Hydro Power Projections Report

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Abstract-
The purpose of this report is to assess the current and future role of hydro power in the UK energy supply market. The historical trends and barriers to potential increase will be explored to aid projection estimates up until the year 2030. It is a preliminary report, which will be amended after consideration of all types of renewable energy promotion in the UK, with regards to the allocation of a £40 billion budget.

Introduction

As demand for energy in today's modern society continues to increase, it is becoming ever more apparent that the current reliance on fossil fuels is unsustainable. Dwindling resources and the associated detrimental environmental effects of fossil fuels, primarily the resulting release of carbon dioxide and its relationship with climate change, are turning the heads of global governors to find cleaner alternative sources of energy.

The UK energy white paper, published in February 2003[1], set out a clear vision and intention to promote sustainable energy. It re-affirms a target for renewables to supply 10% of the UK's electricity by 2010 and an aspiration of 20% by 2020. The government is also targeting a 60% reduction in CO_2 emissions by 2050. Widespread deployment of renewable energy is accepted as a major contributor to the reduction of greenhouse gas emissions. A major advantage of renewable sources is their reduced or lack of emissions or waste. Therefore they can make a major contribution to a more sustainable energy mix (Wolfe, 2004).

Hydro power is a fully commercialised renewable source of energy that has been active in the UK since 1896. It is the utilization of energy available from water flowing in a river or in a pipe, usually from a purpose built dam and reservoir. Energy is generally extracted by using the power of the running water to turn turbines of generating sets in power stations. In the UK hydro power is split into two categories, large and small scale. These are differentiated by the size of the installed capacity. Large scale hydro is a scheme of 5MW or above while small scale is those below 5MW. Large scale in the UK primarily uses damming and reservoir techniques where small scale can also utilize the natural flow of a river. There is also the field of micro hydro, schemes consisting of a few tens of kW. These are not included in national statistics because of their relatively small output and are generally not connected to the national grid.

Within the UK there is little scope for further development of large scale hydro because of the costs and concerns about its environmental impact. The good quality most financially viable sites have already been utilized or lay in protected regions in the highlands of Scotland or Snowdonia, Wales. Therefore this report will focus on the growth of small scale hydro electric production. This report aims to give a brief overview of the current UK position on hydro power as a resource. This is followed by the encountered barriers to implementing schemes. The methodology and assumptions used for the subsequent projections are explained and finally costs are taken into account.

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[1] DTI. White Paper. http://www.dti.gov.uk/energy/whitepaper/wp_summ.pdf

UK Current Position on Hydro Power as a Resource

Currently 2% of the UK's installed generating capacity is supplied by hydro almost all of which is in Scotland and Wales[2]. This is around 50% of the total renewable contribution. In 2003 the DTI reported an installed capacity of 202.9 MWe of small scale hydro power operating from approximately 120 sites providing a Declared Net Capacity (DNC) of 73.5 MW [3]. There is an estimated 400MW (Paish, 2002) to 700 MW (DTI, 1994) of unexploited small scale resources in the UK, approximately 80% of this is in Scotland.

Positive environmental policies such as the renewable obligation are now being backed by favourable tariffs for 'green electricity'. Hydro power is eligible for a renewable obligation certificate and grants are available (contributing up to 50%) for economic viability studies of potential sites, making an increase in hydro generation more attractive.

The governments programme for small scale hydro power has been focused on the stimulation of the wider up-take of existing commercially available small scale hydro in relevant market sectors, including water companies, industry and private individual operators. They also recognise the potential for development in smaller sites, disused mills sites, retrofit to water storage and water supply facilities.

Barriers to Small Scale Scheme Implementation

Hydro electric power can be regarded as being fully commercialised. Although regarded as a 'proven' technology, developments continue on all design aspects, such as new materials, improved construction techniques, and better appropriate ancillary systems. Due to the age of the industry most barriers which could limit growth in hydro power supply are non-technical. A study of the non-technical barriers was carried out by the government in 1994 (DTI 1994). The most prevalent obstacles identified were; initial financial outlay and lack of technical and procedural knowledge by developers.

Developers must not only have the initial financial outlay for the build, but also for feasibility studies on economic viability and environmental impact of a potential site. They must invest in detailed analysis and expensive hardware to prevent adverse effects on fishing; they have to counter a range of perceived conflicts with river based leisure interests, and prove that there will be no impacts to the river bed, river banks, flora and fauna, land drainage, or the ability to remove flood waters. All theses barriers have a sound basis and can be overcome by good scheme design, but at a cost and time delay which can make a project unviable (Paish, 2002). Costs are considerably reduced if existing engineering works can be used and there is a government grant available of 50% contribution towards viability study costs.

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[2] EREC. Renewable Energy Policy Review-UK
http://www.erecrenewables.org/documents/RES_in_EUandCC/Policy_reviews/EU_15/UK_policy_final.pdf

[3] DTI -Digest of United Kingdom Energy Statistics.
http://www.dti.gov.uk/energy/inform/dukes/index.shtml

The lack of technical and procedural knowledge for small scale hydro power on the part of developers has been identified on issues such as planning requirements, electricity sales and identifying potential sites. Planning and technical guidance documents have been produced by the government.

Other barriers effecting increase in hydro generation include:

- Difficulties in gaining affordable connections to the grid are also common, although this situation is tending to improve.
- Many sites in remote location resulting in transmission line complications.
- Gaining permission to occupy land (Ownership of potential sites) and abstract water from a river, sometimes due to multiple ownership of land, fishing and water extraction rights.
- Site specific technology, areas where water power can be exploited are not all that common.
- River flows often vary considerably with the seasons; this can limit the firm power output to quite a small fraction of the possible peak out put.
- There is a maximum useful power output available from a given hydro power site, which limits the level of expansion of activities which make use of the power.
- Few environmental impact issues relating to reduced oxygenation of the water, erosion immediately down stream of the turbine tubes, electrical machinery noise, general hydrological, habitat and sediment changes and the general appearance of an installation. Though not nearly on the scale with a large scale instalment.
- Turbines need to be protected from debris that is commonly found in rivers. The hydro-plant operator is prohibited by law from disposing of the rubbish collected on his screen back into the river. Garbage disposal by a hydro installation can serve to clean up a river for the benefit of everyone downstream, but at the considerable expense of the operator.

Most of these barriers evolve from lack of communication. Better organisation and availability of educational information could combat most circumstances and should not be accepted as long term preventative problems. Other problems presented are capable of being mitigated by using simple design techniques. The end product is a long lasting (30+ years), reliable and potentially economical source of clean energy. With short term investment and strong commitment it should be relatively easily overcome such barriers and is well worth the outlay.

Method of Estimating Projections

Projections for large and small scale energy growth were calculated separately. This is due the lack of potential growth in large scale and the differences in load factors for each technology. Load factors were determined using the installed capacity and the electricity generated figures from the Digest of UK Energy Statistics (DUKES).
Calculations were as follows and results appear in table 1.

Calculation example - small scale load factor for 1999;
Figures from DUKES 2004
Installed capacity = 176.7 MWe
Generation = 207 GWh (*1000 = 207,000 MWh)

Installed capacity * Hours in a year = Total maximum output

176.7 * 8760 =1,547,892 MWh

Generation / Total max output * 100 = Load factor

207,000 / 1,547,892 * 100 = **13.4%**

Table 1- Load Factors

Year	Large Scale Load Factor	Small Scale Load Factor
1999	41.4	13.4
2000	39.2	13.3
2001	30.5	12.7
2002	37.5	12.0
2003	25.5	6.5
Mean	34.8	11.6

The next stage involved examining the historical rates of annual increase within the DNC figures over the last 13 years. In recent years there has been a decline in large scale DNC due to fluctuations in precipitation. Small scale DNC has risen with an average of 3.1 MW (0.056 PJ) annually. These average increases were assessed (and where relevant) manipulated to estimate future projections in the following section. For small scale, these were used to gain an initial understanding of potential, projections were manipulated further with regards to barriers.

Projection figures were estimated on the DNC figures in MW this was then converted as follows;

Projected value (MW) * load factor *hours in a year = MWh

X MWh * 3.6 / 1,000,000 = X PJ

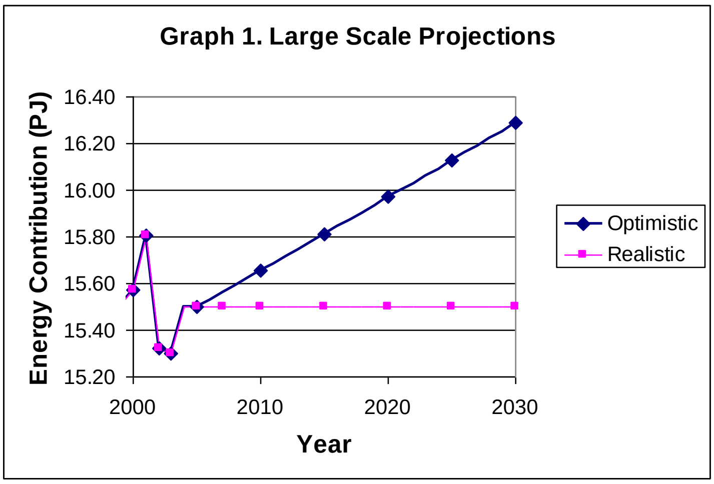
Projections & Assumptions

Large scale

Previously mentioned economic and environmental constraints limit the development of the remaining resource of large scale hydro power in the UK. There is only one large scale site proposed for the foreseeable future, that of the Scottish and southern electricity's 50-100MW capacity facility at Glendoe, Inverness-shire in Scotland[4]. This is yet to be approved and has no conformation on size therefore it is not included in the projections; the assumption being that there will be no *significant* new large scale power stations. It is also quite feasible to presume that this stations contribution could take the place of a station that may be retired in the future, considering this would be the first large scale instalment for 40 years. There is no literature confirming the decommissioning of any stations, as long as geology remains stable the component parts, such as turbines, are replaceable. There is also potential increase in efficiency and production by way of upgrades to these component parts. This is an assumption in the optimistic scenario on graph 1 on the following page. The optimistic scenario produces an unconventional linear increase; this is due to the

[4] SSE – Power from the Gleans. http://www.scottish-southern.co.uk/pftg/popups/HydroStationPlan.htm

method of projection, assuming a 1% increase over every five year period allowing for upgrades in technology. It is more likely that the increase will no be so uniform.

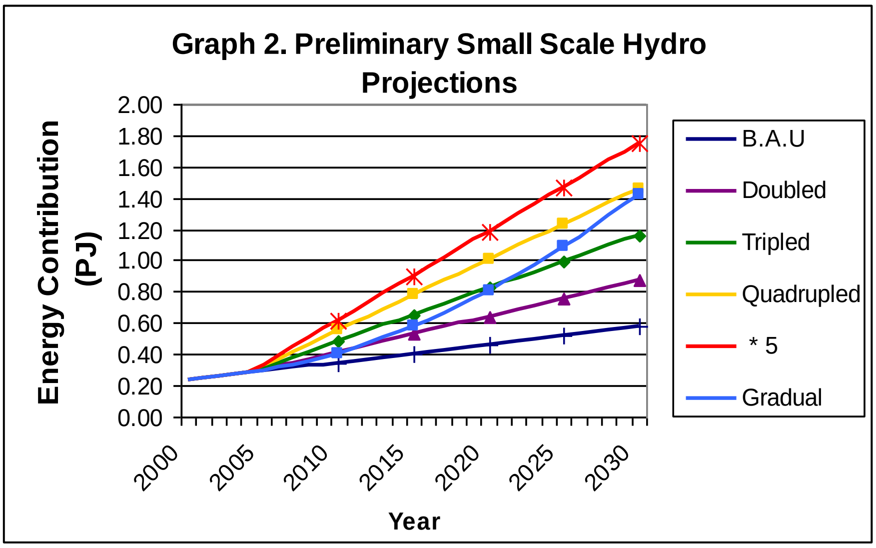


Other assumptions include that the load factor will remain the same as past analysis of 34.8% (this average was also used for all years pre 2004), and that there will be fluctuations due to annual precipitation that are not projected. The realistic scenario assumes that the average DNC figure (15.50PJ) over the past five years will be the norm.

These figures do not include pumped storage stations as their net output can be quite negligible due to energy required for pumping. These stations tend to be used for peak lopping rather than as net contributors. Detailed figures and combined projections for both small and large appear in the summary table at the end of the report.

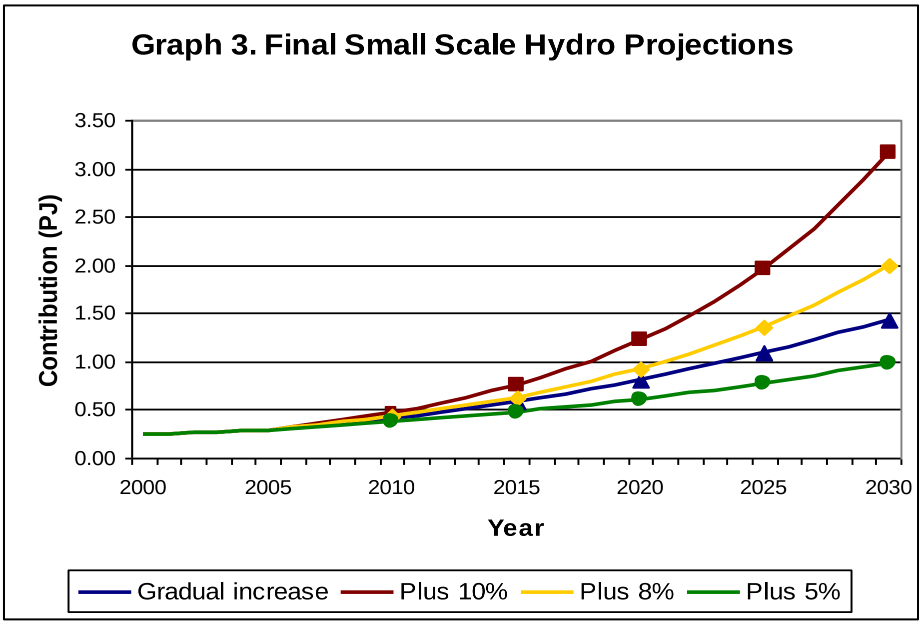
Assumptions and Projections- Small Scale

Assumptions for small scale projections include that planning and technical guidance is improved and available to developers, active advertising and promotion of small scale is increased and financial assistance for viability assessments is available. Again it is assumed that the past analysis of load factors is correct, average 11.6% (although this could be vastly improved on). As projections are based on manipulations of historical rates of increase it is assumed that this has not already reached its maximum. It is also presumed that there will be no change of rate of increase for the first three years in preparation for the accelerated programmes.



Preliminary projections (graph 2) are based on the historical average rate of increase, 0.057 PJ yr^{-1}. The scenarios start with business as usual with no increase in the rate of increase. There is no reason with the current way of thinking for projecting any decrease in contribution, therefore the business as usual scenario would be the most pessimistic. All other projections are based on doubling, tripling, quadrupling or even multiplying the current rate of increase by five 5. The main obstacle to the applicability of these projections is the linear nature. For example in the *5 scenario the initial leap of from increasing 0.057 PJ per year in 2005 to automatically jumping to 0.284 PJ increase in a year would be challenging to say the least. This is why the gradual increase option was included. This works on the basis of no change until 2005, then for the next five years, annual rate of increase is double the original annual average to 0.114 PJ yr^{-1}. After another five year period the 2004 average is tripled for the next five year period and so on resulting in a gradual increase.

After examining the historical data and getting a rough idea of achievable figures for 2030, it became apparent that the current rate of increase is very low considering the barriers and available resource. Using the previous figures to gain a ball park area, the final decided projections are based on a percentage increase of the previous yearly figure (Graph 3).



The gradual increase is included in these figures as it is still a realistic scenario; all assumptions remain the same previous figures. Projections were achieved by increasing the next years DNC by a percentage of the previous years DNC, example calculation for figures;

Year X / 100 * 10 (or 8 or 5) +Year X = Year Z (next years figure)

A summary table including the combination of small and large scale figures follows. Large scale figures used are that of the realistic scenario, as this is what I feel is most likely, mainly due to precipitation fluctuations and increased production through upgrading parts may prove negligible if any aging plants are decommissioned. Figures for all scenarios for small scale are provided

Table 1- Summary table

Scenario	Projections by Year					
	Current (2003)	**2010**	**2015**	**2020**	**2025**	**2030**
Plus 10%						
Small scale	0.27	0.47	0.76	1.22	1.96	3.16
Large scale	15.30	15.50	15.50	15.50	15.50	15.50
Total	**15.57**	**15.97**	**16.26**	**16.72**	**17.46**	**18.66**
Plus 8%						
Small scale	0.27	0.43	0.63	0.92	1.36	2.00
Large scale	15.30	15.50	15.50	15.50	15.50	15.50
Total	**15.57**	**15.93**	**16.13**	**16.43**	**16.86**	**17.50**
Plus 5%						
Small scale	0.27	0.37	0.47	0.61	0.77	0.99
Large scale	15.30	15.50	15.50	15.50	15.50	15.50
Total	**15.57**	**15.87**	**15.98**	**16.11**	**16.27**	**16.49**
Gradual Increase						
Small scale	0.27	0.40	0.58	0.80	1.09	1.43
Large scale	15.30	15.50	15.50	15.50	15.50	15.50
Total	**15.57**	**15.91**	**16.08**	**16.30**	**16.59**	**16.93**

Costs

Costs were estimated on the basis of an investment cost of £1000/kW and operation and maintenance costs of £30/kW/year (Paish, 2002 & Jackson, 1993).

Table 2 – Estimated Cost of Scenarios

Scenario	Cost per Time Period (£'s per Stated Years)					
	2004- 2010	**201 - 2015**	**2016 - 2020**	**2021 - 2025**	**2026 - 2030**	**Totals**
Plus 10%						
Instalment	54,900,000	78,400,000	126,000,000	203,000,000	327,000,000	789,300,000
Maintenance	20,700,000	25,900,000	41,600,000	67,100,000	108,000,000	263,300,000
					Total	**£1,052,600,000**
Plus 8%						
Instalment	43,600,000	55,000,000	80,800,000	119,000,000	174,000,000	472,400,000
Maintenance	19800000	22300000	32700000	48100000	70600000	193,500,000
					Total	**£665,900,000**
Plus 5%						
Instalment	28,200,000	28,100,000	35,900,000	45,800,000	58,400,000	196,400,000
Maintenance	18,600,000	17,700,000	22,600,000	28,800,000	36,800,000	124,500,000
					Total	**£320,900,000**
Gradual Increase						
Instalment	37,200,000	46,500,000	62,000,000	77,500,000	93,000,000	316,200,000
Maintenance	19,400,000	20,700,000	29,100,000	39,900,000	52,900,000	162,000,000
					Total	**£478,200,000**

Estimation method examples- *Instalment costs*;

2000 DNC figure – 1999 figure * 1000 (to get kW) * £1000
This was done for each annual increase.

Maintenance costs

Yearly DNC Figure * 1000 (kW conversion) * £30

This was done for each annual figure and added together for displayed time periods.

Instalment cost and subsidies can vary greatly because each hydro site is unique. Since 75% of the development cost is determined by the location and site conditions. 25% is fixed, being the cost of the equipment. Estimations do not include feasibility studies. They also do not include any subsidies that are in place for the production of hydro power. Hydro power is also eligible for renewable obligation certificates thus reducing the overall cost of production further. None of these are taken into account so that this figure can be taken as a maximum amount. These figures would also need to be added to the maintenance costs of large scale hydro for an overall figure.

However, with the most optimistic scenario coming it at a total maximum of around £1 billion, these figures seem most reasonable in comparison with other renewables.

Conclusion

Where a hydro power resource exists, experience has shown that there is no more cost-effective, reliable and environmentally-sound means of providing power than a hydro power system (Paish, 2002). For this potential to be realised it will require significant efforts and resources allocated towards, loan finance for site-owners and developers, technical support to developers and training in site identification, operation, maintenance, and repair and business management.

With such available potential and such a reasonable investment cost, compared to alternative renewable technology, it is hard to understand the current government's apparent lack of interest in this relatively mature technology. I would recommend that the scenario of an annual increase of at least 8% is adopted for small scale generation. There is an opportunity to out perform this scenario but at the same time it is not being overly optimistic.

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