of a hydrogen economy. The first is an economic barrier in that the costs of manufacture, distribution, storage and use make hydrogen substantially more expensive than traditional fuels such as gasoline. This is even more pronounced where the hydrogen is produced using renewable sources of electricity that may also be uneconomic.

The second barrier is that of infrastructure – the current global fuel distribution infrastructure is based on oil and would require massive investment to replace this system with one based on hydrogen.[66]

11 Connecting renewable energy generators to the grid

Most electricity used in the UK is generated by large power plants connected to the ***high voltage transmission system***, which is owned and operated in England and Wales by the National Grid Company (NGC). Power entering the National Grid is at 275,000 volts or 400,000 volts. This voltage is gradually reduced via electricity transformers and distributed to customers (industrial and domestic) via the ***distribution networks***, which are owned and operated by the Distribution Network Operators (DNOs).

The electricity supply system is a ***displacement system***, so for every bit of electricity used, the same amount must be supplied to the network from somewhere. Electricity is not stored, so if demand for electricity increases, supply must increase at the same time.

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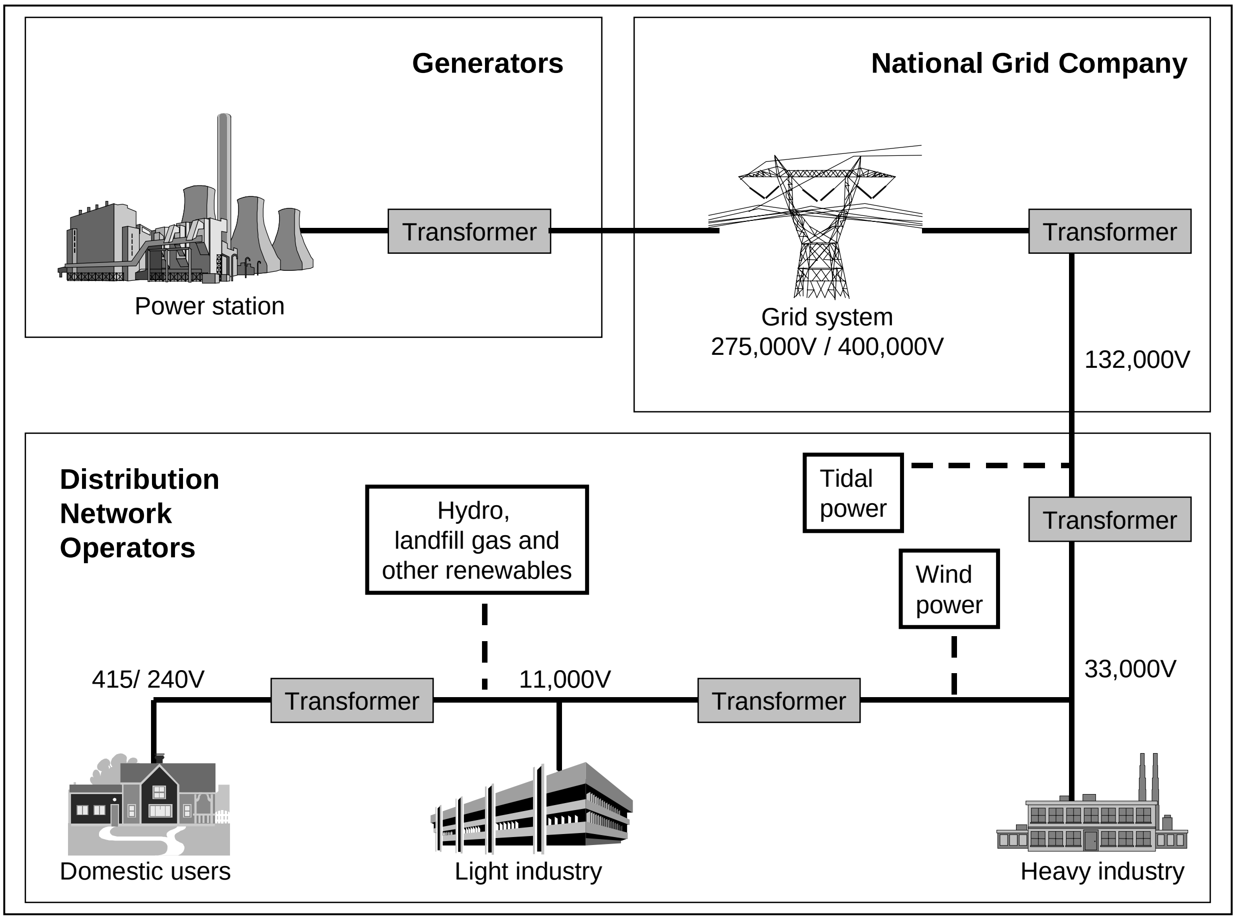
[64] *New and Renewable Energy: Prospects in the UK for the 21st Century: Supporting Analysis*, ETSU, ETSU R-122, Department of Trade and Industry
[65] *Is hydrogen the fuel of the future?*, (2003), Maggie Shiels, BBC News website, Thursday 27 March 2003, http://news.bbc.co.uk/1/hi/business/2880975.stm
[66] *Hydrogen technology route map*, Department of Trade and Industry, DTI website, http://www.dti.gov.uk/energy/renewables/publications/pdfs/technologies/tech11.pdf

Renewable electricity generators produce much less electricity and can supply it at a lower voltage than large coal, gas or nuclear power stations. It would be very expensive to connect these smaller-scale generators to the high voltage transmission system, so they are connected directly to the lower voltage distribution network. It is also usually more convenient to connect renewable power sources to the distribution network because it is more widespread than the National Grid and renewable power sources are often located in remote areas. Power suppliers connected to the distribution network are referred to as **distributed generators** or **embedded generators**.

There are technical problems associated with embedded generation. The local distribution system where embedded power supplies are connected may need to be modified. Embedded generation also tends to increase local voltage levels requiring some means of modifying voltage levels to ensure that customers receive a standard voltage of electricity.

Figure 3 Schematic of the UK electricity system



Source Adapted from DTI *Wind Energy Fact Sheet 11*[67]

Demand for energy is not constant and because electricity cannot be stored in large quantities, the current electricity generation network keeps some generating capacity in reserve, so that output can be increased when demand increases. This is known as the ***running reserve*** or ***spinning reserve***. Many renewable energy sources generate

[67] *Wind Energy Fact Sheet 11: Wind energy and the electricity network*, (2001), Department of Trade and Industry, November 2001

electricity intermittently because they are reliant on intermittent natural forces such as sunlight, wind or water. Times of demand for energy may not always coincide with times of energy generation by such intermittent sources.

The NGC has estimated that it can accommodate up to 20 per cent of total electricity supply from intermittent sources without the need for significant changes to current operating practices. Increasing the proportion of energy produced from intermittent sources above 20 per cent would incur additional costs and may require new electricity storage technologies.[68] Some renewable sources of energy are not, however, as intermittent as solar or wind energy (e.g. biofuels, landfill gas, waste incineration).

12 Renewable energy in Wales

In 2003, 7.5 per cent of the electricity generated in the UK was generated in Wales, 12.4 per cent in Scotland, 1.8 per cent in Northern Ireland and 78.3 per cent in England. Of this electricity generated, less than three per cent was from renewable sources.

Table 2 below shows the percentage of energy generated from renewable sources in each of the four UK countries in 2003. This data refers to the total 'headline' measure of electricity generated in England, Wales, Scotland and Northern Ireland by all types of renewable electricity generation. This is not the same as the measure of renewable energy generation used under the Renewables Obligation (RO).[69] On an RO level, the percentage of renewable electricity in the UK in 2003 was 2.21 per cent. The RO measure is not meaningful at a sub-national level because electricity can be produced in one area and sold in another.

Table 2 Overall percentage of electricity generated from renewable sources

	2002	2003
England	1.70	1.90
Scotland	10.28	7.71
Wales	2.44	2.60
Northern Ireland	1.96	1.59
UK	2.86	2.67

Source: *Energy Trends, December 2004*[70]

In terms of electricity consumption, Wales is a net exporter of electricity to England. Of the electricity consumed in 2003, 6.5 per cent is consumed in Wales, 10.1 per cent in Scotland, 2.3 per cent in Northern Ireland and 81.2 per cent in England.

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[68] *Review of Energy Policy in Wales Part 1: Renewable Energy – Final Report*, (2003), Economic Development Committee, National Assembly for Wales, National Assembly for Wales website, http://www.wales.gov.uk/assemblydata/N0000000000000000000000000009185.pdf
[69] Under the Renewables Obligation (RO), all electricity suppliers must prove that they have bought or produced 3 per cent of the electricity they sell from renewable sources. The RO does not include existing hydro-electric plants over 20MW, plants using renewable sources built before 1990 (unless re-furbished) and energy from mixed waste combustion unless the waste is first converted to fuel using advanced conversion technology. Only energy derived from the biodegradable fraction of any waste is eligible.
[70] *Energy Trends, December 2004*, (2004), Department of Trade and Industry, DTI website, http://www.dti.gov.uk/energy/inform/energy_trends/dec_04.pdf

12.1 Potential to generate renewable energy

It is not possible to say how much renewable energy Wales could generate as the capacity to generate energy by different forms of renewable energy will depend on a number of factors that are subject to continual change, such as:

- technical constraints imposed by the capability of equipment to generate electricity and continual technological improvements;
- economic constraints;
- infrastructure constraints involving the electricity transmission network and the way in which different forms of renewable energy feed into the transmission system;
- land ownership constraints;
- environmental constraints (ecological, archaeological, fisheries, etc.);
- policy constraints / demands.

For example, it may not currently be feasible to build offshore wind farms in some areas due to the large costs involved, but as technology progresses, it may become more cost effective to build offshore wind farms.

A *Strategic Study of Renewable Energy Resources in Wales*[71] was published in 2001, which estimated the potential for renewable energy developments in Wales to be over 250,000GWh heat and energy (250TWh), with an estimated achievable potential of up to about 9,000GWh heat and energy (9TWh). The breakdown of these estimates by different mechanisms is given in table 3.

[71] *Strategic Study of Renewable Energy Resources in Wales*, (2001), Sustainable Energy Limited, http://www.wales.gov.uk/subitradeindustry/content/consultations/renewableresources-e.htm

Table 3 Potential for renewable energy developments in Wales, by technology

	Annual energy contribution – full potential		Annual energy contribution – achievable potential	
	GWh	GWh heat	GWh	GWh heat
Onshore wind energy	121,000	-	3,000	-
Offshore wind energy	79,186	-	188 - 452	-
Hydropower	940	-	473 – 620	-
Biomass	9,145	up to 18,290	1,301	up to 2,603
Biogas	180	-	157	-
Active solar heating	-	665		33
Photovoltaics (PV)	233	-	1	-
Tidal power	>22,000	-	N/A	-
Wave power	3,000 – 6,000	-	N/A	-
Municipal waste	870	-	543	-
Landfill gas	361	-	361	-
Total	>236,000	up to 18,955	6,024 – 6,435	up to 2,636

Source: *Strategic Study of Renewable Energy Resources in Wales*

13 Energy efficiency

Energy efficiency has been identified as an important component of the drive to reduce CO^2 emissions, provide greater security of supply and to de-couple economic growth from energy use.

Defra launched its plan for action on energy efficiency in April 2004[72], which states a belief that 20 million tonnes of carbon (MtC) can be saved by 2020 through increased energy efficiency.

The Welsh Assembly Government launched its *Energy Saving Wales* consultation document in February 2004.[12] This does not set a specific amount of carbon to be saved by efficiency measures, but restates the commitment to achieve a 20 per cent reduction in carbon by 2020.

The *Energy Wales Route Map* identifies a number of key tasks and milestones to implement the *Energy Saving Wales* plan, including:

- communicating cost-effective energy efficiency energy efficiency measures to the individual at the business, domestic and public levels. This includes the establishment of Energy Saving Wales Portal by mid 2005. The Portal has not yet been launched;

- encourage greater development and uptake of micro-renewables, including the development of a draft microgeneration action plan by the end of 2005 and review prospects by the end of 2007;

[72] *Energy Efficiency: The Government's Plan for Action,* (2004), Defra, CM 6167, http://www.archive2.official-documents.co.uk/document/cm61/6168/6168.pdf

- support the energy efficiency infrastructure through relevant training and education;
- strengthen the networking between service providers by encouraging improved networking between service providers by mid 2005.

In addition to the above, TAN 8 encourages local authorities to consider including planning guidance that considers design aspects of construction to minimise energy use, maximise energy efficiency and passive solar gain.[2]

The House of Lords Science and Technology Committee reviewed energy efficiency policy in 2005.[73] They reported a great deal of confusion about what the term 'energy efficiency' meant, how it was measured and sources of information for businesses, industry and consumers.

The Committee identified inefficiencies at every stage of energy production and use - inefficiency in fuel acquisition, in energy generation and distribution, technical inefficiencies in the products using more energy than needed (e.g. overpowering of motors, poor insulation, etc.) and behavioural inefficiency (causing wastage due to people using products inefficiently e.g. leaving appliances on, windows open, etc.). Energy efficiency is normally only associated with technical and behavioural inefficiencies.

13.1 Combined heat and power (CHP)

Combined heat and power (CHP) generators produce both power (usually electricity) and heat and are considered a more efficient means of producing energy than conventional power stations. A CHP plant comprises one or more types of engine (a reciprocating engine, gas turbine, or steam turbine) that drives electrical generators, where the steam or hot water generated in the process is recovered for use either in industrial processes, or in heating.

CHP can use a variety of fuels and technologies across a wide range of sites and scheme sizes, from generation for industrial usage, to community scale projects, to micro-CHP for individual houses. CHP plants are generally located at or near the point of use, reducing electricity transmission losses that occur across the electricity distribution network.

The UK government has set a target of generating 10GW of Good Quality CHP (GQCHP) by 2010. To encourage use of CHP, the White Paper[4] mentions the government's intention to look into setting targets for government departments to use CHP and encourages other parts of the public sector to consider whether setting CHP targets is appropriate.

The Welsh Assembly Government expects planning authorities to help facilitate and encourage developers to use community heating and CHP. Development briefs should require CHP to be investigated and briefs for larger sites should consider including community heating networks.[2]

[73] *Energy Efficiency Volume 1: Report*, (2005), House of Lords Science and Technology Committee, 2nd Report of Session 2005-06, HL Paper 21-I, http://www.publications.parliament.uk/pa/ld200506/ldselect/ldsctech/21/21i.pdf

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