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Quantification of Constraints on the Growth of UK Renewable Generating Capacity

June 2008

In Association with

AEA Energy & Environment
From the AEA group

Quantification of Constraints on the Growth of UK Renewable Generating Capacity

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1. Summary

Sinclair Knight Merz (SKM) in association with AEA Energy and Environment has been commissioned by the Department Business Enterprise & Regulatory Reform (BERR) to advise on the issues in respect of the "Quantification of Constraints on the Growth of UK Renewable Generating Capacity" in the UK.

SKM has also been commissioned by BERR to advise the issues in respect of "Growth Scenarios for UK Renewables Generation and Implications for Future Developments and Operation of the Electricity Network", and this work has taken place concurrently with the work on the Quantification of Constraints. For some renewable generation technologies, in particular offshore wind generation, there has been interaction between the two pieces of work and this is referenced in this report where appropriate.

The renewable generation technologies that have been considered in this report are set out below, the constraints on the growth of which are considered separately in this report.

Onshore wind	Landfill gas	Wave
Offshore wind	Sewage gas	Tidal stream
Onsite wind	Biomass regular	Tidal range
Large hydro	Imported biomass (Co-firing)	
Medium hydro	Biomass energy crops	
Small hydro		

The key observations that arise from the consideration of the constraints on the growth of each of the renewable generation technologies are set out at the end of the report section dealing with the particular technology.

The ten (10) specific questions identified in the BERR Terms of Reference are set out below in bold typeface and the answers are summarised immediately below each question.

1. What are the most important current and potential future supply chain constraints that could limit the deployment of renewable electricity in the UK and why?

a) **Wind turbine generators (WTGs)** for both onshore and offshore windfarms. The supply of WTGs from existing manufacturers is booked up for the next five (5) years and at present most manufacturers are only interested in large orders and require a significant reservation payment. To meet the UK targets for onshore and offshore wind generation will require about 10,000 WTGs of ratings between 3MW and 5MW to be installed over the next 10 to 15 years (approximately 800 WTGs/y). This compares to the current rate of implementation of about 250 WTG/y and a significant increase in manufacturing capacity

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will be required to meet high growth targets. There are currently no indigenous manufacturers of large WTGs based in the UK.

b) **Specialist vessels** for the installation offshore WTGs. Taking into account the level of European offshore oil and wind power activity, there are estimated to be only two (2) installation vessels that could be dedicated to the installation of WTGs in UK waters and this limits installation to about 350MW/year (approximately 100 offshore WTGs), significantly below the rate required to meet UK targets. Under a medium growth scenario an additional five (5) specialised installation vessels will require to be brought into service to meet the targets. There is limited shipbuilding capacity for these vessels to sourced from UK shipbuilders.

c) **HVAC and HVDC cables** to connect offshore wind farms to the onshore electricity infrastructure. As for WTGs, the supply of HVAC and HVDC cables from existing manufacturers is booked up for the next five (5) years. About 1,500km of HVAC and 7,300km of HVDC subsea cable will be required to meet a high growth target of about 30GW of offshore wind generation by 2020 and this is significantly greater than the current rate of supply to the UK offshore wind generation projects under construction. There are no indigenous manufacturers of HVAC and HVDC subsea cables in the UK.

d) **Balance of Plant Equipment** (eg transformers, switchgear etc). Although there are significantly more suppliers of balance of plant equipment than WTG and HV cable suppliers, the worldwide demand for this type of equipment is forcing up prices and prolonging delivery times.

e) **Biomass fuel supply**. The lack of a supply chain aimed at the UK energy market and the lack of suitable UK harvesting and processing equipment for fuel supply will limit the development of electricity generation using biomass fuels.

f) **Skilled engineering resources**. Delays due to lack of skilled engineering resources throughout the process of developing, manufacturing, installing, operating and maintaining renewable generation plant involving all technologies.

2. What are the most important current and potential future national or local planning constraints that could limit the deployment of renewable electricity in the UK and why?

a) **Time** taken for processing Local Planning Authority consents and/or inconsistency in reasons for refusals resulting in uncertainty, delay or abandonment of projects involving:

i. Onshore wind farms.

ii. Onshore substations connecting offshore windfarms to the onshore electricity infrastructure.

iii. Infrastructure reinforcements involving overhead lines that are triggered by large onshore or offshore windfarm developments.

b) **Time** taken for processing National Planning consents and Public Inquiries resulting in uncertainty, delay or abandonment of projects.

3. What are the most important current and future UK grid constraints that could limit the deployment of renewable generating capacity in the UK and why?

a) **Grid infrastructure bottlenecks** constraining the development of onshore wind energy in Scotland. There are about 7GW of onshore wind generation projects with conditional connection agreements pending the outcome of the Beauly-Denny 400kV Interconnector Inquiry. If the Beauly-Denny interconnector goes ahead then it will release a flood of onshore projects that can be implemented and this may introduce further bottlenecks downstream due to competition for resources to build the projects.

b) **Grid entry capacity** at existing onshore substations at coastal sites closest to offshore windfarm developments. The Round 1 and Round 2 offshore wind generation developed to date has taken up most of the spare entry capacity at existing transmission substations and further developments will require either new coastal site substations or connection being made deeper into the electricity network. The current planning and connection processes associated with new connections is likely to cause delay.

c) **System Operator (SO) flexibility** in dealing with the planning, connection and operation of renewable generation. Until relatively recently, the TSO has had to deal with new connections involving large conventional generating plant (eg CCGT) that did not significantly affect the manner in which the network was planned and operated. If the existing codes and standards are applied to the large volumes of renewable generation, in particular wind generation that is intermittent, in the same manner as conventional generation, then this can result in the need for major infrastructure reinforcements with the associated delays. A more flexible approach to the planning and operation of the network may obviate the need for these reinforcements without jeopardising the security and reliability of supply.

4. For each technology, which of these grid constraints are likely to be (regionally) specific and why?

a) **Grid infrastructure bottlenecks in Scotland** are constraining onshore wind projects as the significant volume of wind generation being developed in Scotland exceeds the capacity of the network to transmit the power southwards towards the major load centres.

b) **Offshore wind generation** tends to be located off the West and East coasts of England and Wales where there are local grid entry bottlenecks at transmission substations closest to the offshore developments.

c) Technologies other than wind generation are less likely to be regionally constrained as the new renewable power generation plants are distributed around the UK.

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5. **What are the most important current and potential future technical constraints that could limit the deployment of renewable electricity in the UK and why?**

a) There is a technical limit to the amount of intermittent onshore and offshore wind generation that can be connected to the GB system. The two studies undertaken by SKM in respect of Growth Scenarios for UK Renewables Generation and Implications for Future Developments and Operation of the Electricity Network" indicate that this limit is about 40GW. The SKM analysis indicates:

– There is a need to begin 'curtailing' wind output at the 30GW level of penetration because the GB system cannot physically accept, in some periods, all the output of wind and keep within the required operating parameters for frequency control and load following.

– There are also diminishing financial returns associated with increasing the renewable target beyond about 40GW as total costs begin to rise.

6. **Are there any other physical constraints that need to be considered?**

a) None apparent.

7. **To what extent are the constraints generic across all of the technologies or groups of technologies?**

a) WTG supply chain for onshore and offshore wind.

b) Engineering skills throughout the process of developing, manufacturing, installing, operating and maintaining renewable generation plant.

c) Supply chain for balance of plant equipment.

d) Planning refusals due to MOD/NATS objections (on grounds of interference to military and civilian RADAR) for onshore and offshore wind as well as grid reinforcements.

8. **Which of all the (supply chain, grid, technical, etc) constraints identified above can be quantified (in MW per annum) and which cannot?**

a) Onshore WTG availability currently constrained at 450MW/year determined by current rate of construction.

b) Offshore WTG availability currently constrained at 350MW/year determined by current rate of construction.

c) Installation vessel availability currently constrained at 350MW/year determined by current rate of construction.

d) Subsea HVAC and HVDC cable availability currently constrained at 350MW/year determined by current rate of construction.

9. **Using all the above (supply chain, planning, grid, etc) constraints that can be quantified, review the maximum build rates already developed by BERR and include any necessary modification (e.g. additional constraints that can be quantified and that have not been included). Other things being equal, what would be the high level impacts of these modifications in term of costs (eg grid reinforcement costs, etc)?**

   a) Build rates (where available for particular technologies) already developed by BERR and other parties have been taken into account, where appropriate, when developing Build Rates and Growth Curves for Low, Medium and High Scenarios for this study. The results for each technology are included in Section 3 of this report.

   b) The cost of connecting large volumes of offshore wind generation to the onshore transmission infrastructure and the associated cost of onshore grid reinforcement are the most significant costs associated with renewable generation scenarios. These costs amount to between £8-14 billion depending on the growth scenario, and are dealt with in detail in the SKM work dealing with "Growth Scenarios for UK Renewables Generation and Implications for Future Developments and Operation of the Electricity Network".

10. **Looking at all the above (supply chain, planning, grid, etc) constraints that can be quantified, what particular measures could be implemented to relax the key constraints to increase the max build rate per technology? Other things being equal, what would be the high level costs (eg grid reinforcement costs, etc) of relaxing each of those constraints?**

   a) The supply chain constraints associated with WTGs could be relaxed by setting up a UK manufacturing/assembly facility that would cost about £15 million and take two (2) years to implement. In view of the significant increase in the rate of WTG supply requirements to meet UK targets, and the expected development of a significant number of large offshore windfarms in waters off the east coast and the west coasts of GB, there is scope for the development of more than one (1) WTG manufacturing/assembly facility. This may involve different locations and different WTG manufacturers. The location of these installations will be driven by the availability of suitable onshore assembly areas, preferably co-located with handling/berthing facilities for loading offshore WTG installation vessels.

   b) The constraints associated with the availability of specialised vessels for the installation offshore WTGs could be relaxed with provision of additional vessels at a cost of £50 million each taking about three years (3) to build. An additional 4-5 vessels will be required to deal with the numbers of WTGs to be installed under the scenarios considered. It may also be possible to utilise vessels currently used in the offshore Oil & Gas Sector (or refit other vessels) but the extent of this will depend on water depth, type of WTG foundations and sea bed soil conditions at the particular wind farm sites, and whether floating or jack-up vessels are required.

c) The supply chain constraints associated with HVAC and HVDC subsea cable for connecting offshore wind to onshore infrastructure could be relaxed by setting up a UK sub-sea cable manufacturing facility at a cost of £35 million taking about three years to come into production. The location of these installations will be driven by the availability of suitable sites co-located with berthing facilities for loading offshore cable installation vessels.

d) Although not presently a supply chain constraint, the demand for HVDC converter equipment that will be needed to connect offshore wind farms, located more than about 60km from the onshore connection point, is likely to increase significantly as the more distant offshore wind farm sites are developed in the North Sea. It will be at least five (5) years before these distant sites are constructed therefore as these projects become committed there should be sufficient time for HVDC converter suppliers to increase manufacturing capacity to meet demand.

2. Background

2.1 Information Sources

The basic approach adopted for this study is to mainly use information provided by BERR and other information in the public domain including:

a) BERR Atlas of Marine Renewable Energy Resources, 2004

b) BERR Renewable Energy Supply Gap analysis, 2004

c) BERR Installation Vessel Study, 2006

d) BERR Tables of Existing and Proposed Renewables Projects in the UK, November 2007

e) BERR Digest of UK Energy Statistics, 2007

f) BWEA Statistics from various documents

g) BWEA Report Offshore Wind: Moving up a Gear, 2007

h) Renewables Advisory Board, Overview Paper 21 January 2008, Table 8.1 – Scenario for Renewables Deployment in Bulk Electricity Market in 2020

i) Renewables Advisory Board, Overview Paper 21 January 2008, BWEA Annex on Wind and Marine Resources

j) National Grid PLC, GB Seven Year Statement, May 2007

k) Ofgem Transmission Access Review - Interim Report, 2008

In addition to the above information, reference has also been made to other more specialised information and also to discussions that have taken place with industry stakeholders. These have included major onshore and offshore wind power developers with projects in the UK and in Europe. Where appropriate, specific references to other information and discussions are inserted as footnotes in the text.

2.2 Renewable Generation Technologies

The renewable technologies to be considered by this study, as set out in the BERR Terms of Reference, are listed in Table 1 below that also includes the following information:

a) The Resource Potential (TWh) within UK territorial boundaries irrespective of location and the availability of technology to exploit the resource. This information has been obtained from a number of sources and in some cases reflects a consensus on the potential resource.

b) The Exploitable Resource (TWh) given the limitations of the technology that is expected to be available by 2020. This information has been obtained from a number of sources and in some cases reflects a consensus on the potential resource.

c) The annual Load Factor (%) of the resource. This information has been obtained from a number of sources and in some cases reflects a consensus on the potential resource.

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d) The Total Installed Capacity (MW) required to produce the annual Exploitable Resource inclusive of the existing Installed Capacity.

e) The existing (2007) Installed Capacity (MW). This information has been obtained from a number of sources and in some cases reflects a consensus on the potential resource.

f) Additional commentary as required.

Table 1 – Renewable Generation Technologies

Renewable Generation Technology	Resource Potential (TWh)	Exploitable Resource (TWh)	Load Factor (%)	Total Capacity Required to Exploit Resource (MW)	Installed Capacity 2007 (MW)	Comment
Onshore Wind	>100.0	50.0	28%	19,030	2,107	Resource capped by availability of suitable sites
Offshore Wind	>1,000.0	100.0	40%	30,850	404	Resource virtually unlimited but limited by capability of present seabed standing WTGs
Onsite Wind						Resource limited by availability of suitable sites
Large Hydro (>20MW)			33%	1,200	1,197	Only 100MW (Glendoe) has been identified as exploitable up to 2020
Medium Hydro (1.25-20MW)			33%	313	177	The exploitable resource is considered to be the completion of the 136MW of projects under development
Small Hydro (<1.25MW)			33%	100	35	The exploitable resource is considered to 100MW by 2020
Landfill Gas		7.0	80%	1,000	856	The exploitable resource is likely to deplete after 2010
Sewage Gas		1.0	80%	140	123	The exploitable resource is expected to plateau at 140MW after 2020
Biomass Regular			73%		251	Resource limited by availability of biomass fuel
Biomass Energy Crops			73%		0	Resource limited by availability of biomass fuel
Co-firing						Resource limited by availability of large coal power stations in which to co-fire biomass
Wave	>1,000.0	50.0	27%	21,140	0	Exploitable resource limited by accessibility of practical sites and development of commercial wave power devices
Tidal Stream	18.0	3.6	35%	1,520	0	Exploitable resource capped by availability of 30-40m depth sites where seabed standing devices can be utilised[1]
Severn Barrage	>20.0	17.0	23%	9,700	0	Unlikely to go ahead within study timescales
Other Tidal Range	>2	1.8	23%	1,020	0	Exploitable resource capped by availability of suitable sites

[1] UK Tidal Stream Energy Assessment, Black & Veatch Report to Carbon Trust, July 2005

2.3 Constraints

The constraints that are considered to impede the development of each technology from achieving the exploitable resource are set out below.

2.3.1 Supply Chain Constraints

The supply chain constraints relate to the material and human resources associated with the manufacture and installation of the renewable energy technologies and, where applicable, the fuel supplies for biomass technologies. The following constraints have been considered for each technology with a view to quantifying the impact on the build rates (MW/year) and potential resource (TWh/year) that the constraint may have:

a) **Fuel Supply** – consideration of issues associated with competition for UK sources of biomass, impacts on grain and energy crops, sustainability of imported biomass, and compliance with the Waste Incineration Directive.

b) **Equipment and Materials** – consideration of issues associated with some technologies where significant amounts of equipment are procured from overseas and where there is worldwide demand for limited available capacity of raw and finished materials, especially in the wind generation sector.

c) **Skilled Labour Availability** – consideration of issues in the shorter term for some technologies as the build rates ramp up and fabrication skills become scarce. Also issues associated with skilled engineering resources across all technologies in areas such as project development, local authority planning and grid connection planning.

d) **Installation Capacity** – consideration of issues associated with some technologies, in particular off-shore wind moving into deeper water where specialist installation vessels will need to be built.

2.3.2 Planning Constraints

The following planning constraints have been considered for each technology:

e) **Government Consent** – consideration of the various Acts of Parliament (eg Sections 36 & 37 of the Electricity Act) are not seen to be an issue for most technologies. However there may be some issues with Government dealing with appeals against Local Planning Authority (LPA) decisions.

f) **LPA for Power Plant** – consideration of what can be a major issue where the technology has a significant environmental impact in the locality of the renewable energy generating plant.

g) **LPA for Grid Connection** – consideration of what can be a major issue where the connection equipment has a significant environmental impact in the locality of the connection.

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h) **LPA for Grid Reinforcement** – consideration of can be a major issue where the grid reinforcement involves overhead lines that have a significant environmental impact along the route of the reinforcement. Long distance reinforcements could involve several LPAs.

2.3.3 Grid Constraints

By their nature, electricity networks have limited headroom at entry points to accommodate the capacity of new renewable generation plants and in many cases the network will require augmentation locally at the connection point (shallow connection works) and possibly major distant reinforcement at bottlenecks in the network (deep reinforcement works). In assessing the impact of increasing volumes of renewable generation on the transmission and distribution networks the following factors have been taken into account:

a) Notwithstanding existing limited headroom on the network, some headroom could be freed up by the retirement of conventional generating plant due to age or displacement as a natural consequence of the increase in renewable generation This headroom could be equal to the amount of conventional generating plant retired or displaced if the new renewable generation is connected to the same point on the transmission network as the conventional generation. This is particularly relevant when connecting large volumes of offshore wind generation via HVDC interconnectors as the onshore HVDC terminals can be located close to the conventional generation that the wind generation will displace.

b) The volumes associated with some renewable generation technologies will be distributed around the country broadly in line with population density (eg landfill gas) whilst others will be located at the source of the renewable resource, eg onshore wind in Scotland where the winds are stronger and offshore wind in the North Sea shallow waters.

c) The technologies that involve power plants rated at a few MW (eg small hydro) will tend to connect to the distribution network where there is likely to be sufficient headroom for the connection without triggering a major reinforcement.

d) The technologies that involve power plants rated at several hundred MW (eg Round 2 & 3 offshore wind) will tend to be connected to the transmission network where there may not be sufficient headroom for the connection thus triggering a major shallow and deep reinforcement, unless the connection point is co-located with existing conventional plant that will be retired or displaced.

Some technologies are characterised by having relatively constant output (eg biomass) whereas other technologies have intermittent output (eg wind) and this can introduce technical operational constraints on the network requiring conventional generation to be constrained on or off at potentially significant financial cost to the energy market.

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2.3.4 Scenarios

Based on all the above supply chain, planning and grid constraints identified as quantifiable in MW per annum and those constraints that can be relaxed, 3 scenarios on the maximum amount of capacity that could be built per year in the UK (ie MW/year) have been developed as follows:

a) **SCENARIO 1**: The maximum amount of capacity that could be built per year per renewable technology between now and 2030 given current constraints.

b) **SCENARIO 2**: The maximum amount of capacity that could be built per year per renewable technology between now and 2030 if some constraints are relaxed.

c) **SCENARIO 3**: The maximum amount of capacity that could be built per year (i.e. MW/year) per renewable technology between now and 2030 if additional constraints are relaxed.

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3. Growth Curves

3.1 Methodology

The methodology adopted for the quantification of the constraints on the growth of renewable generation technologies is based on a spreadsheet model that:

a) Requires the manual input[2] of the Build Rate (GW/y) for each year between 2008 and 2030 for Low, Medium and High Scenarios for a particular Constraint (eg the availability of Wind Turbine Generators).

b) For each Constraint and each Scenario the model determines the minimum Build Rate and sets this as the binding Constraint for the Scenario.

c) The Growth Curve (ie the total installed capacity over time) for each Scenario is evaluated as the cumulative total of the Build Rates for each year.

d) The results are presented graphically as a bar chart for Build Rates (GW/y) and as a line chart of Total Installed Capacity (GW) for Growth Curves.

The results of the modelling are described in detail in the following sections.

3.2 Onshore Wind

3.2.1 Development Process

In order to quantify the constraints on the growth of onshore wind generation it is important to understand the development process, the principal parts of which are:

a) **Site Acquisition** – The developer identifies a site with a wind resource that can be commercially exploited, acquires title to the site for the purpose generating electricity and proceeds with the basic design and the associated Environmental Statement (ES). This process can take several months.

b) **Section 36** – In England and Wales under the Electricity Act (1989) Section 36 consent is required on generating station developments with a capacity greater than 50MW:

   i. **Application Stage -** The developer submits the ES to BERR together with any supporting documents. The application is advertised in the London Gazette and local press for two successive weeks.

[2] The manual inputs are derived from a number of sources and are discussed in the sections of the report dealing with the particular technology. The rationale behind build scenarios may differ depending on the generation technology.

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ii. **Consideration of Application –** The Local Planning Authority (LPA) has 4 months consider the application and to inform the Secretary of State (SoS) if it objects to the application in which case the SoS must call for a Public Inquiry (PI). If a PI is called it can take in the order of a year to arrange for the enquiry with the enquiry taking several weeks and the Inspector's Report following some months later.

iii. **Determination of the Application** – Once the SoS has all the relevant representations from the LPA, other consultative bodies and the public, a decision will be taken on whether or not to give consent to the proposed development. Under the Electricity Act there is no time limit for the SoS to determine a Section 36 consent application. If no PI is called the SoS determines the application.

iv. **Post Decision Stage** – The applicant has to comply with consent and planning conditions to proceed with the development.

v. **Judicial Review (if applicable)** – there is no statutory appeals mechanism under the Electricity Act and the decision of the SoS is final unless it is challenged in the High Court within 3 months after the decision in made.

A similar process to the above is in force in Scotland with Scottish Government taking on the role of BERR and the SoS.

c) **Electricity Connection Agreements** – The developer makes an application for a connection to the electricity infrastructure to the GB Transmission System Operator (TSO) or the local Distribution System Operator (DSO) and the SO has to respond with a connection offer within 3 months. The connection offer will state the date at which the connection can be made and may be conditional on certain grid works that are subject to planning consents proceeding by a particular date.

d) **Project Finance** – When the site with full planning consents and a connection agreement with a connection date within the timescale of a construction contract have been achieved the developer should be in a position to go ahead and finance the project with either internal or external finance. Under the present financial climate the smaller developer who is dependant on external finance may face difficulty in arranging finance.

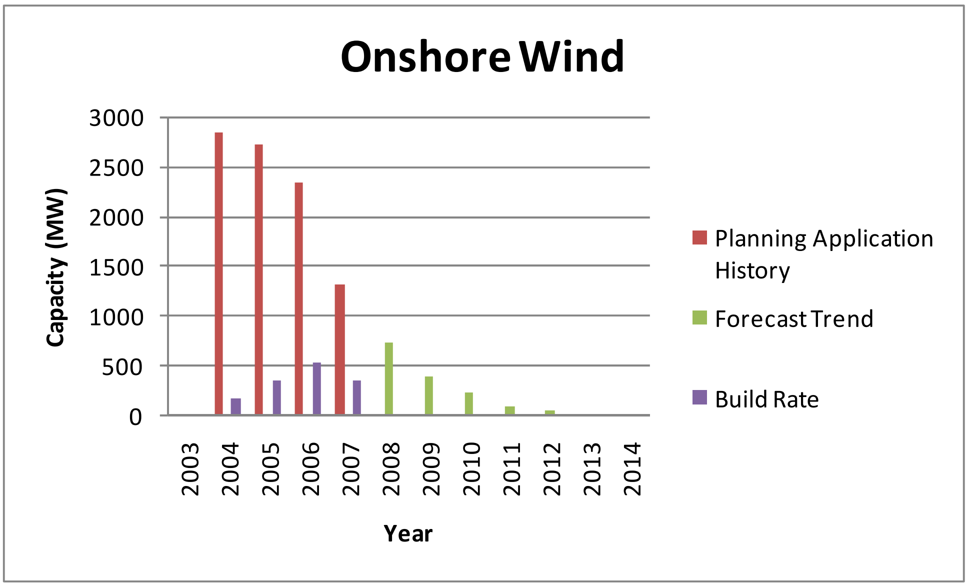
e) **Construction** – Having developed a project up to the stage where finance has been arranged the developer should be in a position to place construction contracts. This may not be straightforward, especially for the smaller developer, because it is a sellers market for wind turbine generators (WTGs). WTG suppliers are not interested in small developments involving a few WTGs and many WTG supplier order books are full for the next 5 years. A project becomes "Committed" when it has title to a site, full planning consents, a connection agreement, project finance and construction contracts for the implementation of the project.

The above processes can proceed sequentially, possibly with some parts concurrent, and a problem in any part of the process can lead to a project being delayed or abandoned.

3.2.2 Background to Growth

Figure 1 below shows the trend in planning applications since 2004 that has been derived from BWEA statistics.

Figure 1 – Onshore Wind Generation Historical Trends



It can be seen that there is a downturn in applications in 2006 and a more significant downturn in 2007. This would appear to indicate that the most favourable sites for onshore wind generation have already been identified by developers who have submitted planning applications. The trend could also indicate that developers are becoming better informed and are not submitting planning applications for sites in areas where it is known that RADAR or ornithology issues exist. On this basis the above scenario indicates that almost all the potential sites that are currently viable for onshore wind generation will have been identified by 2013 and will be covered by a planning application.

3.2.2.1 Construction Backlog

Figure 1 also indicates that there was a surge in submissions for consents and connections between 2004 and 2006. This is considered to be caused by developers rushing to obtain consents and connection agreements before BETA and the more restrictive Grid Code conditions for wind generation came into effect, especially in Scotland where the Grid Code threshold is more limiting. The result of the surge is a ~7GW "backlog" of projects that have been consented but are waiting to be built, mainly conditional on the Beauly-Denny interconnector in Scotland going ahead.

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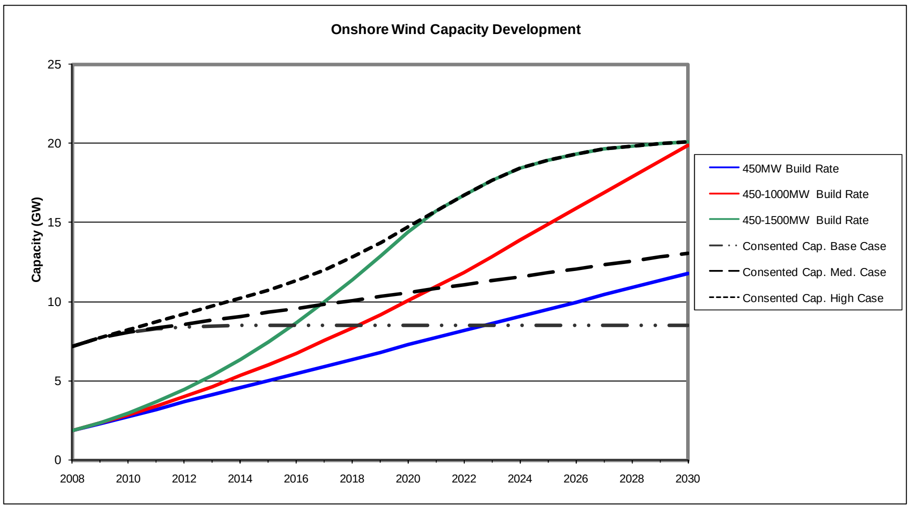
3.2.2.2 Beauly-Denny 400kV Interconnector

The Beauly-Denny Interconnector is a 400kV reinforcement to the transmission network in Scotland that is being driven by the high rate of onshore wind generation development in Scotland. The status of the Beauly-Denny Interconnector is dependent on the outcome of a Public Inquiry, the decision on which is expected by the end of 2008. The earliest the interconnector can be commissioned is by the end of 2012, at which time the backlog of projects can be connected.

3.2.3 Growth Scenarios

In order to determine growth scenarios for onshore wind it has been considered necessary to disaggregate the planning and consenting process from the construction process as the constraints that bind the growth of consented projects and constructed projects are significantly different. The growth curves are shown in Figure 2 and are described in detail below.

Figure 2 – Onshore Wind Generation Growth Scenarios



3.2.4 Consenting Scenarios

3.2.4.1 Low Scenario

Referring to the black chain dotted line on Figure 2 it can be seen that the consented capacity is 7.2GW in 2008 rising to 8.5GW in 2013 where it remains constant onwards on the basis of the forecast trend indicated by the green bars in Figure 1.

3.2.4.2 Medium Scenario

The broken black line on Figure 2 shows a 250MW/y rate of consenting and is based on work SKM undertook in 2007 for the Scottish Executive where the three GB Transmission Licensees indicated about 4,600MW of “unknown onshore wind projects” over the period 2010 to 2030, ie 230MW/y. This estimate was made after the identification of the connection queuing issues, tightness of the market etc, therefore the 250MW/y can be viewed as the historic average rate under an "environment" that it not so conducive to encouraging developers to find and exploit sites.

The Medium Consented Scenario reaches about 13GW in 2030 and this is about 72% of the 18GW maximum exploitable resource (excluding the impact of repowering) and corresponds to the 28% historic rate of planning applications[3] that are refused, mainly for environmental reasons.

3.2.4.3 High Scenario

The initial 500MW/y rate of consenting shown by the dotted black line on Figure 2 is based on work SKM undertook for Ofgem on the Renewable Transmission System (RETS) requirements in Scotland where the three GB Transmission Licensees indicated about 2,400MW of "unknown onshore wind projects" over the period 2006 to 2011, ie 480MW/y. This estimate was made ahead of the identification of the connection queuing issues, tightness of the market etc, therefore the 500MW/y rate of planning consents can be viewed as the historic average rate under an environment conducive to encouraging developers to find and exploit sites.

Notwithstanding the historic trend it is recognized that the "environment" under which developers operate could change significantly from about 2010 onwards and the following factors would tend to increase the consenting rate:

a) **Higher Incentives -** If new measures are put in place to offer more encouragement to the development of onshore wind, then the rate of development would tend to be higher up to about 2020 and lower towards 2030.

b) **Advances in WTG Technology** - Technological advances that lead to larger and more efficient of WTGs will make the more difficult sites that remain to be exploited more bankable. The effect of this will be to bring forward the development of the more difficult sites.

c) **Repowering** – The installed capacities of the older existing onshore wind generation sites can be increased by 1.5 to 4 times by using modern larger and more efficient WTGs. Repowering can be considered for WTGs 15-20 years old when O&M costs become prohibitive or when the existing ROCs cease to have effect. About 330MW of sites were built up to 2000 and about 1,000MW between 2000 and 2005. Assuming a repowering factor of 2.5 times, then an additional 2GW can be added to the 18GW that has been taken to be the maximum exploitable resource in the absence of repowering, giving a total of 20GW to be exploited.

Taking the above into account, the High Scenario has been developed as follows:

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[3] BWEA Statistic

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i. When the High Build (see Section 3.2.5.3) starts to catch up with the backlog in 2016, the initial rate of consenting is increased from 500MW/y to 1000MW/y by 2020 due to the effect of favourable incentives that encourage developers to prospect and develop the remaining sites that can be exploited and also to repower sites that are 15-20 years old.

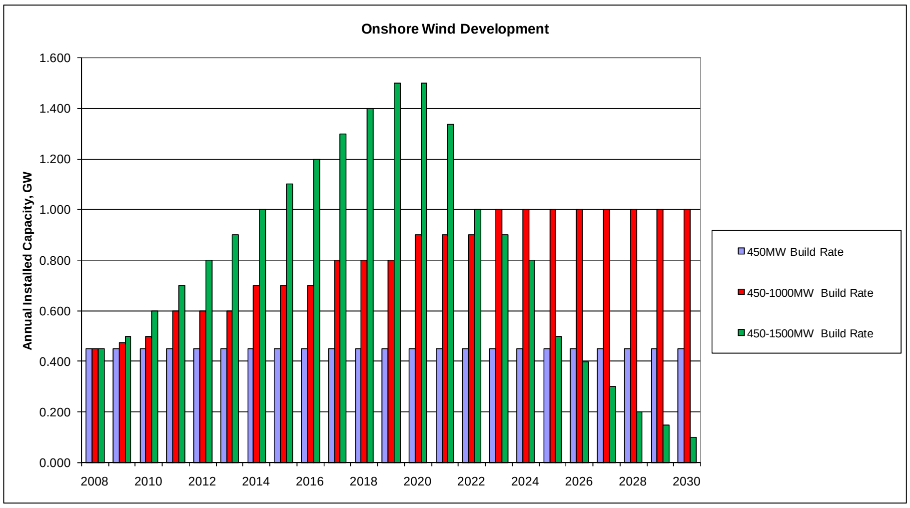
ii. The High Build rate catches up with the Consented High Scenario in 2020 and thereafter growth is constrained by the rate of consented projects that is maintained at 1000MW/y until 2022 and then progressively reduced to reach 20GW in 2030.

iii. The High Consented Scenario reaches 20GW in 2030 and assumes that the environmental constraints that have previously constrained development have been overcome.

3.2.5 Build Scenarios

The Build Rate Scenarios are shown in bar chart form on Figure 3 and described in detail below.

Figure 3 – Onshore Wind Generation Build Scenarios



3.2.5.1 Low Build

The average build rate between 2004 and 2007 as shown on Figure 1 is about 450MW/y and is constrained by the number of projects that can be Committed, in particular the projects held pending the outcome of the Beauly-Denny Enquiry. The 450MW/y build rate will also be constrained by the supply chain associated with the supply of WTGs and the engineering resources associated with the design and construction of the wind farms that is presently established to manage the 450MW/y rate. The Low Build scenario of 450MW/y assumes that the WTG supply chain and engineering resource constraints will remain constant until 2030.

Figure 2 shows the Installed Capacity reaching 7.3GW in 2020 and 11.8GW in 2030 assuming that the latter is not constrained by the Low Consenting Scenario in which case the Installed Capacity will be limited to 8.6GW.

3.2.5.2 Medium Build

The Medium Build Scenario shown as the red bars on Figure 3 starts at 450MW/y and rises to 1000MW/y in 2023 where it remains constant thereafter. The progressive increase in the build rate is representative of the supply of WTGs and engineering resources responding to the increase in demand that would be caused by the flood of projects released by Beauly-Denny going ahead and the modest increase in consented and committed projects.

Figure 2 shows the Installed Capacity reaching 10.1GW in 2020 and 20.1GW in 2030 assuming that the latter is not constrained by the Medium Consenting Scenario in which case the Installed Capacity will be limited to 13.1GW.

3.2.5.3 High Build

The High Build Scenario shown as the green bars on Figure 3 starts at 450MW/y and rises to 1500MW/y in 2019 where it remains constant until it catches up with the High Consenting Scenario in 2023. Thereafter the build rate follows the High Consenting Scenario. The progressive increase in the build rate is representative of the supply of WTGs and engineering resources responding to the increase in demand that would be caused by the flood of projects released by Beauly-Denny going ahead and the significant increase in consented and committed projects due to favourable incentives to develop the more difficult sites and the repowering of existing sites.

Figure 2 shows the Installed Capacity reaching 14.3GW in 2020 and 20.1GW in 2030.

3.2.6 Key Observations

The following key observations have been made from the above:

a) The build rate for onshore wind has averaged about 450MW/y over the past 4 years and the supply chain in terms of WTGs and the engineering resources required to design and implement projects is presently geared up to maintain this rate. To significantly increase the build rate will require an investment in WTG manufacturing capacity and in engineering resources. This industrial capacity may not be forthcoming unless a significant pipeline of committed projects is foreseen and at this point in time this is not the case.

b) The present market for WTGs is tight and it is a sellers market with some manufacturers taking advantage of this by limiting supply and price to make up for recent losses incurred in the wind generation sector and other power sector activities.

c) There are some new entrants appearing in the supply chain but supply is being constrained by the availability of some key components from sub-suppliers, such as large bearings, and it could take some time to build new facilities to increase the availability of these key components. Also the rapidly developing markets in China and India are increasingly being seen to be absorbing sub-supplier capacity.

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d) WTG suppliers are presently targeting markets and projects where there is a reasonable degree of certainty that projects will proceed. This is currently not the case with many projects in the UK that are held up by planning and/or connection agreement problems and this will exacerbate the non-availability of WTGs for UK projects as most WTG supplier order books are full for the next 5 years.

e) The development of smaller projects to the stage where they become committed is being frustrated by developers not being able to procure WTGs within a viable timeframe and/or the finance to proceed with implementation. This is leading to projects being abandoned or being sold on to larger developers who have a portfolio of projects, have internal finance and the purchasing capacity to place large orders with WTG suppliers. This process will tend to delay the implementation of the smaller projects.

f) The shortage of engineering resources available to developers and to the TSO and DSOs is considered to be a major constraint in increasing the rate of development of onshore wind generation. This lack of engineering resource is endemic across many industrial sectors in the UK and a major educational initiative will be required to overcome this problem.

g) The national and local planning processes have tended to delay the development of onshore wind and in some cases what are considered to be superficial and subjective judgements have resulted in planning refusals. The current proposals to centralise the determination of planning applications for projects greater than 50MW, and thereby remove the subjectivity exercised by some LPAs, will go some way to streamlining the planning process going forward. However the projects that remain to be developed will tend to be the more difficult sites and the streamlined process may not overcome the hard environmental and other objections (eg MoD on grounds of interference to RADAR) that lead to projects being refused planning consent.

h) The outcome of the Beauly-Denny public enquiry on the planning application for the reinforcement of the transmission network in Scotland with a 400kV interconnector, that involves new overhead lines between the existing Beauly and Denny substations, represents the most significant uncertainty to the growth of onshore wind generation in the UK. About 7GW of projects have connection applications that are conditional on this project going ahead and a decision is not expected until the end of 2008. Given that the project is consented then it will take about 4 years to procure and construct the interconnector and it is not expected to be in service before 2012.

i) If the Beauly-Denny project goes ahead then this will release a flood of projects to be constructed and this is likely to cause supply chain and other logistical problems. The need for the Beauly-Denny interconnector is driven by the application of the GB Security and Quality of Supply Standard (SQSS) that requires a firm connection to be given to generation connecting to the network. In view of the intermittent nature of wind generation then consideration could be given to granting some wind generation in Scotland a non-firm connection until the Beauly-Denny interconnector is constructed and by this means some wind generation in the connection queue could be connected before 2012. To implement this proposal would require special power system protection arrangements to be put in place to automatically disconnect wind generation that have been granted a non-firm connection under relatively infrequent circumstances when the network is not capable of absorbing the generated power. The proposal would also require arrangements to be put in place to provide financial compensation to wind generators when generation is forced off the network.

3.3 Offshore Wind

3.3.1 Development Process

In order to quantify the constraints on the growth of onshore wind generation it is important to understand the development process, the principal parts of which are:

a) **Site Acquisition** – The developer identifies a site with an offshore wind resource that can be commercially exploited, acquires title to the site from the Crown Estates and proceeds with the basic design and the associated Environmental Statement (ES). This process can take a few years and usually involves sea bed surveys of the offshore site and the route of the export cable to the shore.

b) **Section 36** – In England and Wales under the Electricity Act (1989) Section 36 consent is required on generating station developments with a capacity greater than 50MW:

   i. **Application Stage -** The developer submits the ES to BERR together with any supporting documents. The application is advertised in the London Gazette and local press for two successive weeks.

   ii. **Consideration of Application –** The Local Planning Authority (LPA) has 4 months consider the application and to inform the Secretary of State (SoS) if it objects to the application in which case the SoS must call for a Public Inquiry (PI). If a PI is called it can take in the order of a year to arrange for the enquiry with the enquiry taking several weeks and the Inspector's Report following some months later.

   iii. **Determination of the Application** – Once the SoS has all the relevant representations from the LPA, other consultative bodies and the public, a decision will be taken on whether or not to give consent to the proposed development. Under the Electricity Act there is no time limit for the SoS to determine a Section 36 consent application. If no PI is called the SoS determines the application.

   iv. **Post Decision Stage** – The applicant has to comply with consent and planning conditions to proceed with the development.

   v. **Judicial Review (if applicable)** – there is no statutory appeals mechanism under the Electricity Act and the decision of the SoS is final unless it is challenged in the High Court within 3 months after the decision in made.

A similar process to the above is in force in Scotland with Scottish Government taking on the roles of BERR and the SoS.

c) **FEPA Licence** – For offshore consents a licence is required under the Food and Environmental Protection Act (Part II) 1985 from the Marine and Fisheries Agency, an executive agency under DEFRA.

d) **Electricity Connection Agreements** – The developer makes an application for a connection to the electricity infrastructure to the GB Transmission System Operator (TSO) or the local Distribution System Operator (DSO) and the SO has to respond with a connection offer within 3 months[4]. The connection offer will state the date at which the connection can be made and may be conditional on certain grid works that are subject to planning consents proceeding by a particular date. Large offshore projects usually require connection to the transmission network often requiring a new onshore substation at a coastal site that is covered environmental restrictions (eg Area of Outstanding Natural Beauty) and this can result in planning refusals by the LPA.

e) **Project Finance** – When the site with full planning consents and a connection agreement with a connection date within the timescale of a construction contract have been achieved, the developer should be in a position to go ahead and finance the project with either internal or external finance.

f) **Construction** – Having developed a project up to the stage where finance has been arranged the developer should be in a position to place construction contracts. This may not be straightforward, even for a major offshore developer, because of supply chain issues with major plant items. A project becomes "Committed" when it has title to a site, full planning consents, a connection agreement, project finance and construction contracts for the implementation of the project.

The above processes can proceed sequentially, possibly with some parts concurrent, and a problem in any part of the process can lead to a project being delayed or abandoned.

3.3.2 Background to Growth (Rounds 1 and 2)

The current status of Round 1 and Round 2 offshore wind generation projects[5] is summarised in Table 2 below.

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[4] Note that this is subject to change when Ofgem introduces new regulatory arrangements for Offshore Transmission in 2008.

[5] BWEA Statistic

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Table 2 – Status of Round 1 & 2 Offshore Wind Generation Projects

Site Status	Capacity (MW)	Percent of Total
Site Awarded	3,040	34.4
Withdrawn	108	1.2
Submitted (S36)	1,815	20.6
Approved	2,998	34.0
Under construction	457	5.2
Operational	404	4.6
Total	**8,822**	**100**

The significant points to note from the summary table are:

a) Out of the 8.8GW of sites identified for development only 861MW or about 10% of the total are either Operational or Under Construction.

b) Of the 3GW that are Approved only the Greater Gabbard (500MW) and the Thanet (300MW) projects are currently committed to construction with equipment and construction contracts placed, with implementation expected between 2008 and 2010.

c) The status of the other Approved projects that are not committed to construction has not been established but some developers have indicated[6] that costs have escalated by about 50% since work started and that the commercial viability of many projects is in the balance.

d) Given the above situation where there is no significant pipeline of projects to encourage the supply chain to gear up to a committed increase in demand for WTGs, subsea cables and installation vessels, then the present construction rate of 350MW/y[7] is considered to be indicative the current UK supply chain capability for offshore wind generation.

3.3.2.1 Round 3 Sites

It is assumed that the environmental and planning difficulties associated with onshore wind generation will not be experienced to the same extent by offshore wind generation and that strong incentives will be in place to encourage development under Round 3. Under these circumstances it is considered that development will be driven by the availability of suitable sites in 20-30m water depths. Appendix A considers where the Round 3 projects could be located and indicates that a total Round 1+2+3 installed capacity of 33.7GW could be developed with a significant proportion far offshore on the Dogger Bank as shown in the Table 3 below.

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[6] SKM discussions with offshore wind generation developers and press reports on the withdrawal of Shell from the 1000MW London Array Project

[7] Approximate installation rate for Greater Gabbard and Thanet offshore windfarms

Table 3 – Round 3 Offshore Wind Generation Scenarios

	Round 1+2	R1+R2+R3 Installed Capacity (MW)		
Region	**(MW)**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Wash	4,068	8,000	8,000	8,000
North West	2,588	5,000	5,000	5,000
Thames	1,954	2,800	2,800	2,800
Severn	108	108	108	108
North East	94	94	94	94
Scotland	10	10	10	10
Wales	0	2,500	2,500	2,500
I of Wight	0	0	0	0
Dogger	0	3,600	7,700	15,200
	8,822	**22,112**	**26,212**	**33,712**

The development of Round 3 projects will involve going further offshore than previously required for Round 1 and Round 2 projects and this will require longer lengths of HVAC and HVDC subsea cables. The work undertaken by SKM looking at Grid Issues[8] indicates that about 1,500km of HVAC and 7,300km of HVDC subsea cable will be required for Round 3 projects. There are only 3 suppliers of HVAC and HVDC subsea cables in Europe (ABB, Nexans and Prysmian) and it is understood[9] that manufacturing capacity is fully booked for the next 5 years. Accordingly the availability of HVAC and HVDC subsea cable is considered to be a major constraint on the growth of offshore wind generation under Round 3 as well as Round 1 and Round 2 projects that are not yet committed.

3.3.3 Growth Scenarios

In order to determine the growth scenarios for offshore wind generation it has been considered necessary to disaggregate the process leading to projects becoming committed from the procurement and construction process.

3.3.3.1 Committed Projects

Round 1 plus Round 2 awarded projects amount to 8.8GW and it is assumed that they will all be developed progressively to the stage where construction contracts can be placed and grow to a total installed capacity of 8.8GW by 2012, as shown by the black broken line on Figure 4.

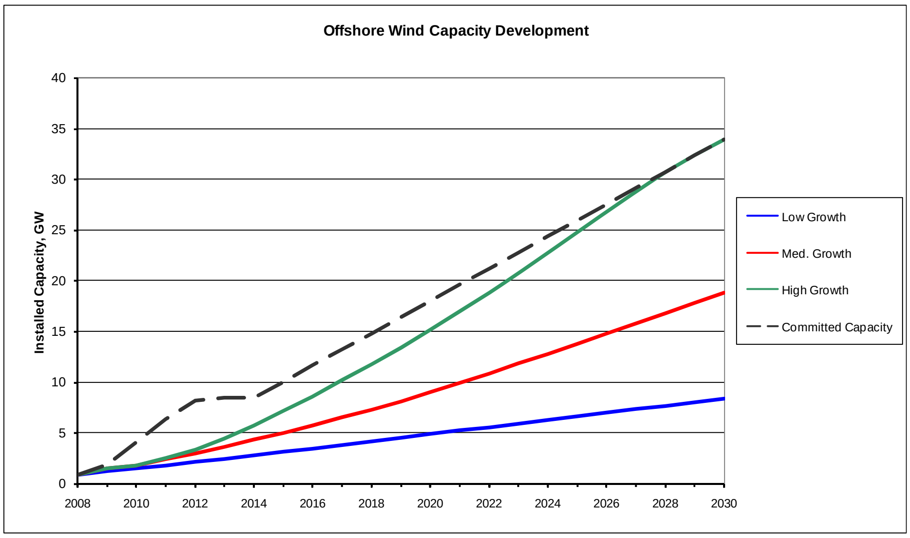
Round 2 projects are taking 5-7 years to develop into a committed projects and it is assumed that the same time will be required for Round 3 projects. Accordingly it is not expected that Round 3

[8] SKM Report to BERR "Growth Scenarios for UK Renewables Generation and Implications for Future Developments and Operation of the Electricity Network", June 2008

[9] SKM discussions with offshore wind generation and HVDC interconnector developers

projects will become committed until 2014 and it is assumed thereafter that the growth in committed projects will be 1.6GW/y based on the average development rate for Round 2 projects. The black broken line on Figure 4 shows that no projects have been committed between 2012 and 2014 and that projects are committed at the rate of 1.6GW/year thereafter.

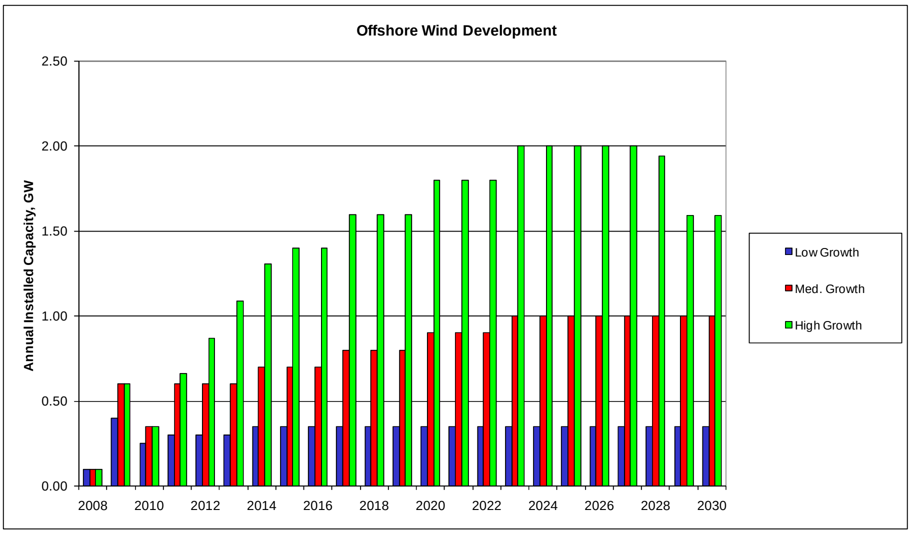
Figure 4 – Offshore Wind Generation Growth Scenarios



3.3.4 Build Scenarios

The Build Rate Scenarios are shown in bar chart form on Figure 5 and as growth curves on Figure 4 and are described in detail below.

Figure 5 – Offshore Wind Generation Build Scenarios



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3.3.4.1 Low Build

Low growth up to 2013 reflects the rate of construction of Round 1 and Round 2 projects that are currently committed and is constrained thereafter as follows:

a) WTGs and subsea cable supply chain capacity limits growth to 350MW/y from 2013 up to 2030.

b) Two (2) installation vessels capable of handling a WTG with rating of 3.6MW each requiring on average 3.5 days to install a WTG during an annual 170 day weather window.

Under the Low Scenario the installed capacity grows to 4.9GW by 2020 and 8.4GW by 2030 as shown by the blue line on Figure 4.

3.3.4.2 Medium Build

Medium growth is assumed to be constrained as follows:

a) WTG and subsea cable supply chain capacity increased from 350MW/y in 2008 to 1,000MW/y by 2023 with WTG ratings increasing from 3.6MW in 2010 to 5.0MW in 2015 and continuing at the 5.0MW rating thereafter.

b) The number of installation vessels increased to seven (7) by 2015 at the rate of one vessel per year from 2011 onwards. New vessels are assumed to capable of handling a 5.0MW WTG.

Under the Medium Scenario the installed capacity grows to 9.0GW by 2020 and 18.8GW by 2030 as shown by the red line on Figure 4.

3.3.4.3 High Build

High growth is assumed to be constrained as follows:

a) WTG and subsea cable supply chain capacity increased from 350MW/y in 2008 to 2,000MW/y by 2023 with WTG ratings increasing from 3.6MW in 2010 to 5.0MW in 2015 and continuing at 5.0MW rating thereafter.

b) Number of vessels increased to fifteen (15) by 2023 at the rate of one vessel per year from 2011 onwards. New vessels are assumed to be capable of handling a 5.0MW WTG.

Under the High Scenario the installed capacity grows to 15.2GW by 2020 with and catches up with availability of committed projects in 2028 growing to 33.9GW in 2030, as shown by the green line on Figure 4.

3.3.5 Key Observations

The following key observations have been made from the above:

a) The supply chain associated with WTGs suitable for a marine environment is a significant constraint to growth of offshore wind generation in the UK. About 7,000 WTGs will need to be installed to generate 34GW offshore and this compares with about 300 WTGs currently in operation or under construction. Wind generation developers are indicating that new orders for WTGs will not be delivered until 2013 and as the current UK market for WTGs is smaller than markets such as the USA and China, UK developers are tending to fall to the back of the queue.

b) To meet the UK requirements for offshore wind generation will require the WTG supply capacity to be increased by about three (3) times under the Medium Growth Scenario and to be increased by about six (6) times under the High Growth Scenario. The UK currently has no offshore WTG manufacturing/assembly capacity and setting up such a WTG facility in the UK will require a suitable location with port facilities to be found. It is estimated that a facility to assemble an existing manufacturers design (eg Siemens or Vestas) WTGs using brought in components will cost about £15 Million and would take about two (2) years to set up.

c) The supply chain associated with high voltage alternating current (HVAC) and high voltage direct current (HVDC) chain subsea cables is a significant constraint to growth. About 1,500km of HVAC and 7,300km of HVDC subsea cable will be required for Round 3 projects. The UK does not have a high voltage sub-sea cable manufacturing capability[10] and there are only three (3) suppliers of HVAC and HVDC subsea cables in Europe (ABB, Nexans and Prysmian) with capacity fully booked for the next five (5) years.

d) The technology associated with the manufacture of high voltage cable is vested with the existing cable suppliers and it is unlikely that a new entrant could get product to market within several years, if at all, because of the research needed to overcome the technological barriers. Accordingly if high voltage sub-sea cables are to manufactured in the UK it will be necessary to encourage one or more of the existing European suppliers to set up a manufacturing facility in the UK at a suitable port location to facilitate loading onto specialist cable laying vessels. Setting up such a facility is estimated to cost about £35 Million and would take about three (3) years to reach production.

e) The availability of vessels suitable for the installation of WTGs in water depths of up to 30m is a significant constraint to growth. Given the amount of offshore oil and wind generation activity in the North Sea it is estimated that there are currently two (2) vessels that could be allocated to work full time in UK waters on the installation of offshore WTGs. Two vessels corresponds to a build rate of 350MW/y and this will have to be increased significantly if UK targets are to be met. New vessels will cost in the region of £40-50 million each and will take about three (3) years to build. The Medium Growth Scenario assumes an additional five (5) specialised installation vessels and this will require an investment of about £250 million over

[10] The BICC sub-sea cable manufacturing facility at Erith was acquired by Pirelli (now Prysmian) about 10 years ago and closed down and the riverside site redeveloped

seven (7) years. At present the global market for shipbuilding is tight and there are only limited resources available in the UK for this type of work.

f) As for onshore wind generation, the shortage of specialist engineering resources available to developers and to the TSO for design and implementation activities is considered to be a major constraint in increasing the rate of development of offshore wind generation. This lack of engineering resource is endemic across many industrial sectors in the UK and a major educational initiative will be required to overcome this problem.

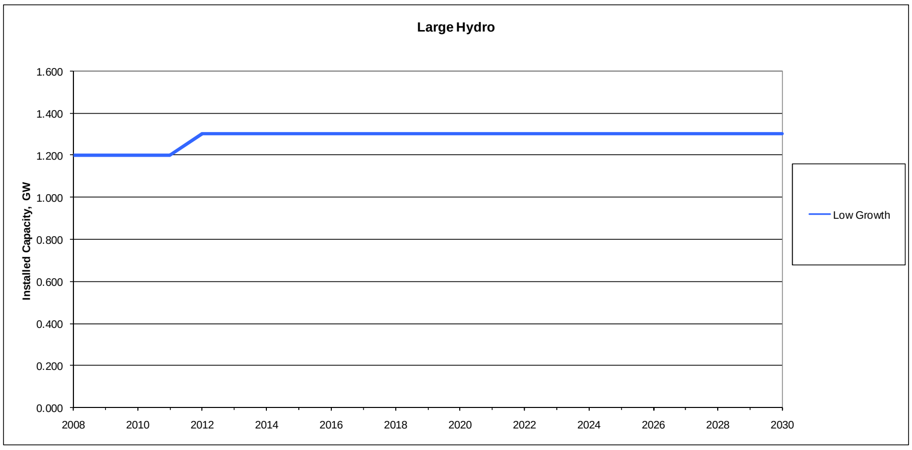
3.4 Onsite Wind

Onsite wind is not expected to develop significantly due to the non-availability of suitable sites. A recent development to install WTGs in a football stadium car park has suffered a major setback due to HSE concerns over WTG blades shedding ice during winter conditions. To avoid the problem will require exclusion zones to be set up around the WTGs and the extent of the zone is likely to prevent the site from being used effectively for its original purpose.

3.5 Large Hydro (>20MW)

The majority of UK large hydro projects were constructed in Scotland in the 1950s and early 1960s and the existing installed capacity of Large Hydro generating plant is 1,200MW[11]. The 100MW Glendoe project is under development and is scheduled by NGC to be in operation in 2012. There are no other large hydro projects under development or known to be planned, and it is considered that there are no further sites suitable for the development of large hydro schemes within the time frame of this study. On this basis the growth scenario is shown on Figure 6.

Figure 6 – Large Hydro Growth Scenario



[11] NGC Seven Year Statement, May 2007

The Low Growth reflects the commissioning of Glendoe in 2012 and with no large hydro projects presently in planning the growth is capped at 1,300MW until 2030.

3.6 Medium Hydro (1.25-20MW)

3.6.1 Background

The existing installed capacity of Medium Hydro generating plant is 177MW[12]. Consented projects not yet operational amount to 110MW with a further 26MW of projects currently under consideration[13]. No further developments have been identified and the resource potential for Medium Hydro is considered to be 313MW (ie 177MW + 110MW + 26MW).

Planning consents are not expected to be a significant constraint on the development of the 26MW of Medium Hydro that are under consideration and it is assumed the projects will be consented by 2010 on the basis that the process will take no longer than 2 years.

The supply chain associated with Medium Hydro plant and equipment (eg hydro turbines, penstocks, gate valves etc) is not considered to be a constraint on growth of the 136MW (ie 110MW + 26MW) that has been identified, as the civil works will have a significant lead time (typically 2-3 years) when compared to plant and equipment lead times (typically 1-2 years). Growth is likely to be limited by the rate at which developers commit to construct projects that will take about 3-5 years to construct from the placement of a construction contract. In the absence of detailed project information growth is assumed to be between 8-15MW/y.

Grid connection issues are also not considered to be a constraint on growth for Medium Hydro generating plants with capacities between 1.25-20MW, as plants will be connected to the distribution networks in areas where there is unlikely to be a connection problem.

3.6.2 Growth Scenarios

Taking into account the background described above, the Growth Scenarios and Build Scenarios are shown on Figure 7 and Figure 8 and described further below.

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[12] NGC Seven Year Statement, May 2007

[13] BERR Statistic

Figure 7 – Medium Hydro Growth Scenarios

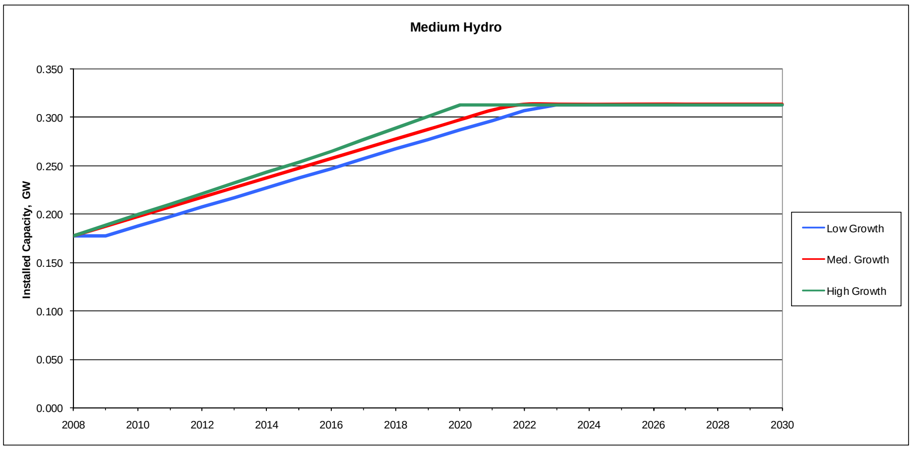
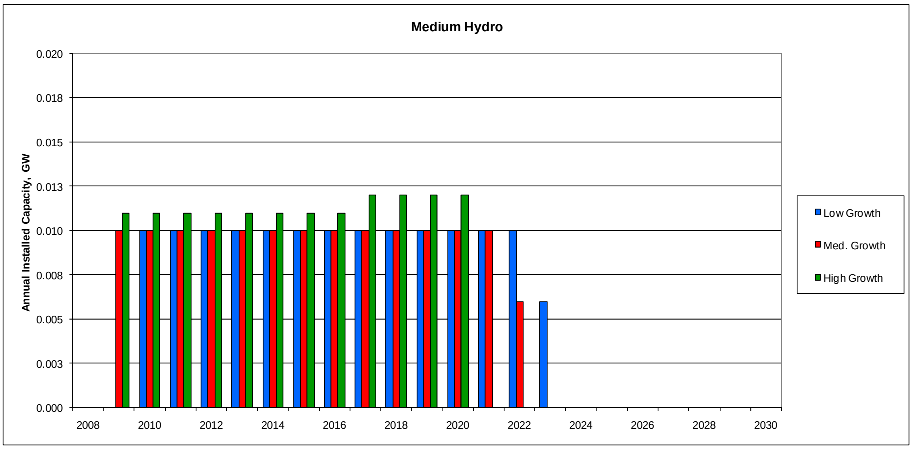


Figure 8 – Medium Hydro Build Scenarios



3.6.2.1 Low Growth

Low Growth reflects 136MW of projects being built at the rate of 10MW/y starting in 2010 and growing to 287MW by 2020 and 313MW in 2023.

3.6.2.2 High Growth

High Growth reflects 136MW of projects being built at the rate of 11-12MW/y starting in 2009 and growing to 313MW by 2020.

3.6.2.3 Medium Growth

Medium Growth reflects growth midway between High and Low Growth and reaching 300MW in 2020 and 313MW in 2022.

3.6.3 Key Observations

The key observation associated with the development of Medium Hydro is that that are no significant problems in developing a number of projects up to 2020 but that there is limited scope for further development of projects beyond those that are in the pipeline due to the lack of suitable sites.

3.7 Small Hydro (<1.25MW)

3.7.1 Background

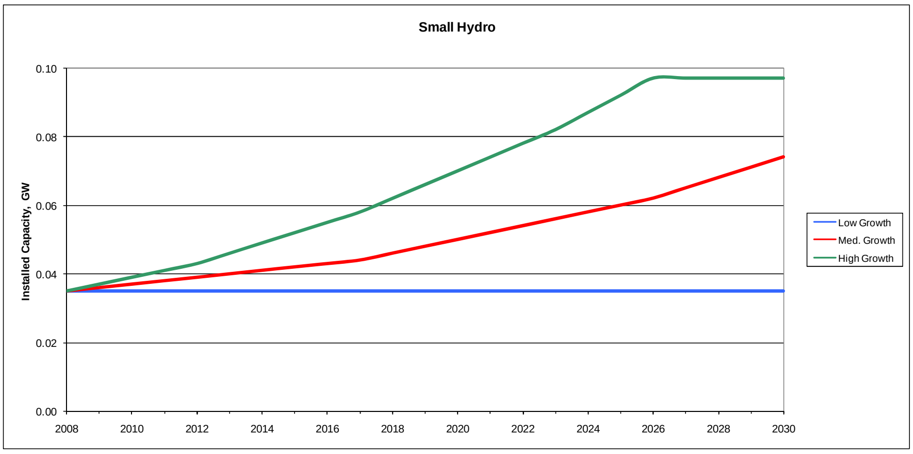
The existing installed capacity of Small Hydro generating plants is 35MW[14] and although the potential to be developed may be significant, the maximum exploitable resource is considered to be limited to about 100MW by 2020.

There are no significant constraints to the growth of Small Hydro that are similar to those described for Medium Hydro plant but are likely to be less binding. Growth is likely to be limited by the rate at which developers commit to construct projects that will take about 1-2 years to construct from the placement of a construction contract.

3.7.2 Growth Scenarios

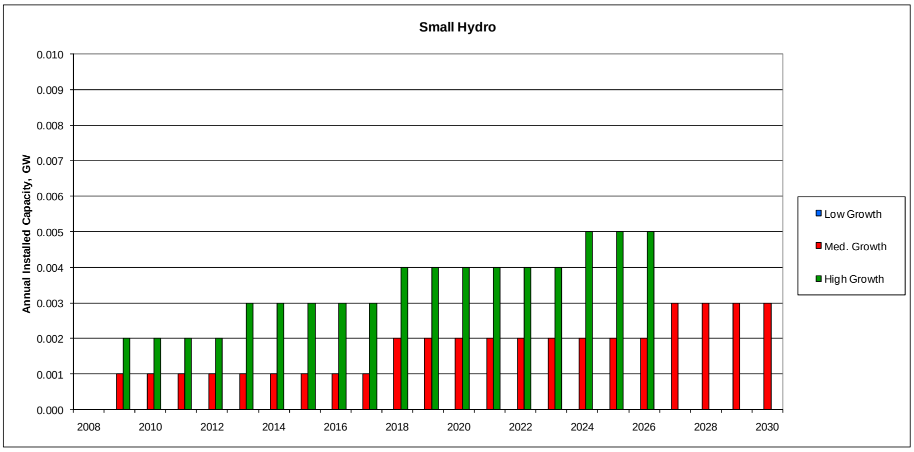
Taking into account the background described above, the Growth Scenarios and Build Scenarios are shown on Figure 9 and Figure 10 and described further below.

Figure 9 – Small Hydro Growth Scenarios



[14] Table 4.1, NGC Seven Year Statement, May 2007

Figure 10 – Small Hydro Build Scenarios



3.7.2.1 Low Growth

Low Growth reflects no further development with the total installed capacity capped at 35MW.

3.7.3 Medium Growth

Medium Growth reflects a build rate of 1-3MW/y growing to an installed capacity of 50MW by 2020 and 74MW by 2030.

3.7.4 High Growth

High Growth reflects a build rate of 2-5MW growing to an installed capacity of 70MW by 2020 and 97MW by 2030.

3.7.5 Key Observations

The key observation associated with the development of Small Hydro is that that are no significant problems in developing projects up to 2020 but that there is limited scope for further development due to lack of suitable sites.

3.8 Landfill Gas

3.8.1 Background

The existing installed capacity of Landfill Gas generation plants is about 860MW[15] with 109MW of consented but not yet operational projects and a further 16MW[16] of projects under consideration. RAB[15] forecast 1,000MW as the Land fill Gas resource potential for 2020.

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[15] Renewables Advisory Board, Overview Paper 21 January 2008, Table 8.1 – Scenario for Renewables Deployment in Bulk Electricity Market in 2020

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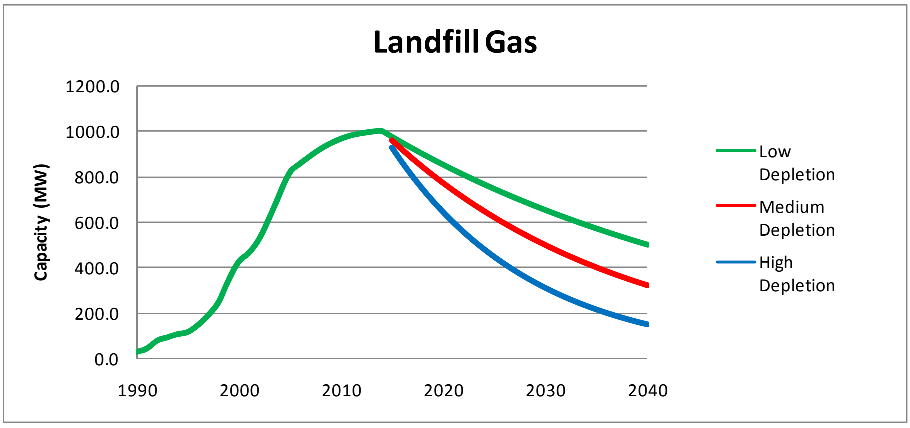
The UK Landfill Gas Growth curve from 1990 to 2014 and subsequent Depletion Curves from 20015 to 2040 are shown on the chart below. The curves take into account the declining levels of gas in existing sites and the projected closure of sites due to the European Landfill Directive, as explained in detail below.



a) Growth 1990 to 2006 (856MW) based on actual production as set out in DUKES Table 7.1.1 and Table 7.4.

b) Growth 2006 to 2014 based on BERR[17] list of Submissions and Consents and the SKM estimate of how these and others not yet registered will grow to reach a 1,000MW ceiling in 2014.

c) In 2014, as a result of European Landfill Directive, it is assumed that there will be no further landfill of biodegradable waste for the purpose of gas production for electricity generation and that the existing gas production landfill sites will deplete thereafter.

d) The rate of depletion of Landfill Gas Generation after 2014 has to recognise that there will be about 350 landfill projects in operation in the UK at this time, and that they will be in various stages of growth/depletion at rates which are dependant on the age and physical characteristics of the individual landfill sites. For the purpose of predicting depletion scenarios, information contained in article[18] has been taken to be typical of landfill gas production and used to predict depletion as set out below.

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[16] BERR Statistic

[17] Tables of Existing and Proposed Renewables Projects in the UK, November 2007

[18] Predictions and Projections, Waste Management World, 01 November 2003

3.8.2 High Depletion

Assumes an exponential decay from 2014 value to 50% of the peak value over 30 years. The capacity corresponds to 852MW by 2020 and 653MW by 2030.

3.8.3 Medium Depletion

Assumes an exponential decay from 2014 value to 37.5% of the peak value over 30 years. The capacity corresponds to 772MW by 2020 and 501MW by 2030.

3.8.4 Low Depletion

Assumes and exponential decay from 2014 value to 15% of the peak value over 30 years. The capacity corresponds to 645MW by 2020 and 331MW by 2030.

3.8.5 Key Observations

The key observation associated with the development of Landfill Gas is that there is a finite and limited resource that will be capped by the European Landfill Directive and will deplete thereafter.

3.9 Sewage Gas

3.9.1 Background

The existing installed capacity of Sewage Gas generating plants is 123MW[15] and there are no projects under consideration or awaiting construction. RAB forecast 150MW[15] as the resource potential for 2020.

Growth is likely to be limited by the rate at which developers commit to construct projects that will take about 2-3 years to construct from the placement of a construction contract.

3.9.2 Growth Scenarios

Taking into account the background described above, the Growth Scenarios and Build Scenarios are shown on Figure 11 and Figure 12 and described further below.

Figure 11- Sewage Gas Growth Scenarios

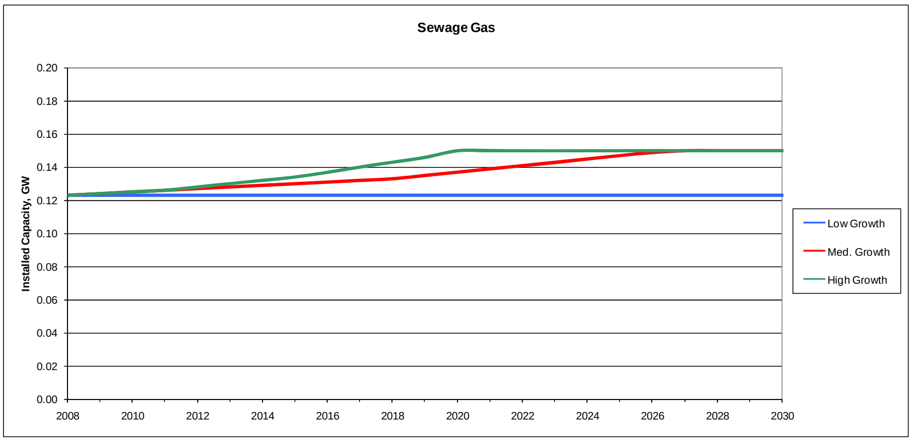
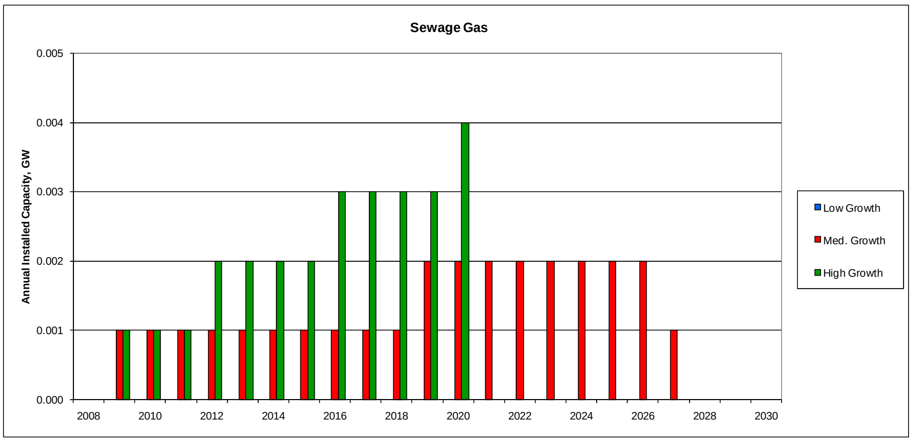


Figure 12 – Sewage Gas Build Scenarios



3.9.2.1 Low Growth

Low Growth reflects no further development of Sewage Gas generating capacity.

3.9.2.2 Medium Growth

Medium Growth reflects a Build Rate of 1-2MW/y growing to an Installed Capacity 137MW by 2020 and 150MW by 2026.

3.9.2.3 High Growth

High Growth reflects a Build Rate of 2-4MW/y growing to an Installed Capacity of 150MW by 2020 and remaining at that level to the end of the modelling period.

3.9.3 Key Observations

The key observation associated with the development of Sewage Gas is that there is a finite and limited resource and that there are no significant barriers to development other than the rate that developers seek to exploit the resource.

3.10 Biomass Background

The use of biomass involves a wide range of potential fuels of biological origin, which can be converted via a wide range of processes to produce electricity, heat or fuels. In this study we have concentrated on the use of biomass to produce electricity, and have focussed on the most widely available dry biomass feedstocks that can be converted to electricity by conventional and well developed technologies. These technologies are based on combustion and the use of the heat generated to produce steam for use via a steam turbine to produce electricity.

Given that fuel supply is seen as the major rate-determining factor, this analysis concentrates on the three fuel supply sectors, since there are particular issues that will constrain the rate of development of each. These are:

a) Regular biomass (indigenous residues).

b) Imported biomass (currently used primarily for co-firing).

c) Fuel from energy crops.

A general background to biomass power generation technologies is given in Appendix B and the growth scenarios for the three fuel supply sectors are set out below

3.11 Biomass Regular

3.11.1 Potential Resource

The available quantities of UK biomass materials has been assessed in a number of recent studies and summarised in the UK Biomass Strategy[19]. Based on this information BERR have put together a biomass supply curve. This estimates the total available resource at 170PJ[20] by 2010, rising to 216PJ by 2020 as a further 1 million tonnes of products from forestry sector (increases in thinning etc) come on stream. The main sources of material involved are summarised in.

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[19] www.defra.gov.uk/Environment/climatechange/uk/energy/renewablefuel/pdf/ukbiomassstrategy-0507.pdf

[20] Peta Joule (Joule x 10^{+15})

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Table 4 - Principal Sources of "Regular Biomass" in the UK

	Resource (PJ)	
Source	2010	2020
Straw	40.6	52.2
Waste wood	92.5	93.6
Sawmill products etc	23.9	46.8
Other wastes	13.0	23.7
Total	**170.0**	**216.3**

Note: 1.0PJ = 0.0612 million oven dry tonnes (MODT)

3.11.2 Current and Planned Capacity

Currently the UK has[21]:

a) 251MW of power generation capacity in operation and using these sources.

b) 59.6 MW under construction,

c) 99.2 MW with consents in place and awaiting construction,

d) 170.6 MW in the planning system (plus the very large scale, 350 MW, Port Talbot installation which will rely on imported raw material - see below).

When all this capacity (total of 380.4 MW) is operational it will in principle use around 50PJ (3 MODT) of fuel each year (assuming an 80% availability and a 30% fuel efficiency) – about 30% of the fuel thought to be available by 2010.

In common with all of this sector, the project lead time for medium scale projects will be around 3 years if significant delays with the planning system can be avoided. This means that little additional capacity (over and above that in the project development pipeline) is likely to be operational by 2010.

3.11.3 Growth Scenarios

Taking into account the background described above, the Growth Scenarios and Build Scenarios are shown on Figure 13 and Figure 14 and described further below.

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[21] www.restats.org.uk/2010_target/2010_Datasheets/Data_sheet_March2008.xls

Figure 13 – Biomass Regular Growth Scenarios

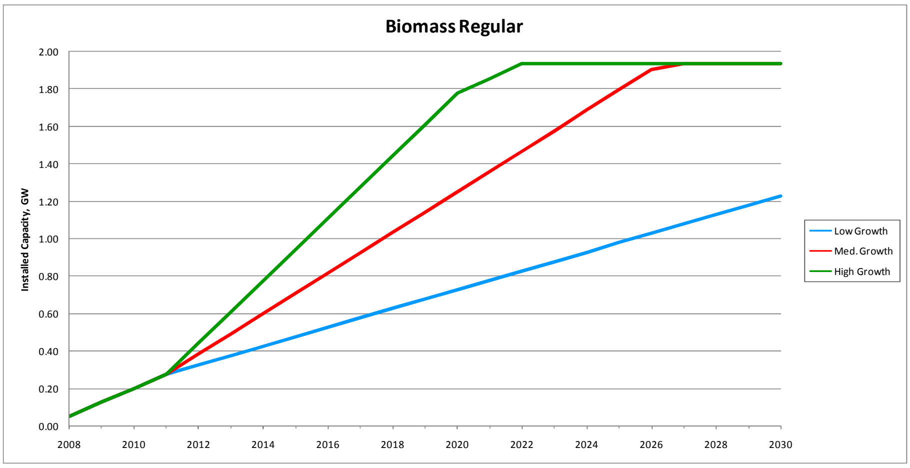
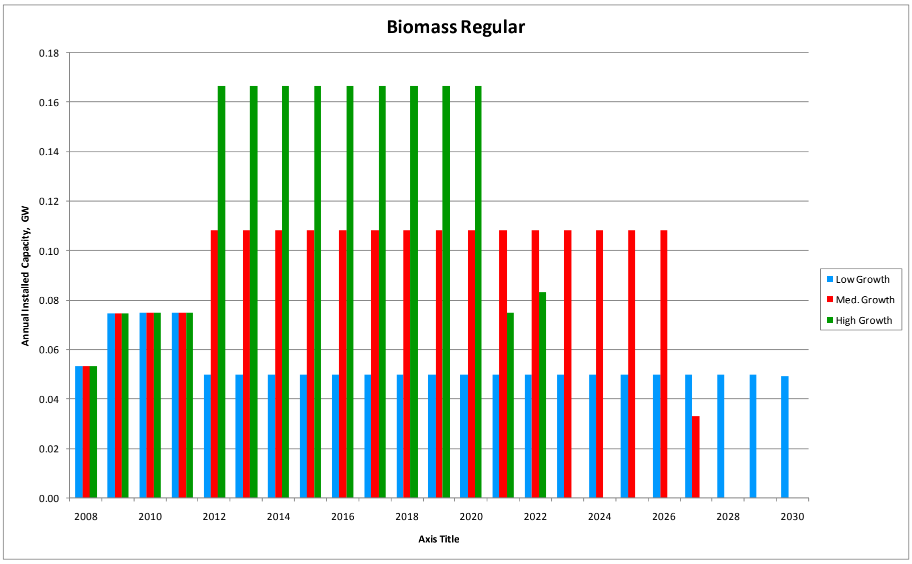


Figure 14 – Biomass Regular Build Scenarios



3.11.3.1 Low Growth

The base scenario is based on "business as usual" assuming that resource availability increases at a rate which supports a continuing rise in capacity at around the recent rate of 50 MW/year, bringing fuel use up to some 103 PJ (6.3 MODT) by 2020 (47% of likely supply in 2020).

3.11.3.2 Medium Growth

In this scenario fuel supply increases at a faster rate as confidence in the sector is higher and investment in project development and supply systems increases, with fuel use rising to around 150 PJ (9.2 MODT) by 2020 (70% of likely supply in 2020). This would lead to a capacity increase of around 100 MW/year.

3.11.3.3 High Growth

In the high scenario, fuel supply increases at a rate that uses all the available resource by 2020 (implying a capacity increase of ~175 MW/year).

3.11.4 Key Observations

The key observations associated with Regular Biomass are:

a) The availability of resources places a cap on the maximum likely contribution to energy supply. Further increases can only be achieved if more indigenous resource were made available, for example by more efforts to encourage production of energy products from early forest thinning and residues.

b) The principal barriers and constraints affecting the rate of development of Regular Biomass are associated with developing the supply chains for fuel, which needs to involve the forestry, agriculture and waste sectors, for whom the energy sector is a relatively new market. This rate of development will be constrained and influenced by:

   vi. Confidence in investing in the fuel market (which has been undermined by several previous project failures and by relatively slow market development)

   vii. The lack of a supply chain aimed at energy market (since traditionally the raw materials have been used in the paper and board markets, and in agriculture).

   viii. Availability of suitable harvesting and processing equipment for fuel supply from the forestry sector.

c) There may be other constraints associated with the supply of systems for utilising the fuel in this sector including handling and processing equipment, combustion systems, steam turbines, emission control systems etc. However the expected rate of market development is likely to be a relatively small multiple of current deployment rates, and a minor fraction of the likely EU wide market development, so it is not felt that this will be the rate determining step for exploitation of this sector.

3.12 Imported Biomass (Co-firing)

3.12.1 Background

In 2006 co-firing generated 2,528 GWh[22]. Nearly all of this was fuelled from imported biomass. Producing this electricity at typical power station efficiencies requires energy input of around 26PJ, equivalent to over 1.5 MODT of fuel.

[22] DUKES 2007, BERR

The supply of imported biomass was stimulated by the availability of the co-firing market. This grew quickly once it was clear that there was a significantly large and profitable market, that the initial problems associated with handling and burning the fuel were overcome and that investment was made in the necessary supply systems. Any constraints were relatively quickly overcome.

The market for co-firing has been restricted through caps on the amount of co-firing eligible under the Renewables Obligation. In the future, banding of the RO will reduce the number of ROCs that can be earned for each unit of regular biomass co-firing, and the co-firing market will further decline as the impact of the Large Combustion Plant Directive (LCPD) reduces capacity and generation. SKM estimate[23] that this market will decline having a maximum potential of about 1,300 GWh/year in 2020, reducing fuel use to a maximum of 14 PJ.

The volumes of biomass being imported to supply the co-firing market will therefore be likely to decline, but there is potential to maintain or increase the level of imported biomass for use in other projects, and in particular in large scale power generation systems. The largest such project under discussion is the Prenergy 350 MW Port Talbot biomass project. This will rely on imported biomass, and it is assumed that this will use some 24.5 PJ (1.5 MODT of fuel or 2-3 million tonnes of as–received wood chip) and operation is scheduled for 2011/12.

3.12.2 Growth Scenarios

Taking into account the background described above, the Growth Scenarios and Build Scenarios are shown on Figure 15 and Figure 16 and described further below.

[23] SKM Report to BERR "Growth Scenarios for UK Renewables Generation and Implications for Future Developments and Operation of the Electricity Network", May 2008. This report indicates the closure in 2015 of large coal stations without FGD leaving only new supercritical coal (operating at 70% load factor) and FGD coal (operating at about 5% load factor) in which to co-fire. Co-firing 5% biomass results in 1,300GWh with 10% biomass producing 2,600GWh.

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Figure 15 – Imported Biomass Growth Scenarios

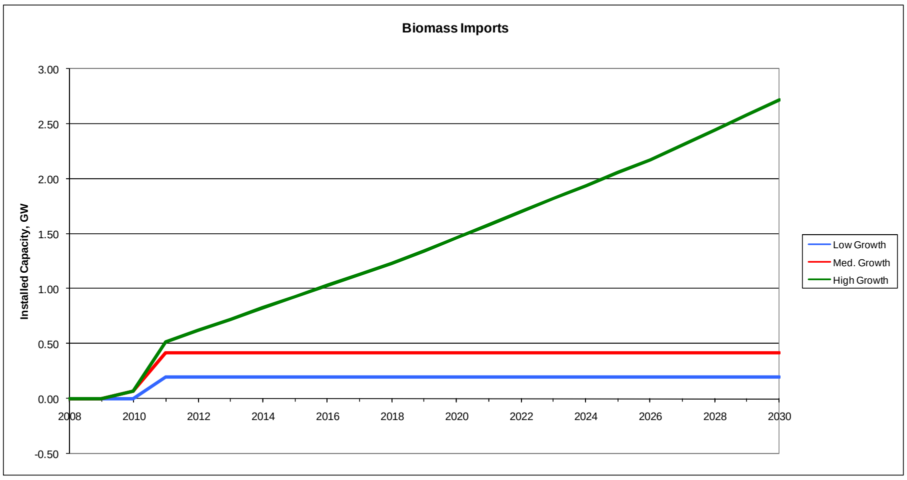
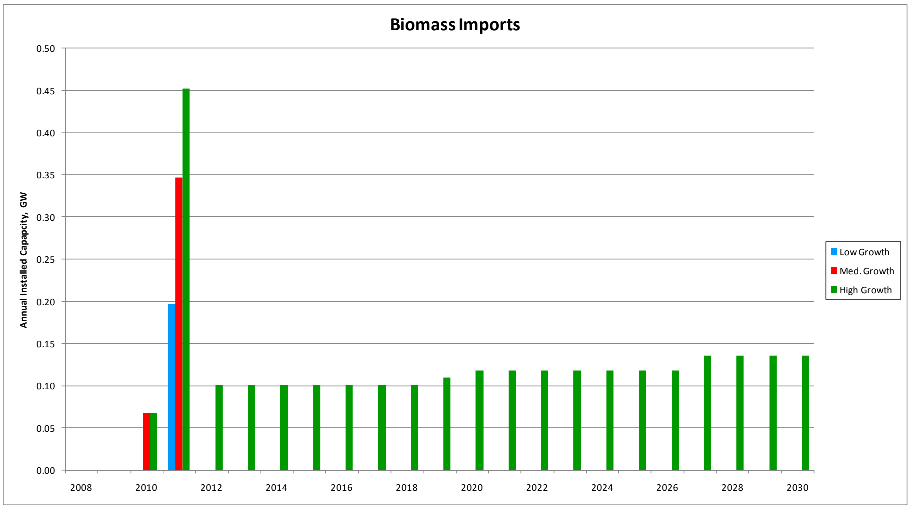


Figure 16 – Imported Biomass Build Scenarios



3.12.2.1 Low Growth

In this scenario, it is assumed that competition, sustainability concerns and uncertainty around the future market in the UK constrain rapid growth in bioenergy imports. Reducing levels of cofiring reduce the contribution from these fuel sources. The Port Talbot plant comes into operation and some new capacity comes into play, with imports settling down at around 38 PJ, similar to present levels of import.

3.12.2.2 Medium Growth

In this scenario, current level of imports continue, with diversion from co-firing as this happens to new capacity, and Port Talbot plant comes on stream, but competition and availability constrain total imports to around 50PJ.

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3.12.2.3 High Growth

In this scenario, fuel imports are relatively unconstrained, and as well as the Port Talbot plant, additional capacity based on imported fuel is stimulated, with fuel imports rising to 150PJ by 2020 and to 250PJ by 2030. This leads to an increase in capacity of around 100MW/y between 2010 and 2020 and 120MW/y from 2020 to 2030.

3.12.3 Key Observations

Currently there is a very significant potential for biomass imports from US/Canada, South America, Asia. However there are a number of potential factors that could constrain imported biomass supply. These include:

a) Potential for competition for supply with other European importing countries, and with growth of use in country or region of origin, (particularly as other uses, such as deployment of second generation biofuels technology which uses cellulosic feedstock on a large scale, from perhaps 2015 onwards).

b) increasing concerns about the sustainability of removing and transporting residues.

c) Confidence in UK market for imported biomass.

d) Physical assets needed for biomass import at docks/harbours etc.

3.13 Biomass Energy Crops

3.13.1 Background

It is assumed that increased energy crop production is based around increased levels of planting of short rotation coppice (willow) and miscanthus.

Long term potential for land use from these crops is estimated at 350,000 hectares (6.5% of UK land).

Current planting rates are low, because of uncertainty about the marketability of the fuel, the high prices being achieved for other agricultural products, and the changes to the Energy Crops Scheme.

3.13.2 Growth Scenarios

Taking into account the background described above, the Growth Scenarios and Build Scenarios are shown on Figure 17 and Figure 18 and described further below.

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Figure 17 – Energy Crop Growth Scenarios

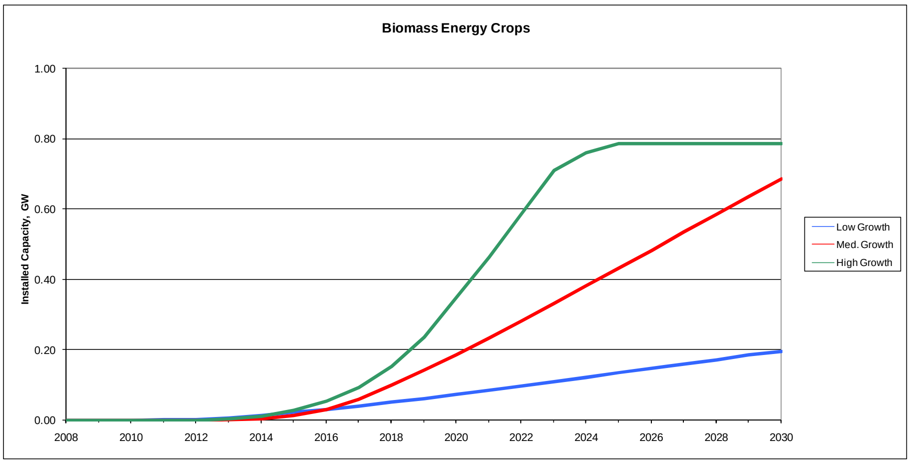
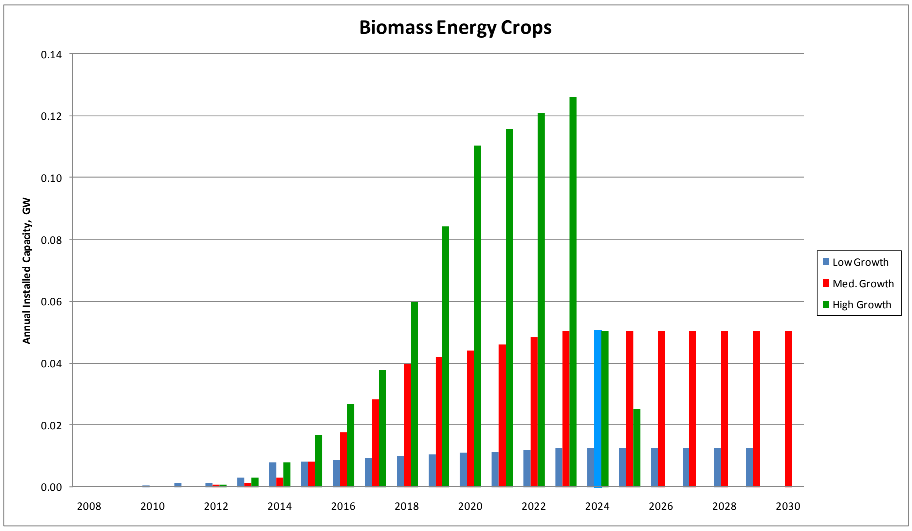


Figure 18 – Energy Crop Build Scenarios



3.13.2.1 Low Growth

In this scenario planting rates remain low, building up to 5,000ha/year by 2015, and remaining at that level. Installed capacity rises to 73MW by 2020, and to 195MW by 2030.

3.13.2.2 Medium Growth

In this scenario rates of planting rise more rapidly as infrastructure is developed and put in place, with planting rates reaching 20,000 ha by 2015, and continuing at that rate. The full potential for planting (350,000 ha) is reached by 2030. This level of planting would support a total installed capacity of 187MW by 2020, rising to 686MW by 2030.

3.13.2.3 High Growth

In this scenario planting rates are assumed to build up rapidly over a 5 year period reaching 50,000 ha/year by 2015 and continuing at that level to 2020, when new planted area is 322,500 ha, and then rising to the anticipated maximum of 350,000 hectares[24] by 2022. Fuel production increases from the current levels of around 155 kODT, to 2.2 MODT by 2020 (37.9 PJ), and peaks at 4.8 MODT (82.1 PJ) by 2025 and then continues at that level. This fuel would supply an installed capacity of 787MW.

3.13.3 Key Observations

The key observations associated with Biomass Energy Crops are:

a) Barriers which will limit the rate of increased production of energy crops are summarised in Table 5 below, along with some proposed measures which could help reduce or overcome the barriers.

Table 5 – Barriers to Energy Crop Production

Barrier/Constraint	Measures
Confidence in land users that crops will find a market	Development of long term supply contracts and supply intermediaries
Competitive position of energy crops versus other crops (with cereals etc at record price levels)	Incentives or requirements for energy crop use in projects
Confidence that support mechanisms will be in place	Long term commitment of stable support systems
Availability of planting materials (willow cuttings and miscanthus rootstock)	Development of cuttings/rootstock supply stimulated by incentives (eg extension of planting grants to cover cuttings supply)
Availability of sufficient machinery for planting and harvesting the crops	Availability of additional planting and harvesting systems as market develops

b) The extent to which the above barriers are overcome will determine the rates of planting and therefore the availability of energy crop material. In the short term acceleration of the rate of planting will be restricted by the physical constraints, in particular of rootstock/cutting supply.

[24] Approximately twice the area of Greater London

3.14 Wave

3.14.1.1 Exploitable Resource

The exploitable resource associated with wave energy in UK waters is about 50TWh/y[25] and the total installed capacity of wave energy devices required to exploit this resource is about 21GW based on a 27% load factor for a wave power site. There are several wave power devices being evaluated in small scale demonstration projects and to date none have reached the stage where they are commercially available for large scale projects.

3.14.1.2 Project Lead Times and Build Rates

Wave power project lead times and build rates are based on the following:

a) It will be at least 4 years from now before wave power devices are commercially available for large scale projects.

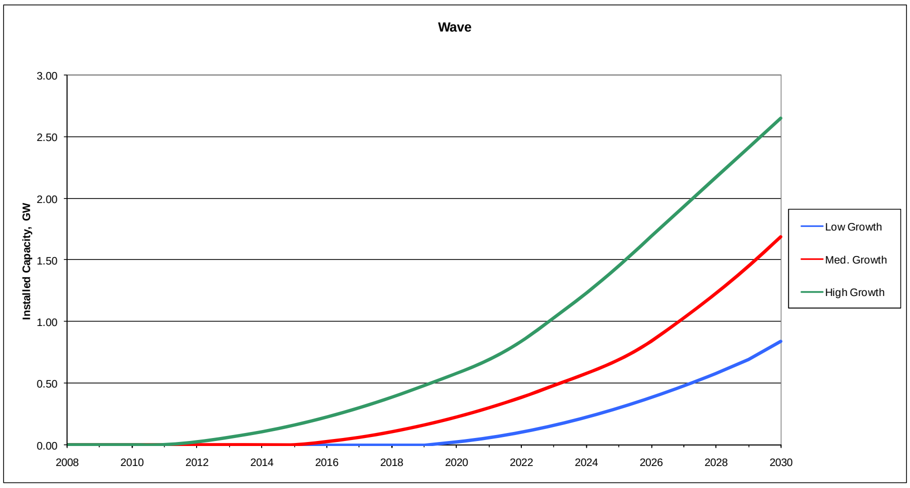
b) Wave power devices will be floating devices anchored to the sea bed and there will be a wide variety of general purpose vessels that can be used to install the devices and as such the availability of vessels will not be a constraint on growth.

c) Build rates assumed to be limited by the size of the arrays that can be positioned offshore and that arrays in multiples of up to hundreds of megawatts are feasible.

3.14.1.3 Growth Scenarios

Taking into account the background described above, the Growth Scenarios and Build Scenarios are shown on Figure 19 and Figure 20 and described further below.

Figure 19 – Wave Growth Scenarios



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[25] BERR ETSU Statistic, as reported in: www.bwea.com/marine/resource.html

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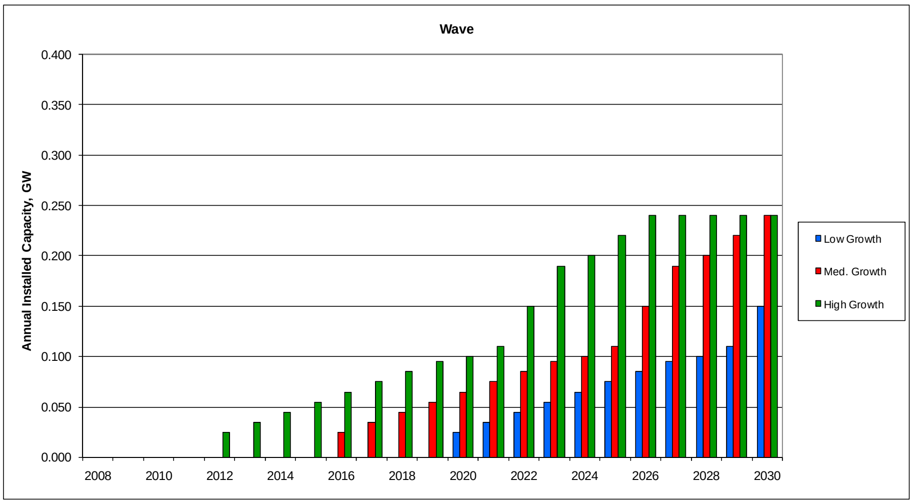
Figure 20 – Wave Build Scenarios



3.14.1.4 High Growth

High Growth reflects a Build Rate of 25MW/y in 2012, increasing to 100MW/y by 2020 and further increasing to a maximum of 240MW/y by 2026. This results in the Installed Capacity growing to 580MW by 2020 and 2,650MW by 2030.

3.14.1.5 Medium Growth

Medium Growth reflects the Build Rates for the High Growth Scenario but with the year in which wave devices become commercially available moved back to 2016. This results in the Installed Capacity growing to 225MW by 2020 and 1,690MW by 2030.

3.14.1.6 Low Growth

Low Growth reflects the Build Rates for the High Growth Scenario but with the year in which wave devices become commercially available moved back to 2020. This results in the Installed Capacity growing to 25MW by 2020 and 840MW by 2030.

3.14.2 Key Observations

The key observation associated with Wave power generation is that the technology is presently not ready for commercial deployment on a large scale, and so the development curve and growth forecasts are based on present predictions. The technology has potential, but as yet there is little certainty as to the extent to which this will be realised, and when.

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3.15 Tidal Stream

3.15.1 Exploitable Resource

The resource associated with Tidal Stream in the UK is shown in Table 6 below [26]. Also shown is the Installed Capacity required to exploit the maximum resource based on a 27% load factor for a tidal stream site.

Table 6 – UK Tidal Stream Resource

Site Name	Area	Resource (TWh/y)	Installed Capacity Required to Exploit Resource (MW)
Pentland Skerries	Pentland Firth	3.9	1650
Stroma	Pentland Firth	2.8	1200
Duncasby Head	Pentland Firth	2.0	850
Casquets	Aldernney	1.7	720
South Ronaldsay	Pentland Firth	1.5	630
Hoy	Pentland Firth	1.4	590
Race of Alderney	Aldernney	1.4	590
South Ronalday	Pentland Firth	1.1	470
Rathlin Island	North Channel	0.9	380
Mull of Galloway	North Channel	0.8	340
	Total all depths	17.5	7420
	Total <40m depth	3.5	1480

According to Black & Veatch[27] only about 20% of the UK resource potential (B&V state this as being 18GWh which lines up with the SDC position) is within sites of depth 30-40m and these sites are probably the most suited (economically) to near term developments that use seabed-standing devices (using for example monopile designs). Approximately 50% of the UK resource is within deep (>40m) sites and these are only suited to device designs that are capable of being installed and operated in water depths greater than 40m.

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[26] Sustainable Development Commission, Tidal Power in the UK, October 2007

[27] B&V Report - Phase II UK Tidal Stream Energy Resource Assessment, Carbon Trust, July 2005

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Given that the tidal stream devices presently being evaluated in demonstration projects are installed in water depths of less than 40m, and are not yet commercially available, it would be very optimistic to expect tidal stream devices capable of operating in water depths greater than 40m to be available before 2020. Accordingly for the purpose of this assessment only 20% of the potential resource is considered to be available for exploitation ie **3.5TWh** with an installed capacity of **1,480MW** noting that of this it may not be possible to harness all of the available resource because of a wide range of constraints which are discussed below.

3.15.2 Project Lead Times and Build Rates

Tidal stream project lead times and build rates are based on the following:

a) It will be 4 years from now before tidal stream devices are commercially available.

b) 1.2MW (2x600kW) propeller type turbines are expected to become the preferred devices initially.

c) Based on experience of installing offshore wind turbines it is estimated that it will take 3.5 vessel days to install and commission a tidal stream device based on seabed standing design.

d) A 170 day weather window for installation over a year resulting in a build rate of ~60MW/vessel/year.

3.15.3 Growth Scenarios

Taking into account the background described above, the Growth Scenarios and Build Scenarios are shown Figure 21 on and Figure 22 and described further below.

Figure 21 – Tidal Stream Growth Scenarios

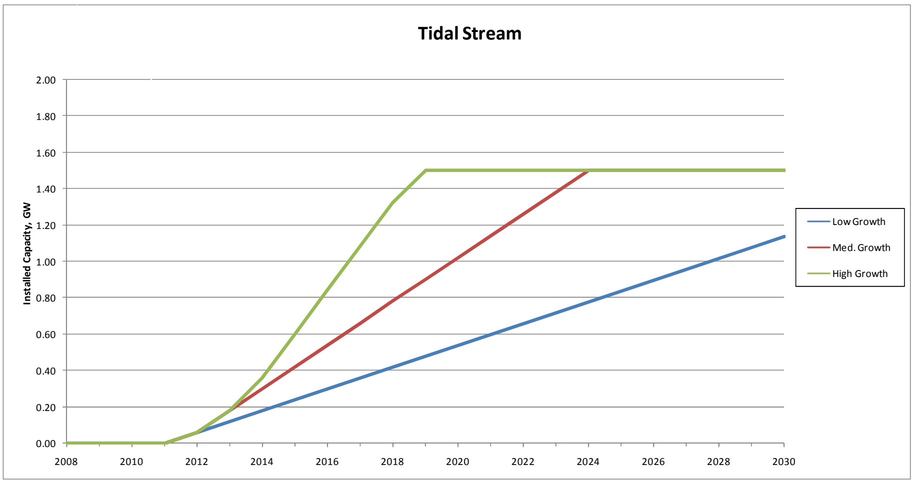

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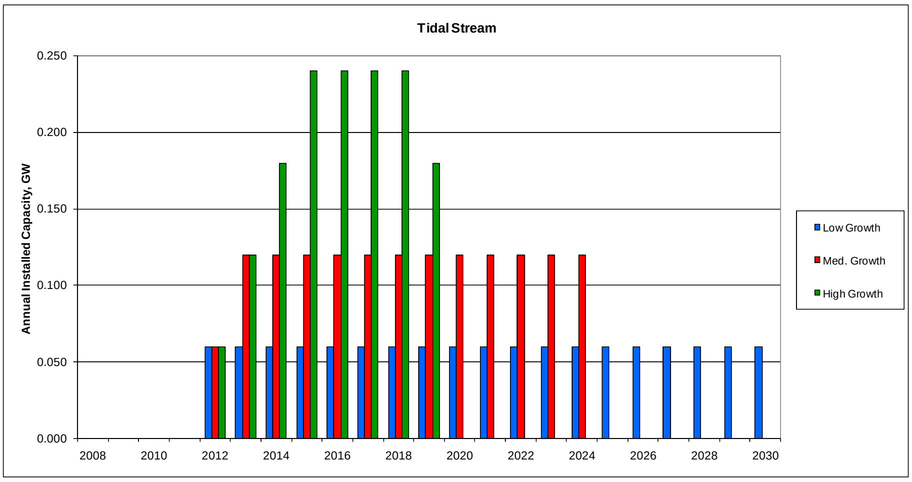
Figure 22 – Tidal Stream Build Rates



It is assumed that tidal stream devices will become available in 2012 and that the binding constraint on development will be the availability of installation vessels that lead to the following growth scenarios:

3.15.3.1 Low Growth

Low Growth reflects one (1) vessel installing at the rate of 60MW/y with the Installed Capacity growing to 540MW in 2020 and 1,140MW in 2030.

3.15.3.2 Medium Growth

Medium Growth reflects one (1) vessel in 2012 installing at the rate of 60MW/y increasing to two (2) vessels from 2013 onwards installing at the rate of 120MW/y. The Installed Capacity grows to 1,020MW in 2020 and reaches the 1,480MW cap in 2024.

3.15.3.3 High Growth

High Growth reflects one (1) vessel in 2012 increasing to three (3) vessels in 2014 installing at the rate of 180MW/y until the 1,480MW cap is reached in 2019.

3.15.4 Key Observations

Considering that tidal stream is not a mature technology on which growth scenarios can be based, the uncertainties associated with the above assumptions can lead to a number of other scenarios in addition to the ones described above. The above scenarios assume the following:

a) Commercially available devices will be available in 2012 but this could take longer.

b) Devices are limited to 1.2MW but higher ratings could be developed if the resource is available for exploitation – this will tend to increase the build rate per installation vessel.

c) The full 1,480MW potential may not be harnessed due to numerous possible constraints that will only become apparent through a detailed sea bed survey of the site to be exploited and taking into account other uses of the marine environment in the vicinity of the sites.

The principal uncertainty is considered to be the year in which commercially available devices become available and this will tend to move the Low/Medium/High Growth scenarios towards the right noting that the cap will remain at 1,480MW.

3.16 Tidal Range

3.16.1 Exploitable Resource

The resource associated with Tidal Range in the UK is shown on Table 7 below [28]. Also shown is the Installed Capacity required to exploit the maximum resource based on a 20% load factor for a tidal range site. Because of its size, the Severn Barrage is treated as separate resource and is not included in this analysis.

Table 7 – UK Tidal Range Exploitable Resource

Site Name	Resource (TWh/y)	Installed Capacity Required to Exploit Resource (MW)
Severn	17	9,700
Mersey	1.4	800
Duddon	0.212	120
Wyre	0.131	75
Conwy	0.06	35

Excluding the Severn Barrage the growth scenarios developed below for Tidal Range are capped at 1,030MW although it is recognised that there may be some physical constraints that prevent all of this potential from being developed in practice. These constraints are discussed below.

3.16.2 Project Lead Times

The earliest date by which generating plant will be commissioned and in commercial operation is based on the following:

a) Entities to take on the projects and the associated finance will be forthcoming in the short term.

[28] Sustainable Energy Commission, Tidal Power in the UK, October 2007

b) It will take 3-4 years to complete the necessary planning, regulatory, design, tender, and contract processes before construction contracts can be placed.

c) Bulb hydro turbines of suitable ratings will be commercially available for each of the projects

d) It will take 3-4 years to undertake the civil works and construct and commission the power generating equipment

On the basis of the above the earliest date by which a Tidal Range project could be brought into commercial operation is 8 years from now and this is considered to be challenging.

3.16.3 Project Commissioning Rates

The majority of the time taken to construct a tidal range project will be the civil works associated with a barrage and the generating plant power house. When the civil works have been completed the mechanical and electrical plant can be installed and commissioned and it is assumed that this will progress as follows:

a) **Conwy** – 35MW with all generators commissioned over a 1 year period.

b) **Wyre** – 75MW with all generators commissioned over a 1 year period.

c) **Duddon** – 120MW with all generators commissioned over a 1 year period.

d) **Mersey** – 800MW with generators commissioned at the rate of 200MW/y.

For the purpose of developing growth scenarios it is assumed that the smallest project will be developed first followed by the other projects.

3.16.4 Growth Scenarios

Taking into account the background described above, the Growth Scenarios and Build Scenarios are shown on Figure 23 and Figure 24 and described further below.

Figure 23 – Tidal Range Growth Scenarios

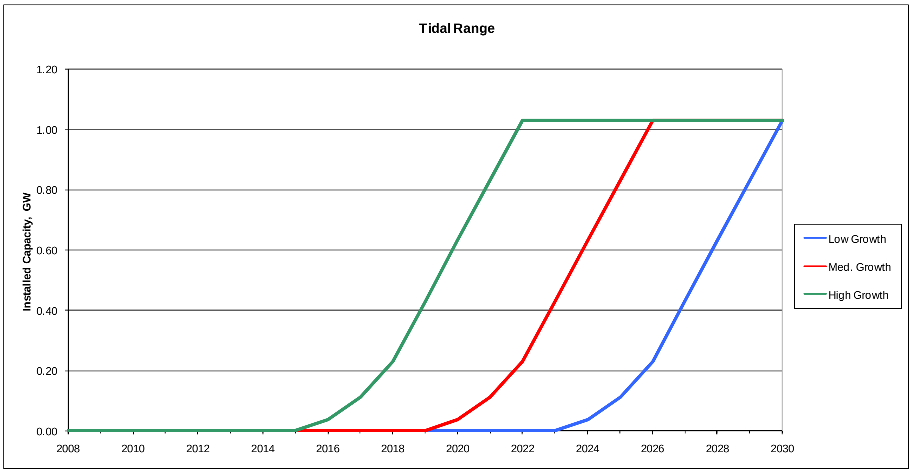


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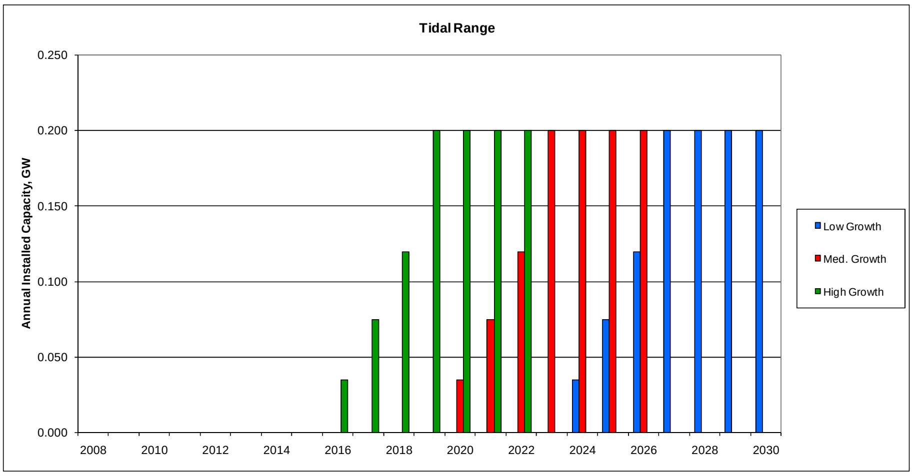
Figure 24 – Tidal Range Build Rates



3.16.4.1 High Growth

The high growth scenario is based on the following:

a) Conwy – 35MW with all generators commissioned in 2016.

b) Wyre – 75MW with all generators commissioned in 2017.

c) Duddon – 120MW with all generators commissioned in 2019.

d) Mersey – 800MW with generators with 200MW of generation commissioned in 2019, 2020, 2021 and 2022.

The High Growth scenario is representative of the earliest time that Tidal Range resources can be brought into commercial operation.

3.16.4.2 Medium Growth

The medium growth scenario is based on the development of the Tidal Range resources being 4 years later than the High Growth scenario.

3.16.4.3 Low Growth

The medium growth scenario is based on the development of the Tidal Range resources being 8 years later than the High Growth scenario.

3.16.5 Key Observations

The key observations associated with Tidal Range power generation are:

a) The environmental impact of tidal range projects is significant and represents a major barrier to be overcome before a scheme can proceed to the stage where construction can be considered.

b) Given that the environmental and financial barriers can be overcome it will be at least 8 years before a project can be constructed and commissioned.

3.17 Growth Summary

The Installed Capacity (GW) for years 2010, 2020 and 2030 for all of the technologies and for the Low, Medium and High growth scenarios is summarised in Table 8 below

Table 8 – Summary of Installed Capacities (GW)

	Low Growth			Medium Growth			High Growth		
Technology (GW)	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
Onshore Wind	2.860	7.280	11.780	2.980	10.060	20.070	2.980	14.380	20.070
Offshore Wind	1.840	4.890	8.390	1.840	9.040	18.840	1.840	15.170	33.890
Large Hydro	1.200	1.300	1.300	1.200	1.300	1.300	1.200	1.300	1.300
Medium Hydro	0.177	0.287	0.313	0.199	0.297	0.313	0.199	0.313	0.313
Small Hydro	0.035	0.035	0.035	0.037	0.050	0.074	0.039	0.066	0.097
Landfill Gas	0.966	0.646	0.311	0.966	0.772	0.501	0.966	0.852	0.653
Sewage Gas	0.123	0.123	0.123	0.125	0.137	0.150	0.125	0.150	0.150
Biomass Regular	0.203	0.728	1.227	0.203	1.253	1.936	0.203	1.778	1.936
Biomass Imported	0.000	0.198	0.198	0.068	0.415	0.415	0.068	1.413	2.721
Biomas Energy Crop	0.000	0.073	0.195	0.000	0.187	0.686	0.000	0.348	0.787
Wave	0.000	0.025	0.840	0.000	0.225	1.690	0.000	0.580	2.650
Tidal Stream	0.000	0.540	1.140	0.000	1.020	1.500	0.000	1.500	1.500
Tidal Range	0.000	0.000	1.030	0.000	0.040	1.030	0.000	0.630	1.030

Based on the installed capacities set out in Table 8 the energy production for each of the technologies is set out in Table 9 below.

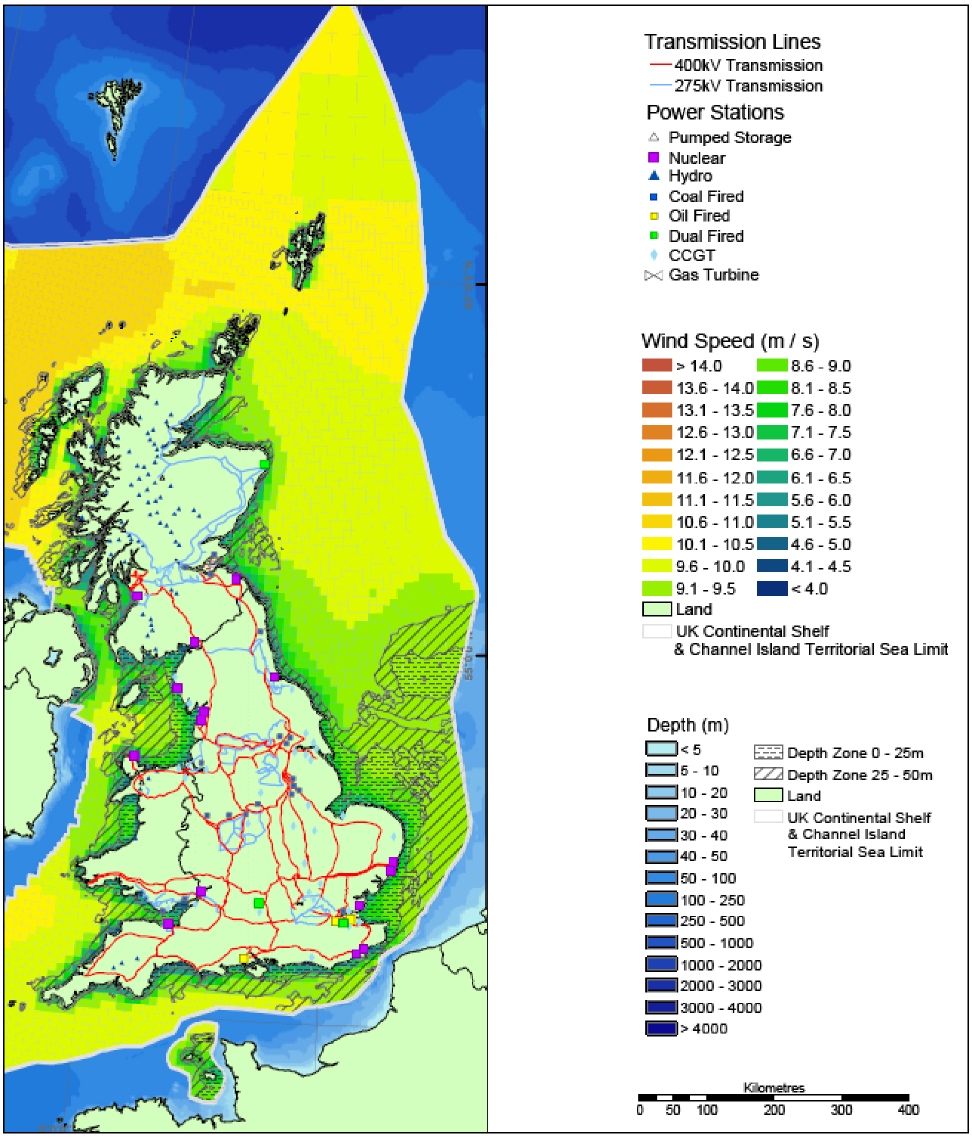
Table 9 – Summary of Annual Energy Production (GWh)

	Low Growth			Medium Growth			High Growth			Load
Technology (GWh)	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**	**Factor**
Onshore Wind	7,015	17,856	28,894	7,309	24,675	49,228	7,309	35,271	49,228	28%
Offshore Wind	6,447	17,135	29,399	6,447	31,676	66,015	6,447	53,156	118,751	40%
Large Hydro	3,469	3,758	3,758	3,469	3,758	3,758	3,469	3,758	3,758	33%
Medium Hydro	512	830	905	575	859	905	575	905	905	33%
Small Hydro	101	101	101	107	145	214	113	191	280	33%
Landfill Gas	6,770	4,527	2,179	6,770	5,410	3,511	6,770	5,971	4,576	80%
Sewage Gas	862	862	862	876	960	1,051	876	1,051	1,051	80%
Biomass Regular	1,298	4,655	7,846	1,298	8,013	12,380	1,298	11,370	12,380	73%
Biomass Imported	0	1,266	1,266	435	2,654	2,654	435	9,036	17,400	73%
Biomass Energy Crop	0	467	1,247	0	1,196	4,387	0	2,225	5,033	73%
Wave	0	59	1,987	0	532	3,997	0	1,372	6,268	27%
Tidal Stream	0	1,656	3,495	0	3,127	4,599	0	4,599	4,599	35%
Tidal Range	0	0	2,075	0	81	2,075	0	1,269	2,075	23%

Appendix A Round 3 Offshore Wind Generation Locations

The wind resource and sea depths within GB territorial waters and the onshore electricity infrastructure are shown on Figure 25 below.

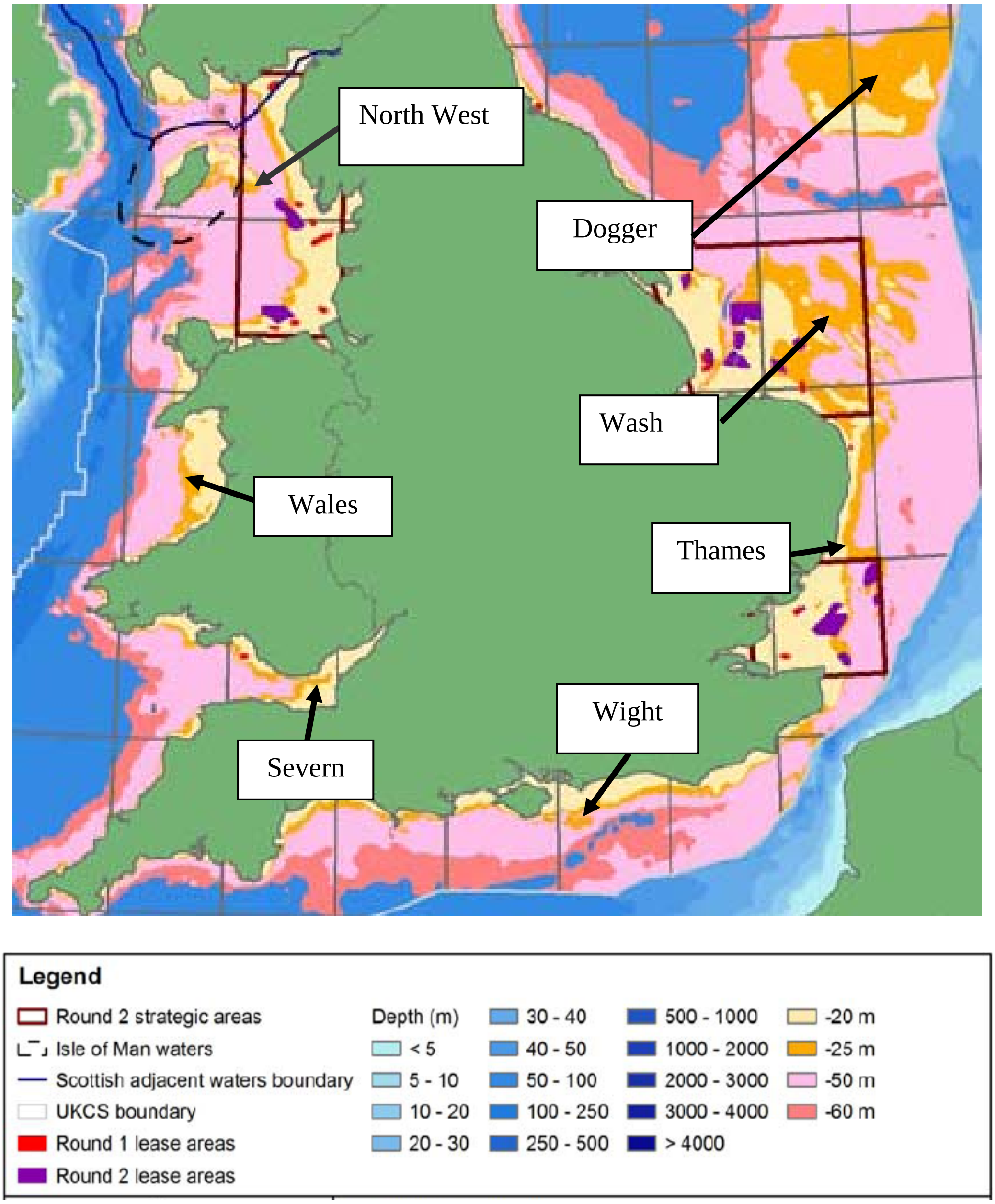
Figure 25 – GB Offshore Resources and Onshore Electricity Infrastructure[29]



[29] Merging of two diagrams from BERR Atlas of Marine Renewable Energy Resouces

The potential regions where offshore wind generation developments are expected to take place is shown on Figure 26 and discussed further below.

Figure 26 - Offshore Wind Generation Development Regions[30]



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[30] Background extracted from BERR Atlas of Marine Renewable Energy Resources

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A.1 General Assumptions

The general assumptions made in identifying potential for offshore wind generation development are:

a) Developments preferably situated in 20-30m depths where WTG driven pile foundations are feasible at locations with favourable wind speeds.

b) Near shore developments would connect directly into HVAC onshore electricity infrastructure

c) Far offshore developments with route lengths greater than 60km would utilise HVDC interconnectors.

A.2 Development Scenarios

The scenarios described below are representative of the total potential of offshore wind generation (MW) that can be exploited off UK coastal waters based on the general assumptions set out above.

Table 10 below shows the total installed offshore wind generation capacities in UK waters for the scenarios that have been developed in conjunction with the work being undertaken by SKM on Grid Issues[31] that are discussed further below.

Table 10 Round 3 Development Scenarios

Region	Round 1+2 (MW)	R1+R2+R3 Installed Capacity (MW)		
		Scenario 1	Scenario 2	Scenario 3
Wash	4,068	8,000	8,000	8,000
North West	2,588	5,000	5,000	5,000
Thames	1,954	2,800	2,800	2,800
Severn	108	108	108	108
North East	94	94	94	94
Scotland	10	10	10	10
Wales	0	2,500	2,500	2,500
I of Wight	0	0	0	0
Dogger	0	3,600	7,700	15,200
	8,822	**22,112**	**26,212**	**33,712**

A.3 Round 1 + 2

The base case on which to develop scenarios assumes that all of the existing offshore wind sites awarded under Round 1 and Round 2 have been built noting that:

a) In early 2008 861MW of Round 1 projects were either operational or under construction with a further 856MW under various stages of development.

[31] SKM Report to BERR “Growth Scenarios for UK Renewables Generation and Implications for Future Developments and Operation of the Electricity Network”, May 2008

b) In early 2008 only 800MW of Round 2 projects were committed for construction with a further 1,450MW fully consented and a further 4,855MW under various stages of development.

c) At the present rate of development, completion of Round 1 and Round 2 projects is not envisaged before 2015.

A.4 Scenario 1 – 22.1GW Total Offshore Capacity

With this Scenario a total of 22.1GW of offshore wind generation is assumed to be installed by 2020. To meet this requirement the installed capacities in the offshore regions are assumed to develop as follows:

A.4.1 The Wash

Round 1 + 2 developments in the Wash amount to about 4GW and reference to Figure 26 indicates that further development could take place in the 20-25m sea depth areas further east of the existing Round 2 leases. On this basis it is estimated that a further 4.0GW could be developed in the Wash.

A.4.2 North West

Round 1 + 2 developments in the North West amount to about 2.5GW and reference to Figure 26 indicates that further development could take place in the 20-25m sea depth contours occupied by the existing Round 2 developments and possibly further offshore towards the Isle of Mann. On this basis it is estimated that a further 2.5GW could be developed in the North West.

A.4.3 Thames

Round 1 + 2 developments in the Thames region amount to about 2GW and reference to Figure 26 indicates that further development would be somewhat constrained by the lack of suitable sites. However it is understood that the Greater Gabbard development that is committed to 500MW has room for expansion to 1000MW using 3.6MW WTGs and the capacity could be increased if larger WTGs are employed. On this basis and on the assumption that a further 500MW site can be found it is estimated that a further 1.3GW could be developed in the Thames region.

A.4.4 Severn

Offshore wind development in the Severn region is limited to about 100MW and reference to Figure 26 indicates that further development could be undertaken in the 20-25m sea depth areas off Weston-super-Mare. On the basis that development in this area has not taken place it is assumed that there are significant environmental barriers and possibly technical difficulties due to the high tidal flow and tidal range within the Severn Estuary. Accordingly it is assumed that offshore wind development in the Severn region is limited to the existing 100W.

A.4.5 North East

Offshore wind development in the North East region is limited to about 90MW and reference to Figure 26 indicates that there is little opportunity for further development in the 20-25m depth areas.

A.4.6 Scotland

Offshore wind development in Scotland comprises the 2x5MW Beatrice demonstration project in 50m of water and further development in this area is not foreseen.

A.4.7 Wales

There are no existing offshore wind generation developments off the west coast of Wales but reference to Figure 25 and Figure 26 indicates that there is a significant resource in the 20-25m depth area.. The drawback on developments in this area is the lack of proximity to the onshore electricity infrastructure on which to connect offshore wind generation. Accordingly it is assumed that 2.5GW can be developed off the west coast of Wales noting that connections to the shore may be more expensive than some other options.

A.4.8 Isle of Wight

There are no existing offshore wind generation developments off the Isle of Wight although reference to Figure 25 and Figure 26 indicates that there is a resource in the 20-25m depth area to the south east of the island. However this resource lies in an area of significant merchant shipping and naval activity and it is considered unlikely that significant developments will take place.

A.4.9 Dogger Bank

The Dogger Bank is a major resource located far offshore the North East coast as shown on Figure 26. It is assumed that there will be few restrictions in developing this area therefore it is assumed that the Dogger Bank will make up the balance of 3.6GW to achieve the 2020 scenario total of 22.1GW.

A.5 Scenario 2 – 26.2GW Total Offshore Capacity

In this scenario it is assumed that all regions apart from the Dogger Bank have been fully developed and that the Dogger Bank is developed to 7.7GW to achieve the 2020 scenario total of 26.2GW.

A.6 Scenario 3 – 33.7GW Total Offshore Capacity

In this scenario it is assumed that all regions apart from the Dogger Bank have been fully developed and that the Dogger Bank is developed to 15.2GW to achieve the 2020 scenario total of 33.7GW.

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Appendix B Biomass Power Generation Background

B.1 Resources

The use of biomass involves a wide range of potential fuels of biological origin, which can be converted via a wide range of processes to produce electricity, heat or fuels. In this study we have concentrated on the use of biomass to produce electricity, and have focussed on the most widely available dry biomass feedstocks that can be converted to electricity by conventional and well developed technologies. These technologies are based on combustion and the use of the heat generated to produce steam for use via a steam turbine to produce electricity.

In this section of the report we assume that all available material is channelled to electricity production, and take no account of the potential for heat or CHP production (although in practice there will be competition for fuel for these uses, with biomass use to supply heat for commercial and industrial purposes being the most cost effective use of the resource in any cases). For the purposes of this report we make no allowance for the development and deployment of less well established conversion processes (such as pyrolysis and gasification) nor for the diversion of resources for liquid biofuel production. The use of landfill gas and sewage gas is considered separately in this report.

The principal constraint to an increased contribution from biomass to electricity supply in the UK is considered to be fuel availability, which is constrained by the relatively low quantities of resource available in the UK. The rate at which this is deployed is also principally constrained by issues affecting the development of a fuel supply infrastructure, such as lack of confidence in the sector, which in turn reduces the necessary investment in supply infrastructure (physical and commercial).

There may in principle be other constraints (such as the availability of key conversion process equipment like biomass boilers and suitable steam turbines, and skilled labour for installation, maintenance and operation). However, the maximum rate of deployment which is allowed by material availability means that maximum installation rates are likely to be small multiples of historical levels of activity. So these other issues are likely to be short term constraints, rather than issues which are major barriers to the rate of deployment.

Given that fuel supply is seen as the major rate-determining factor, this analysis concentrates on the three fuel supply sectors, since there are particular issues that will constrain the rate of development of each. These are:

a) Regular biomass (indigenous residues).

b) Imported biomass (currently used primarily for co-firing).

c) Fuel from energy crops.

B.2 Power Generation

The biomass fuels involved can be used to some extent interchangeably in a range of types and scales of conversion systems, which may range from relatively small scale CHP or power only projects (at a scale of a few megawatts or less) to much larger projects which will tend to be power only projects. The largest scale project currently under consideration has a capacity of 350MW, but projects are most typically in the 10-50MW range. Recently a number of plants have been built and brought into operation, with support from the Bio-energy Capital Grants Scheme.

In addition, there is a market for fuels in the UK co-firing market, replacing fuel at a small percentage (typically 5-10%) in large (GW scale) coal fired power plants.

Unlike other forms of renewable energy biomass can be transported, hence the location of biomass projects can be driven by several factors:

a) The availability of power generation assets – mainly an influence on co-firing as conventional coal fired plant will tend to be displaced by renewable generation.

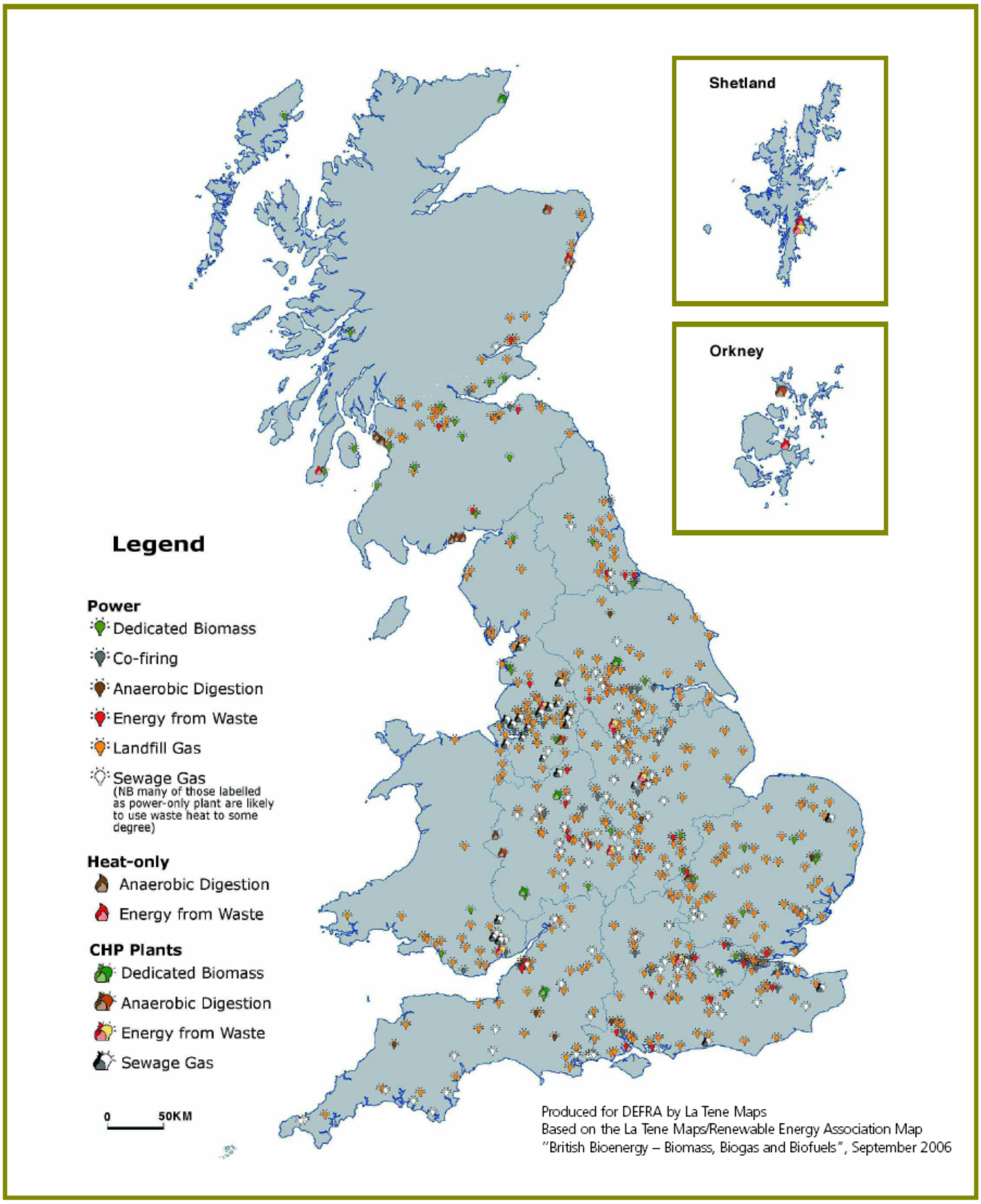
b) The availability of low cost fuel – for example the Lockerbie scheme in Dumfries and Galloway an area of high forest cover.

c) The availability of key transport infrastructure – for example the import of biomass for the Prenergy Port Talbot project.

d) The location of heat loads to increase revenue – for example the UPM paper mills at Shotton and Irvine.

The grid constraints that affect other renewable energy technologies are less relevant to biomass projects as they are less likely to be located in areas with less developed or weaker grid infrastructure. Furthermore biomass projects can take some advantage from the locational signals within transmission pricing.

The following map from the UK Biomass Strategy illustrates the wide distribution of existing power, heat and CHP.



The financial viability of projects tends to improve as scale increases and achievable power generation efficiencies are higher. On the other hand, availability of fuel within a cost effective radius of the plant becomes more of an issue as scale increases. For these reasons smaller scale plants will generally take their fuel supply from relatively local sources (within say 50 km of the plant). Larger scale plant will need to take fuel from a wider catchment area, and it is likely that

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these larger scale operations (for co-firing or power only operation) will tend to be the major routes for the use of imported fuels. New large scale projects may tend to be located close to ports or good transport hubs to facilitate fuel supply.

B.3 Regular Biomass

Regular biomass covers the use of a range of sources of "indigenous" biomass available in the UK including

a) Forestry and sawmill residues

b) Straw

c) Waste wood

d) Other waste products

These are typically by-products from the forest products, agriculture and waste management sectors, and some of the product is already used in some non-energy markets. Use of these products in the energy sector is technically and commercially established, with support available under the Renewable Obligation. This will be enhanced once the proposals to "Band" the Obligation come into force, since biomass projects will be eligible for 1.5 ROC/MWh, or for 2 ROC if CHP operation is possible.

B.4 Biomass Imports

A wide range of types of biomass is currently being imported into the UK particularly for co-firing with coal in large power stations. Fuels include wood chips and pellets, olive and palm residues. This market developed rapidly in response to the large scale and profitable co-firing market, but is now somewhat constrained by caps on the level of non energy crop co-firing eligible under the banded RO. In the medium term the co-firing market will be further constrained as the support available under the RO for co-firing is reduced, and in the longer term by reductions in UK coal fired generation capacity.

Fuel suitable for import for power generation is currently widely available internationally. The 350MW power station discussed above will be entirely fuelled by imported fuel delivered to a UK port. A recent IEA report indicates that there may be over 11 million tonnes of biomass material available for export from Canada alone[32].

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[32] IEA Bioenergy Agreement, Task 40

B.5 Energy Crops

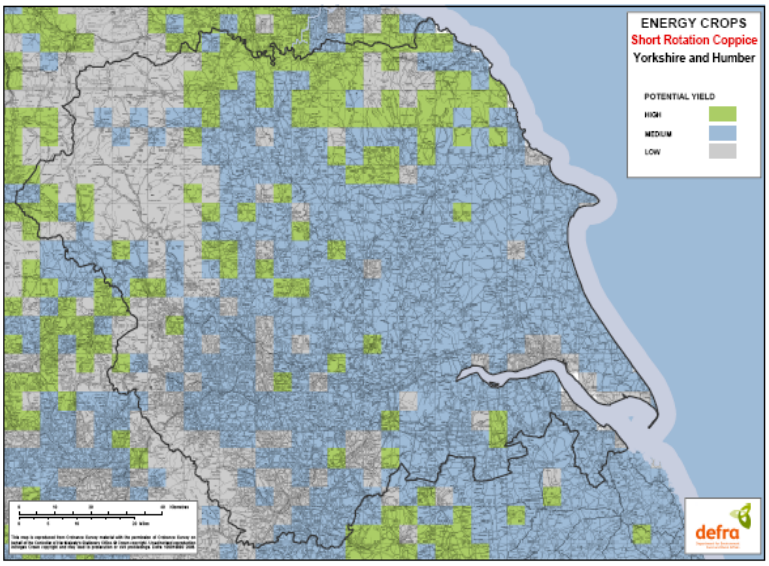
Given the relatively low levels of availability of biomass residues in the UK, some priority has been given to expanding the available resource through the growth of energy crops, principally of short rotation coppice (willow and poplar) and miscanthus.

Willow coppice is planted from cuttings. The first significant harvest is usually 4 years after planting, with further harvesting on a three year rotation. Current yield of around 8 ODT (over dried tonnes)/ha/year of material are being achieved, but improvements in planting stock should push yields up to 10 and eventually 15 ODT/ha/year. The calorific value (CV) of the harvested material is around 17 GJ/dry tonne.

Miscanthus is planted as rhizomes. The crop yield builds up gradually, with the first significant harvest after 3-4 years and then annual harvests, with current yield around 10 ODT/ha/year, with potential to rise to around 15 ODT/ha/year. The CV is around 17 GJ/dry tonne.

Growth of these crops has been encouraged through the availability of grants to reduce the costs of planting the fuel crops (through the Energy Crops Scheme), by making the use of energy crops a condition of some of the projects which have received grants under the Bioenergy Grants Scheme, and by providing for higher levels of incentive under co-firing elements of the RO and in the banding proposals (where dedicated biomass schemes using energy crops will be eligible for 2 ROC/MWh). Current planting rates are low, because of uncertainty about the marketability of the fuel, the high prices being achieved for other agricultural products, and the recent changes to the Energy Crops Scheme. However Drax Power have contracted for the supply of 300,000 tonnes/year of miscanthus which will be developed over the coming years.

Defra have produced a series of regional maps to provide guidance to those seeking to develop energy crops. They show the best areas for growing the crops plus the areas where this is not appropriate or care would need to be taken from an environmental point of view. The following example identifies areas where high, average and low SRC yields may occur in Yorkshire & Humberside.


ENERGY CROPS
Short Rotation Coppice
Yorkshire and Humber
POTENTIAL YIELD
HIGH
MEDIUM
LOW
defra