

= Renewable energy in Scotland =

The production of renewable energy in Scotland is an issue that has come to the fore in technical , economic , and political terms during the opening years of the 21st century . The natural resource base for renewable energy is extraordinary by European , and even global standards , with the most important potential sources being wind , wave , and tide .

At the end of 2015 , there was 7 @, @ 723 megawatts (MW) of installed renewable electricity capacity in Scotland , an increase of 5 @. @ 5 % (or 406 MW) from the end of 2014 . Renewable electricity generation in Scotland was 21 @, @ 983 GWh in 2015 , up 15 @. @ 2 % on 2014 . 57 @. @ 7 per cent of Scotland 's electricity came from renewables in 2015 . Scottish renewable generation makes up approximately 26 @. @ 4 % of total UK renewable generation (down from 32 % in 2014) . In 2014 , Scotland exported over 24 per cent of generation .

Continuing improvements in engineering and economics are enabling more of the renewable resources to be utilised . Fears regarding peak oil and climate change have driven the subject high up the political agenda and are also encouraging the use of various biofuels . Although the finances of many projects remain either speculative or dependent on market incentives , it is probable that there has been a significant , and in all likelihood long @-@ term change , in the underpinning economics .

In addition to planned increases in large @-@ scale generating capacity and microsystems using renewable sources , various related schemes to reduce carbon emissions are being researched . Although there is significant support from the public , private and community @-@ led sectors , concerns about the effect of the technologies on the natural environment have been expressed . There is also an emerging political debate about the relationship between the siting , and the ownership and control of these widely distributed resources .

= = Realisation of the potential = =

The natural resource base for renewables is extraordinary by European , and even global standards . In addition to an existing installed capacity of 1 @. @ 3 Gigawatts (GW) of hydro @-@ electric schemes , Scotland has an estimated potential of 36 @. @ 5 GW of wind and 7 @. @ 5 GW of tidal power , 25 % of the estimated total capacity for the European Union and up to 14 GW of wave power potential , 10 % of EU capacity . The renewable electricity generating capacity may be 60 GW or more , considerably greater than the existing capacity from all Scottish fuel sources of 10 @. @ 3 GW . Scotland exceeded its renewable energy target , set in 2007 , for 31 % of total power generation coming from renewables by 2011 , and the 2020 target for the renewable share of total electricity generation has been raised from 50 % to 80 % .

In January 2006 the total installed electrical generating capacity from all forms of renewable energy was less than 2 GW , about a fifth of the total electrical production . By January 2007 wind power capacity , which has been growing rapidly , reached 1 GW capacity , and the total for renewables had grown to over 2 @. @ 3 GW . By August 2009 wind power capacity was a fraction short of 1 @. @ 5 GW and total renewables capacity had reached over 3 @. @ 1 GW . By mid @-@ 2011 these figures were 2 @. @ 76 GW and 4 @. @ 6 GW respectively .

In 2012 , over 40 per cent of Scotland 's electricity came from renewable energy , and Scotland contributed almost 40 per cent of the UK 's renewables output . At the end of 2012 , there was 5 @, @ 801 megawatts (MW) of installed renewables electricity capacity in Scotland , an increase of 20 @. @ 95 per cent (1 @, @ 005 MW) on the end of 2011 . Renewable electricity generation in 2012 was a record high at 14 @, @ 756 GWh ? an increase of 7 @. @ 3 per cent on 2011 , the previous record year for renewables output . The bulk of electricity production is derived from gas and oil . 2002 figures used in RSPB Scotland et al . (2006) are gas (34 %) , oil (28 %) , coal (18 %) and nuclear (17 %) , with renewables 3 % (principally hydro @-@ electric) , prior to the substantial growth in wind power output . It should be borne in mind that electricity production is only part of the overall energy use budget . In 2002 , Scotland consumed a total of 175 Terawatt @-@ hours (TWh) of energy in all forms , some 2 % less than in 1990 . Of this , only 20 % was

consumed in the form of electricity by end users , the great majority of energy utilised being from the burning of oil (41 %) and gas (36 %) .

The renewable energy industry supports more than 11 @, @ 500 jobs in Scotland , according to a 2013 study by Scottish Renewables . However a 2011 study by 4 @-@ Consulting calculated that there was probably a small net loss in jobs in Scotland from government support for renewable energy . They estimated that the offshore wind industry might create between 300 ? 2 @, @ 200 long @-@ term jobs by 2020 . With 20 GW of renewable energy projects in the pipeline , the sector has the potential to grow quickly in the years ahead creating more jobs in the region . Glasgow , Fife and Edinburgh are key centres of offshore wind power development , and the emerging wave power and tidal power industries are centred around the Highlands and Islands . Rural job creation is being supported by bioenergy systems in areas such as Lochaber , Moray and Dumfries and Galloway .

Scotland also has significant quantities of fossil fuel deposits , including 62 @. @ 4 % of the EU 's proven reserves of oil , 12 @. @ 5 % of the EU 's proven reserves of gas and 69 % of UK coal reserves . Nonetheless , the Scottish Government has set ambitious targets for renewable energy production . In 2005 the aim was for 18 % of Scotland 's electricity production to be generated by renewable sources by 2010 , rising to 40 % by 2020 . In 2007 this was increased to 50 per cent of electricity from renewables by 2020 , with an interim target of 31 per cent by 2011 . The following year new targets to reduce overall greenhouse gas emissions by 80 % by 2050 were announced and then confirmed in the 2009 Climate Change Delivery Plan . Maf Smith , director of the Sustainable Development Commission in Scotland said " Governments across the world are shying away from taking the necessary action . The Scottish Government must be commended for its intention to lead the way " .

An important reason for this ambition is growing international concern about human @-@ induced climate change . The Royal Commission on Environmental Pollution 's proposal that carbon dioxide emissions should be reduced by 60 % was incorporated into the UK government 's 2003 Energy White Paper . The 2006 Stern Review proposed a 55 % reduction by 2030 . The recent Intergovernmental Panel on Climate Change 's Fourth Assessment Report has further increased the profile of the issue .

= = Hydro @-@ electric power = =

Scotland has 85 % of the UK 's hydro @-@ electric energy resource , much of it developed by the North of Scotland Hydro @-@ Electric Board in the 1950s . The " Hydro Board " , which brought " power from the glens " , was a nationalised industry at the time although it was privatised in 1989 and is now part of Scottish and Southern Energy plc .

Current capacity is 1 @. @ 54 GW and includes major developments such as the 120 MW Breadalbane scheme and the 245 MW Tummel system . Several of Scotland 's hydro @-@ electric plants were built to power the aluminium smelting industry . These were built in several " schemes " of linked stations , each covering a catchment area , whereby the same water may generate power several times as it descends . Numerous remote straths were flooded by these schemes , many of the largest of which involved tunnelling through mountains as well as damming rivers . Emma Wood , the author of a study of these pioneers wrote :

I heard about drowned farms and hamlets , the ruination of the salmon @-@ fishing and how Inverness might be washed away if the dams failed inland . I was told about the huge veins of crystal they found when they were tunnelling deep under the mountains .

It is estimated that as much as another 1 @. @ 2 GW of capacity remains available to exploit , mostly in the form of micro and small @-@ hydro developments such as the existing one in Knoydart and a system planned for Kingussie . In reality , environmental constraints and given that the most easily available catchment areas have already been exploited it is unlikely that the full 1 @. @ 2 GW will be exploited . There is also further potential for new pumped storage schemes (at present used to meet peak demand) that would work with intermittent sources of power such as wind and wave . Examples include the 440 MW Cruachan Dam and 300 MW Falls of Foyers schemes . The 100 MW Glendoe Project which opened in 2009 was the first large scale scheme in

Scotland for almost fifty years but is likely to be one of the last of its kind . A 2011 report calculated that pumped storage hydro capacity could supply 2 @. @ 8 GW of electricity for 5 hours , then drop to 1 @. @ 1 GW and run out of water in 22 hours . The report concluded that even with projected new schemes at Loch Ness and Loch Sloy , pumped storage would not be able to replace wind electricity during extended windless periods .

= = Wind power = =

Wind power in Scotland is the country 's fastest growing renewable energy technology , with 5587 MW of installed capacity as of 2015 . The Robin Rigg Wind Farm is a 180 MW development completed in April 2010 , which is Scotland 's first offshore wind farm , sited on a sandbank in the Solway Firth . The United Kingdom 's largest onshore wind farm (539 MW) is at Whitelee in East Renfrewshire . The Clyde Wind Farm is a 548 MW wind farm under construction near Abington , South Lanarkshire , Scotland , which will be Europe 's largest onshore wind farm when completed . Two very large offshore wind turbines (5 MW each) are located in the Moray Firth . There are many other large onshore wind farms including some , both planned and operating , which are in community ownership .

The siting of turbines is sometimes an issue , but surveys have generally shown high levels of community acceptance for wind power in Scotland . Wind farm developers sometimes offer " community benefit funds " to help address any disadvantages faced by those living adjacent to wind farms . There is further potential for expansion , especially offshore given the high average wind speeds , and a number of large offshore wind farms are planned .

It is estimated that 11 @. @ 5 GW of onshore wind potential exists , enough to provide 45 TWh of energy . More than double this amount exists on offshore sites where mean wind speeds are greater than on land . The total offshore potential is estimated at 25 GW , which although more expensive to install , could be enough to provide almost half the total energy used in Scotland . Plans to harness up to 4 @. @ 8 GW of the potential in the inner Moray Firth and Firth of Forth were announced in January 2010 . Moray Offshore Renewables and SeaGreen Wind Energy were awarded development contracts by the Crown Estate as part of a UK @-@ wide initiative . Also in 2010 , discussions were held between the Scottish Government and Statoil of Norway with a view to developing a 5 @-@ turbine floating windfarm , possibly to be located off Fraserburgh . In July 2016 , RSPB challenged development in the Firth of Forth and Firth of Tay .

= = Wave power = =

Various systems are under development at present aimed at harnessing the enormous potential available for wave power off Scotland 's coasts . Pelamis Wave Power (previously Ocean Power Delivery) are an Edinburgh @-@ based company whose Pelamis system has been tested off Orkney and Portugal . Their second generation P2 Pelamis machines are 180 metres (591 ft) long and 4 metres (13 @. @ 1 ft) diameter . Five tubes joined together by hinged joints float semi @-@ submerged on the surface of the ocean and move relative to each other as waves pass down the length of the machine . This motion is resisted by hydraulic cylinders which drive generators inside the machine to produce electricity . Future wave farm projects around Scotland could involve an arrangement of interlinked 1 MW machines connected to shore by a subsea transmission cable .

Another approach was used by the LIMPET 500 (Land Installed Marine Power Energy Transformer) energy converter which was installed on the island of Islay by Wavegen Ltd . It was a shore @-@ based unit and generated power when waves run up the beach , creating pressure inside an inclined oscillating water column . This in turn creates pneumatic power which drives the twin 250 kW generators . Islay LIMPET was opened in 2001 and was the world 's first commercial scale wave @-@ energy device . In March 2013 Voith Hydro decided to close down Wavegen choosing to concentrate on tidal power projects .

Funding for the UK 's first wave farm was announced by the then Scottish Executive on 22 February 2007 . It will be the world 's largest , with a capacity of 3 MW generated by four Pelamis

machines at a cost of over £ 4 million . The funding is part of a new £ 13 million funding package for marine power projects in Scotland that will also support developments to Aquamarine 's Oyster and Ocean Power Technologies ' PowerBuoy wave systems , AWS Ocean Energy 's sub @-@ sea wave devices , ScotRenewables ' 1 @.@ 2 MW floating rotor device , Cleantechcom 's tidal surge plans for the Churchill barriers between various Orkney islands , the Open Hydro tidal ring turbines , and further developments to the Wavegen system proposed for Lewis as well as a further £ 2 @.@ 5 million for the European Marine Energy Centre (EMEC) based in Orkney . This is a Scottish Executive @-@ backed research facility that has installed a wave testing system at Billia Croo on the Orkney mainland and a tidal power testing station on the nearby island of Eday . At the official opening of the Eday project the site was described as " the first of its kind in the world set up to provide developers of wave and tidal energy devices with a purpose @-@ built performance testing facility . "

The Siadar Wave Energy Project was announced in 2009 . This 4 MW system was planned by npower Renewables and Wavegen for a site 400 metres off the shore of Siadar Bay , in Lewis . However , in July 2011 holding company RWE announced they were withdrawing from the scheme , and Wavegen are seeking new partners . In early 2010 two areas were identified for substantial offshore wind development , in the Moray Firth basin and outer Firth of Forth . Shortly afterwards the Government earmarked eleven sites they expected to benefit from the construction of up to 8 @,@ 000 offshore turbines by 2020 . These included Campbeltown and Hunterston , four sites previously used for offshore oil fabrication at Ardersier , Nigg Bay , Arnish and Kishorn and five east coast locations from Peterhead to Leith . In May 2010 the " Vagr Atferd P2 " Pelamis 750 kW system was launched for testing by EMEC . The device weighs 1 @,@ 500 tonnes (1 @,@ 500 long tons ; 1 @,@ 700 short tons) and is 180 metres (590 ft) long .

= = Tidal power = =

Unlike wind and wave , tidal power is an inherently predictable source . However the technology is in its infancy and numerous devices are in the prototype stages . Today it is known that a tall tubular tower with three blades attached to it is the typical profile of a wind turbine , but twenty @-@ five years ago there were a wide variety of different systems being tested . This is the current situation with regard to tidal power . Some systems capture energy from the tides in a vertical direction . The tide comes in and raises the water level in a basin . As the tide lowers the water in the basin is discharged through a turbine . Tidal stream power captures energy from the flow of tides , usually using underwater plant resembling a small wind turbine . An example is Marine Current Turbines SeaGen 1 @.@ 2 MW device at Strangford Lough in Northern Ireland , which is the largest tidal stream turbine in the world . To date the only installed tidal power plant of any size is the 240 MW rated barrage scheme at the Rance Estuary in Brittany , which has been operating successfully for more than 25 years , although there are a number of other much smaller projects around the world .

The Pentland Firth between Orkney and mainland Scotland has been described as the " Saudi Arabia of tidal power " and may be capable of generating up to 10 GW although a more recent estimate suggests an upper limit of 1 @.@ 9 GW . In March 2010 a total of ten sites in the area , capable of providing an installed capacity of 1 @.@ 2 GW of tidal and wave generation were leased out by the Crown Estate . Several other tidal sites with considerable potential exist in the Orkney archipelago . Tidal races on the west coast at Kylerhea between Skye and Lochalsh , the Grey Dog north of Scarba , the Dorus Mòr off Crinan and the Gulf of Corryvreckan also offer significant prospects .

In August 2010 the Atlantis Resources Corporation 's AK @-@ 1000 turbine , which has 18 @-@ metre (59 ft) blades was unveiled at Invergordon . It is claimed to be the largest tidal turbine ever built and will be tested by EMEC off Eday . In October 2010 MeyGen , a consortium of Morgan Stanley , Atlantis Resources Corporation and International Power , received a 25 @-@ year operational lease from the Crown Estate for a 400 MW tidal power project in the Pentland Firth . However , in 2011 the plans were in difficulty after Norwegian partners Statkraft pulled out of the project . In December 2014 , Atlantis announced that onshore construction at the project site for

connection to the electricity transmission grid would commence in January 2015 . The first power to the national grid is expected to be delivered in 2016 .

In 2010 it was announced that 10 Hammerfest Strom HS1000 Norwegian turbines , capable of generating 1 MW each , could be installed in the Sound of Islay and that the BiFab yard at Arnish had won a £ 2 million contract to build some of the structures ' components . The following March this project , which will become the largest tidal array in the world , was approved by the Scottish Government with 10 planned tidal turbines predicted to generate enough power for over 5 @, @ 000 homes . The Sound of Islay offers both high currents and shelter from storms . A single 1 MW HS1000 was installed at EMEC off Eday , Orkney by the end of 2011 .

The " world 's first community @-@ owned tidal power generator " became operational in Bluemull Sound off Yell , Shetland in early 2014 . This 30 kW Nova Innovation device feeds into the local grid . At the opposite end of the country a 2010 consultants ' report into the possibility of a scheme involving the construction of a Solway Barrage , possibly south of Annan , concluded that the plans " would be expensive and environmentally sensitive . " In 2013 an alternative scheme using the VerdErg Renewable Energy spectral marine energy converter was proposed for a plan involving the use of a bridge along the route of an abandoned railway line between Annan and Bowness @-@ on @-@ Solway .

= = Biofuels = =

= = = Biodiesel = = =

Various biodiesel schemes exist at present , and as with most renewables , interest is growing in the subject . Westray Development Trust operate a biodiesel vehicle fuelled by the residual vegetable oils from the Orkney archipelago fish and chip outlets . On a larger scale Argent Energy 's plant in Motherwell recycles tallow and used cooking oil to produce 50 @, @ 000 @, @ 000 litres (13 @, @ 000 @, @ 000 US gal) of biodiesel per annum .

A major benefit of biodiesel is lower carbon emissions , although the energy balance of liquid biofuels is a matter of controversy . Research is being undertaken into converting rapeseed oil into biodiesel , and the European biofuels directive intends to ensure that 5 @. @ 75 % Europe 's transport fuel comes from renewable sources by 2010 . However , there is only enough used vegetable oil in the UK to contribute 0 @. @ 38 % of current road fuel demand and if all the arable land in the UK were turned over to biofuel crops this would still only satisfy 22 % of the existing requirement for road transport . Serious concerns regarding the ethics of growing biodiesel in developing countries and importing the fuel to Europe have been raised on the grounds that they may replace much needed food crops . Converting any mainstream transport system to a renewable one also involves the conundrum that for consumers to use it the infrastructure must be in place , but high levels of use may be required to finance the infrastructure . Developments are thus slow at present and renewably powered vehicles very much the exception .

Due to the relatively short growing season for sugar producing crops , ethanol is not commercially produced as a fuel in Scotland at present . However , there are encouraging developments in cellulosic decomposition that might enable grass or tree crops to be used to this end in future and which may prove to have lower net carbon emissions than other production techniques .

= = = Biogas , anaerobic digestion and landfill gas = = =

Biogas , or landfill gas , is a biofuel produced through the intermediary stage of anaerobic digestion consisting mainly of 45 ? 90 % biologically produced methane and carbon dioxide . In early 2007 a thermophilic anaerobic digestion facility was commissioned in Stornoway in the Western Isles . The Scottish Environment Protection Agency (SEPA) and the Renewable Energy Association are also leading the way towards the establishment of a digestate standard to facilitate the use of solid outputs from digesters on land . Anaerobic digestion and mechanical biological treatment facilities

have been planned at a number of other locations in Scotland , such as Westray .

It has been recognised that biogas (mainly methane) ? produced from the anaerobic digestion of organic matter ? is potentially a valuable and prolific feedstock . It is estimated that 0 @. @ 4 GW of generating capacity might be available from agricultural waste in Scotland . The Scottish Executive and SEPA has funded seven small scale farm trial plants with the British anaerobic digestion company Greenfinch in Southwest Scotland . Landfill sites have the potential for a further 0 @. @ 07 GW with sites such as the Avondale Landfill in Falkirk already utilising their potential .

= = = Solid biomass = = =

A 2007 report concluded that wood fuel exceeded hydroelectric and wind as the largest potential source of renewable energy . Scotland 's forests , which made up 60 % of the UK resource base , were forecast to be able to provide up to 1 million tonnes of wood fuel per annum . The biomass energy supply in Scotland was forecast to reach 450 MW or higher , (predominantly from wood) , with power stations requiring 4 @, @ 500 ? 5 @, @ 000 oven dry tonnes per annum per megawatt of generating capacity . However a 2011 Forestry Commission and Scottish government follow @-@ up report concluded that : " ... there is no capacity to support further large scale electricity generation biomass plants from the domestic wood fibre resource . " A plan to build in Edinburgh a 200 MW biomass plant which would have imported 83 % of its wood , was withdrawn by Forth Energy in 2012 . The energy company E.ON has constructed a 44 MW biomass power station at Lockerbie using locally sourced crops while the smaller EPR Westfield power plant in Fife produces 9 @. @ 8 MW of output using chicken litter as fuel . The Scottish Executive and the Forestry Commission issued a Scottish Biomass Action Plan in 2007 . The Scottish Government set up the Scottish Biomass Support Scheme in 2006 with a £ 7 @. @ 5 million grant , later increased to £ 10 @. @ 5 million , to support biomass energy . £ 6 million of grants were drawn down by the time the scheme finished in March 2008 and a 2009 review of results concluded that the scheme had " ... achieved limited success against its strategic aims objectives . " A 2007 article by Renew Scotland claimed that automatic wood pellet boilers could be as convenient to use as conventional central heating systems . These boilers might be cheaper to run and , by using locally produced wood fuel , could try to be as carbon neutral as possible by using little energy for transportation .

There is also local potential for energy crops such as short @-@ rotation willow or poplar coppice , miscanthus energy grass , agricultural wastes such as straw and manure , and forestry residues . These crops could provide 0 @. @ 8 GW of generating capacity .

= = Micro systems = =

The Energy Savings Trust has estimated that micro @-@ generation could provide a significantly increased proportion of the UK 's electricity demand by 2050 although only a fraction of this would come from renewable sources . The current Scottish output is negligible . In May 2006 the then Communities Minister Malcolm Chisholm launched a Planning Advice Note aimed at promoting micro @-@ renewables . Small @-@ scale ' wind2heat ' projects , which use wind turbines to power electrical storage heaters directly , have proven to be successful in remoter rural areas ; as have various other local schemes such as air source heat pumps .

Whisky distilleries may have a locally important part to play . Caithness Heat and Power have announced plans to tackle fuel poverty in Wick by utilising a wood chip CHP scheme in partnership with the Old Pulteney Distillery . On the island of Islay , a swimming pool is heated using waste heat from the Bowmore distillery . In Edinburgh , Tynecastle High School , due to be completed in 2010 , will be heated by waste heat from the neighbouring North British Distillery . In 2009 the Diageo Cameron Bridge distillery announced plans for a £ 65 million facility to generate energy from the spent " wash " created in the manufacturing process , which will aim to replace 95 % of the plant 's existing fossil fuel use .

There are also a growing number of micro hydro systems on smaller watercourses , especially in more remote rural locations .

The Inner Hebrides island Eigg is not connected to the National Grid , and has an integrated renewable power supply with wind , hydro and solar and battery storage , and diesel backup (which is rarely used) .

== Solar energy ==

Despite Scotland 's relatively low level of sunshine hours , solar thermal panels can work effectively as they are capable of producing hot water even in cloudy weather . The technology was developed in the 1970s and is well @-@ established with various installers in place , although AES Solar based in Forres (who provided the panels for the Scottish Parliament building) are Scotland 's only manufacturer .

Since the introduction of feed @-@ in tariffs there has been a growth in the volume of installed photovoltaic panels , which generate electricity . In 2004 , the largest installation in Scotland was a 21 kWp system at the Sir E. Scott secondary school in Tarbert , Harris although larger systems have been completed since then . The UK 's practicable resource is estimated at 7 @.@ 2 TWh per annum , which in the Scottish context is the approximate equivalent of 70 MW or less of installed capacity .

The " road energy system " uses water pipes buried beneath a layer of tarmac . In the summer , the dark asphalt is heated by the sun which in turn heats the water in the pipes . This water can be stored in an underground aquifer and the heat extracted in winter using a heat pump . The system can be used to warm or cool down roads , keeping them ice @-@ free and / or preventing softening due to overheating . Alternatively , the stored energy can be used for cooling buildings . The system was developed in the Netherlands and has been licensed by Ullapool @-@ based Invisible Energy Systems , who have installed the technology in their car park .

== Geothermal energy ==

Geothermal energy is obtained by tapping the heat of the earth itself . Most systems in Scotland provide heating through a ground source heat pump which brings energy to the surface via shallow pipe works . An example is the Glenalmond Street project in Shettleston , which uses a combination of solar and geothermal energy to heat 16 houses . Water in a coal mine 100 metres (328 ft) below ground level is heated by geothermal energy and maintained at a temperature of about 12 ° C (54 ° F) throughout the year . The warmed water is raised and passed through a heat pump , boosting the temperature to 55 ° C (131 ° F) , and is then distributed to the houses providing heating to radiators .

Although the pumps may not be powered from renewable sources , up to four times the energy used can be recovered . Installation costs can vary from £ 7 @,@ 000 to £ 10 @,@ 000 , and grants may be available from the Scottish Community and Householders Renewables Initiative operated by Community Energy Scotland for domestic properties up to a maximum of £ 4 @,@ 000 . Perhaps up to 7 @.@ 6 TWh of energy is available on an annual basis from this source .

There is also potential for geothermal energy production from decommissioned oil and gas fields .

== Other means of reducing carbon emissions ==

It is clear that if carbon emissions are to be reduced , a combination of increased production from renewables and decreased consumption of energy in general and fossil fuels in particular will be required . On the latter front , Gordon Brown , the then UK Chancellor of the Exchequer , announced in November 2006 that within a decade all new houses would have to be ' zero carbon ' . A variety of other options exist , most of which may affect development of renewable technologies even if they are not means of producing energy from renewable sources themselves .

== Other renewable options ==

Various other ideas for renewable energy in the early stages of development , such as ocean thermal energy conversion , deep lake water cooling , and blue energy , have received little attention in Scotland , presumably because the potential is so significant for less speculative technologies .

== Carbon offsetting ==

Carbon offsetting involves individuals or organisations compensating for their use of fossil fuels by making payments to projects that aim to neutralise the effect of these carbon emissions . Although the idea has become fashionable , the theory has received serious criticism of late .

Nonetheless , a credible option may be to plant trees within the local bioregion and maintain the forest on a permanent basis , thus locking up carbon produced by burning fossil fuels . In British growing conditions this method can compensate for carbon at a rate of 200 tonnes per square kilometre (0 @. @ 89 tons / acre) planted over a 100 @- @ year period . Thus a 4 @- @ square @- @ kilometre (988 @- @ acre) plantation could uptake 200 tonnes (220 tons) of carbon over twenty @- @ five years . This is the equivalent of 10 @, @ 000 tonnes (11 @, @ 000 short tons) of carbon dioxide . The weaknesses of the approach include uncertainty as to whether the planting might have occurred anyway and who , in the future , will ensure permanence . However , there is likely to be a greater level of credibility inherent in a nearby and visible scheme than in a far @- @ distant one .

== Challenges and opportunities offered by non @- @ renewables ==

The following technologies are means of reducing the effect of carbon emissions and form an important aspect of the energy debate in Scotland and are included here for completeness . Their effect is likely to influence the future direction of commercial renewable energy , but they are not renewable forms of energy production themselves .

Carbon sequestration : Also known as carbon capture and storage , this technology involves the storage of carbon dioxide (CO₂) that is a by @- @ product of industrial processes through its injection into oil fields . It is not a form of renewable energy production , but it may be a way to significantly reduce the effect of fossil fuels whilst renewables are commercialised . It may also be an intermediate step towards a ' hydrogen economy ' (see below) , which could either enable further renewable development or conceivably out @- @ compete it . The technology has been successfully pioneered in Norway but is still a relatively untried concept .

'Clean coal ' technology : It has been estimated that it will be 2020 to 2025 before any commercial @- @ scale clean coal power stations (coal @- @ burning power stations with carbon capture and sequestration) are widely adopted . Moreover , some have criticised the clean coal approach and it is at best a means of ameliorating carbon emissions . It is not a form of renewable energy production , although like carbon sequestration it offers a significant commercial challenge to renewable developments . In 2009 a licence to test underground coal gassification technology in Fife was granted to Thornton New Energy . However , a plan to build a new " clean coal " power station at Hunterston collapsed in 2009 after financial backing was withdrawn .

Nuclear power : Renewable energy as a concept generally excludes nuclear power although this stance has been challenged .

Incineration : There is a successful waste @- @ to @- @ energy incineration plant at Lerwick in Shetland which burns 22 @, @ 000 tonnes (24 @, @ 250 tons) of waste every year and provides district heating to over 600 customers . Although such plants generate carbon emissions through the combustion of the biological material and plastic wastes (which derive from fossil fuels) , they also reduce the damage done to the atmosphere from the creation of methane in landfill sites . This is a much more damaging greenhouse gas than the carbon dioxide the burning process produces , although other systems which do not involve district heating may have a similar carbon footprint to straightforward landfill degradation .

== Hydrogen ==

Although hydrogen offers significant potential as an alternative to hydrocarbons as a carrier of energy, neither hydrogen itself nor the associated fuel cell technologies are sources of energy in themselves. Nevertheless, the combination of renewable technologies and hydrogen is of considerable interest to those seeking alternatives to fossil fuels. There are a number of Scottish projects involved in this research, supported by the Scottish Hydrogen & Fuel Cell Association (SHFCA).

The PURE project on Unst in Shetland is a ground breaking training and research centre which uses a combination of the ample supplies of wind power and fuel cells to create a wind hydrogen system. Two 15 kW turbines are attached to a 'Hypod' fuel cell, which in turn provides power for heating systems, the creation of stored liquid hydrogen and an innovative fuel cell driven car. The project is community owned and part of the Unst Partnership, the community's development trust.

In the Western Isles a plan to enable a £ 10 million waste management plant into a hydrogen production facility was announced in June 2006. The Council have also agreed to purchase hydrogen fuelled buses and hope the new plant, which will be constructed in partnership with the local Hydrogen Research Laboratory, will supply island filling stations and houses and the industrial park at Arnish.

ITI Energy was a division of ITI Scotland and was established with the aim of funding Research and Development programmes in the energy sector. It is a division of ITI Scotland, which also includes a life sciences and digital media division. ITI Energy attracted the Alterg project, a French company that is developing technology for the cost effective storage of hydrogen.

In July 2008 the SHFCA announced plans for a "hydrogen corridor" from Aberdeen to Peterhead. The proposal involves running hydrogen powered buses along the A 90 and is supported by Aberdeenshire Council and the Royal Mail. The economics and practical application of hydrogen vehicles are being investigated by the University of Birmingham in England.

The "Hydrogen Office" in Methil aims to demonstrate the benefits of improved energy efficiency and renewable and hydrogen energy systems.

= = Local vs national concerns = =

A significant feature of Scotland's renewable potential is that the resources are largely distant from the main centres of population. This is by no means coincidental. The power of wind, wave and tide on the north and west coasts and for hydro in the mountains makes for dramatic scenery, but sometimes harsh living conditions. W. H. Murray described the Hebrides as "the Isles on the Edge of the Sea where men are welcome? if they are hard in body and in spirit tenacious."

This happenstance of geography and climate has created various tensions. There is clearly a significant difference between a renewable energy production facility of modest size providing an island community with all its energy needs, and an industrial scale power station in the same location that is designed to export power to far distant urban locations. Thus, plans for one of the world's largest onshore windfarms on the Hebridean island of Lewis have generated considerable debate. A related issue is the high voltage Beaulieu/Denny power line which brings electricity from renewable projects in the north and west to the cities of the south. The matter went to a public inquiry and has been described by Ian Johnston of The Scotsman as a "battle that pitches environmentalists against conservationists and giant energy companies against aristocratic landowners and clan chiefs". In January 2010 Jim Mather, the Energy Minister, announced that the project would be going ahead, notwithstanding the more than 18,000 objections received. 53km of the 132kV line inside the park was taken down and not replaced. The Beaulieu/Denny line was energized by Christmas 2015.

There is considerable support for community scale energy projects. For example, Alex Salmond, First Minister of Scotland, has stated that "we can think big by delivering small" and aspires to have a "million Scottish households with access to their own or community renewable generation within ten years". The John Muir Trust has also stated that "the best renewable energy

options around wild land are small @-@ scale , sensitively sited and adjacent to the communities directly benefiting from them " , although even community @-@ owned schemes can prove controversial .

A related issue is the position of Scotland within the United Kingdom . It has been alleged that UK transmission pricing structures are weighted against the development of renewables in Scotland , a debate which highlights the contrast between the sparsely populated north of Scotland and the highly urbanised south and east of England . Although the ecological footprints of Scotland and England are similar the relationship between this footprint and the biocapacities of the respective countries are not . Scotland 's biocapacity (a measure of the biologically productive area) is 4 @. @ 52 global hectares (gha) per head , some 15 % less than the current ecological effect . In other words , with a 15 % reduction in consumption , the Scottish population could live within the productive capacity of the land to support them . However , the UK ecological footprint is more than three times the biocapacity , which is only 1 @. @ 6 gha head , amongst the lowest in Europe . Thus , to achieve the same end in the UK context , consumption would have to be reduced by about 66 % .

The developed world 's economy is very dependent on inexpensive ' point @-@ source ' fossil fuels . Scotland , as a relatively sparsely populated country with significant renewable resources , is in a unique position to demonstrate how the transition to a low @-@ carbon , widely distributed energy economy may be undertaken . A balance will need to be struck between supporting this transition and providing exports to the economies of densely populated regions in the Central Belt and elsewhere , as they seek their own solutions . The tension between local and national needs in the Scottish context may therefore also play out on the wider UK and European stage .

= = Promotion of renewables = =

Growing national concerns regarding peak oil and climate change have driven the subject of renewable energy high up the political agenda . Various public bodies and public @-@ private partnerships have been created to develop the potential . The Forum for Renewable Energy Development in Scotland , (FREDS) is a partnership between industry , academia and Government aimed at enabling Scotland to capitalise on its renewable energy resource . The Scottish Renewables Forum is an important intermediary organisation for the industry , hosting the annual Green Energy Awards . Community Energy Scotland provides advice , funding and finance for renewable energy projects developed by community groups . Aberdeen Renewable Energy Group (AREG) is a public @-@ private partnership created to identify and promote renewable energy opportunities for businesses in the north @-@ east . In 2009 AREG formed an alliance with North Scotland Industries Group to help promote the North of Scotland as an " international renewable energy hub " .

The Forestry Commission is active in promoting the biomass potential . The Climate Change Business Delivery Group aims to act as a way for businesses to share best practice and address the climate change challenge . Numerous universities are playing a role in supporting energy research under the Supergen programme , including fuel cell research at St Andrews , marine technologies at Edinburgh , distributed power systems at Strathclyde and biomass crops at the UHI Millennium Institute 's Orkney College .

In 2010 the Scotcampus student Freshers ' Festivals held in Edinburgh and Glasgow were powered entirely by renewable energy in a bid to raise awareness among young people in Scotland .

= = Recent events = =

New data appears on a regular basis and milestones in 2007 ? 14 include the following .

In February 2007 the commissioning of the Braes of Doune wind farm took the UK renewables installed capacity up to 2 GW . Total Scottish capacity in October 2007 was 1 @. @ 13 GW from 760 turbines , and increased to 1 @. @ 3 GW by September 2008 , and 1 @. @ 48 GW by August 2009 .

Also during 2007 Scottish and Southern Energy plc in conjunction with the University of Strathclyde began the implementation of a ' Regional Power Zone ' in the Orkney archipelago . This ground @-@ breaking scheme (that may be the first of its kind in the world) involves ' active network management ' that will make better use of the existing infrastructure and allow a further 15 MW of new ' non @-@ firm generation ' output from renewables onto the network . Heat and Power Ltd. of Westray are involved in developing an innovative digester system that is being trialled at Tuquoy farm . Designed by Sam Marcus and Colin Risbridger , it is capable of handling up to 1 @,@ 500 tonnes of feedstock per annum . Scottish & Southern Energy have been asked to provide for an export capacity of 40 kWe . The aim is to help move the farm towards being powered by 100 % renewable energy .

In January 2008 it was reported that Professor Graeme Walker of the University of Abertay is leading a project aimed at using grain that is a by @-@ product of whisky distilling as a biofuel . In February 2008 plans to build a 10 MW prototype tidal energy plant in the Pentland Firth were announced by Tocardo Tidal Energy Ltd. of Wick . Production was expected to commence in 2009 . The following September , Scottish Power announced plans for two tidal projects in the same area , pending successful tests of a £ 6 million prototype .

In January 2009 the government announced the launch of a " Marine Spatial Plan " to map the potential of the Pentland Firth and Orkney coasts and agreed to take part in a working group examining options for an offshore grid to connect renewable energy projects in the North Sea to on @-@ shore national grids . The potential for such a scheme has been described as including acting as a " 30 GW battery for Europe 's clean energy " .

In July 2009 Friends of the Earth , the Royal Society for the Protection of Birds , World Development Movement and World Wildlife Fund published a study called " The Power of Scotland Renewed . " This study claimed that the country could meet all its electricity needs by 2030 without the requirement for either nuclear or fossil fuel powered installations .

In April 2010 permission was granted for four new hydro schemes totalling 6 @.@ 7 MW capacity in the Loch Lomond and The Trossachs National Park .

Sea Energy Renewables Ltd was purchased by Spanish company Repsol in June 2010 . This move paved the way for the Inch Cape 180 wind turbine project offshore from Dundee , scheduled for a 2018 completion . Work is not expected to start before 2015 .

In 2013 , a YouGov energy survey concluded that :

New YouGov research for Scottish Renewables shows Scots are twice as likely to favour wind power over nuclear or shale gas . Over six in ten (62 %) people in Scotland say they would support large scale wind projects in their local area , more than double the number who said they would be generally for shale gas (24 %) and almost twice as much as nuclear (32 %) . Hydro power is the most popular energy source for large scale projects in Scotland , with an overwhelming majority (80 %) being in favour .

In August 2013 Scottish Hydro Electric Power Distribution connected a 2 MW lithium @-@ ion battery at Kirkwall Power Station . This was the UK 's first large scale battery connected to a local electricity distribution network .

In September 2013 the Scottish Government granted permission for the commencement of the " largest tidal energy project in Europe " . MeyGen intends to install a 9 MW demonstration turbine and then an 86 MW array tidal array in the Pentland Firth , with expected completion in 2020 .

In July 2014 the Crown Estate gave approval to four new demonstration wave and tidal sites at the Stronsay Firth , the Mull of Galloway , Islay and Harris .

= = Summary of Scotland 's resource potential = =

Table notes

= = Main references = =