Hydro Power
Technology Overview 2007
September 2008

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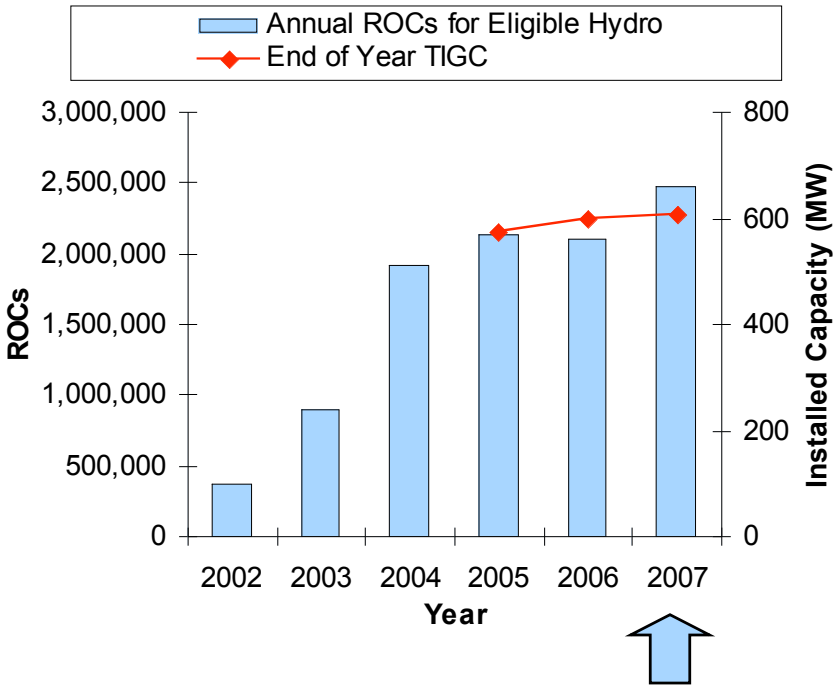
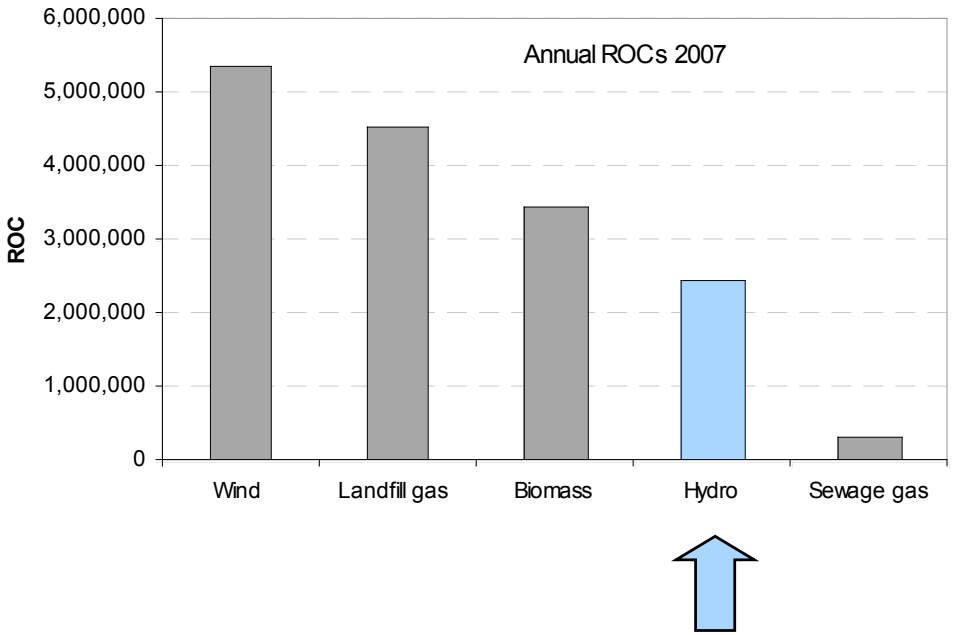
Hydro Introduction

- Renewable Obligation data has been downloaded from the Ofgem web site (see Appendix A) and the data used to generate a summary on the performance and growth of hydro plant under the RO scheme.



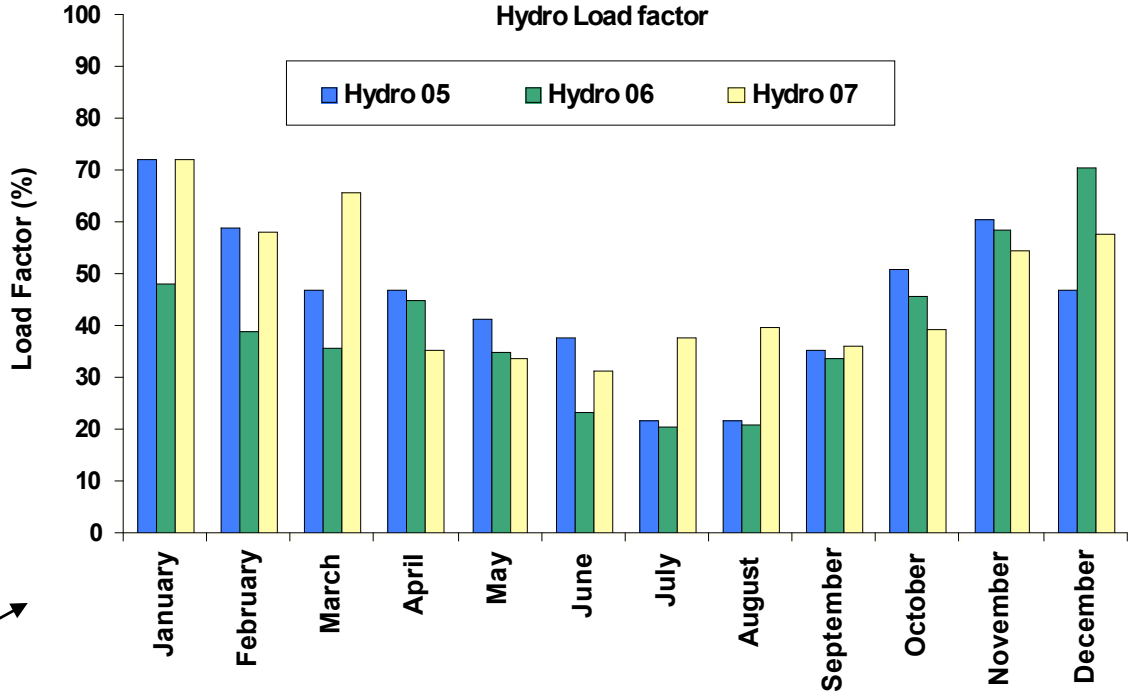


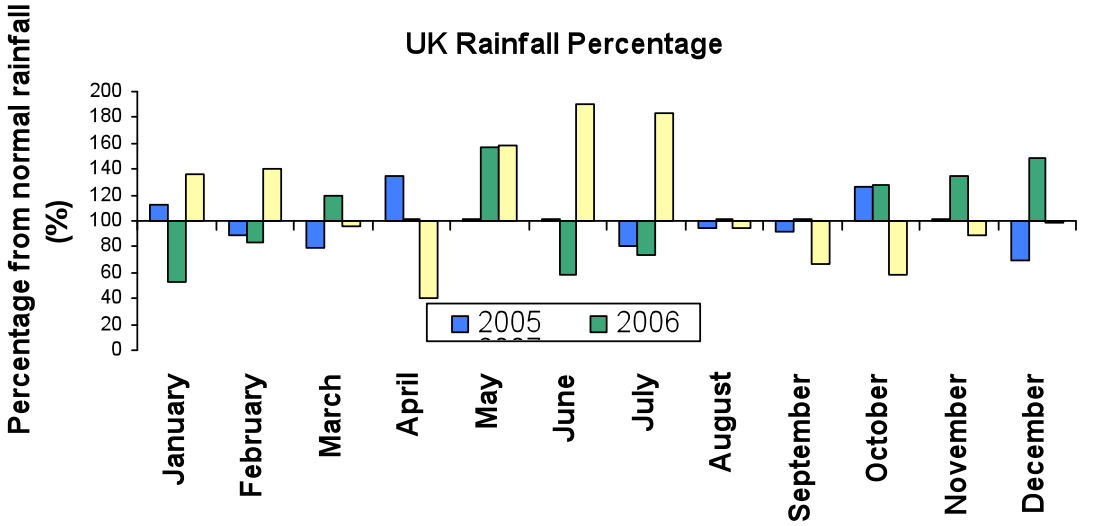
- Claimed Hydro ROCs have increased by 176% since the first full year of the RO in 2003, rising from 0.9 to 2.5 million ROCs
- Installed capacity registered (year end total installed generating capacity, TIGC) has increased from 598MW to 606MW between year end 2006 and year end 2007

- Hydro claimed the second least ROCs in 2007. It should be noted that large hydro plants (> 20MW) will have contributed much more than this but are not eligible for ROCs

Monthly Load Factor Plots

- Graph of Load Factor by month for the whole UK eligible sector < 20MW installed capacity
- Summing the months gives the National Annual Hydro Load Factors (for the 'valid data set' – see Appendix A) which are:
  - 2005: 45.2%
  - 2006: 39.9%
  - 2007: 46.7%
- Hydro power is strongly affected by the weather.
  - Note how January 05 and Jan 07 was much better than January 06. This is explained by the low rainfall in January 06 (MetOffice[1])





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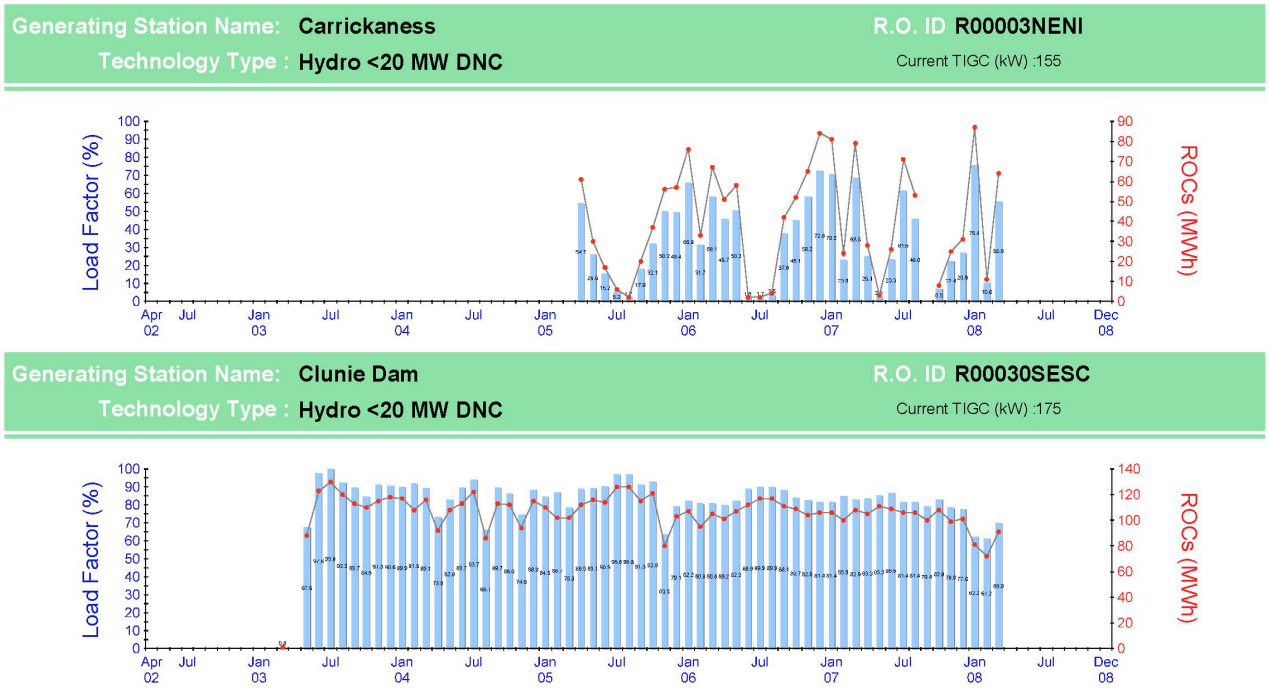
1. MetOffice Past UK Weather http://www.metoffice.gov.uk/climate/uk/index.html

Seasonal Variation and Storage Capacity

- The effect of seasonal variation in hydro power production can be minimised by having storage capability – by means of a dam
- Carrikaness station in Northern Ireland shows strong seasonal variation due to run of river nature of the plant
- Clunie station in Scotland shows steady monthly power output due to the presence of a dam, but the natural ebb and flow of the river will be altered



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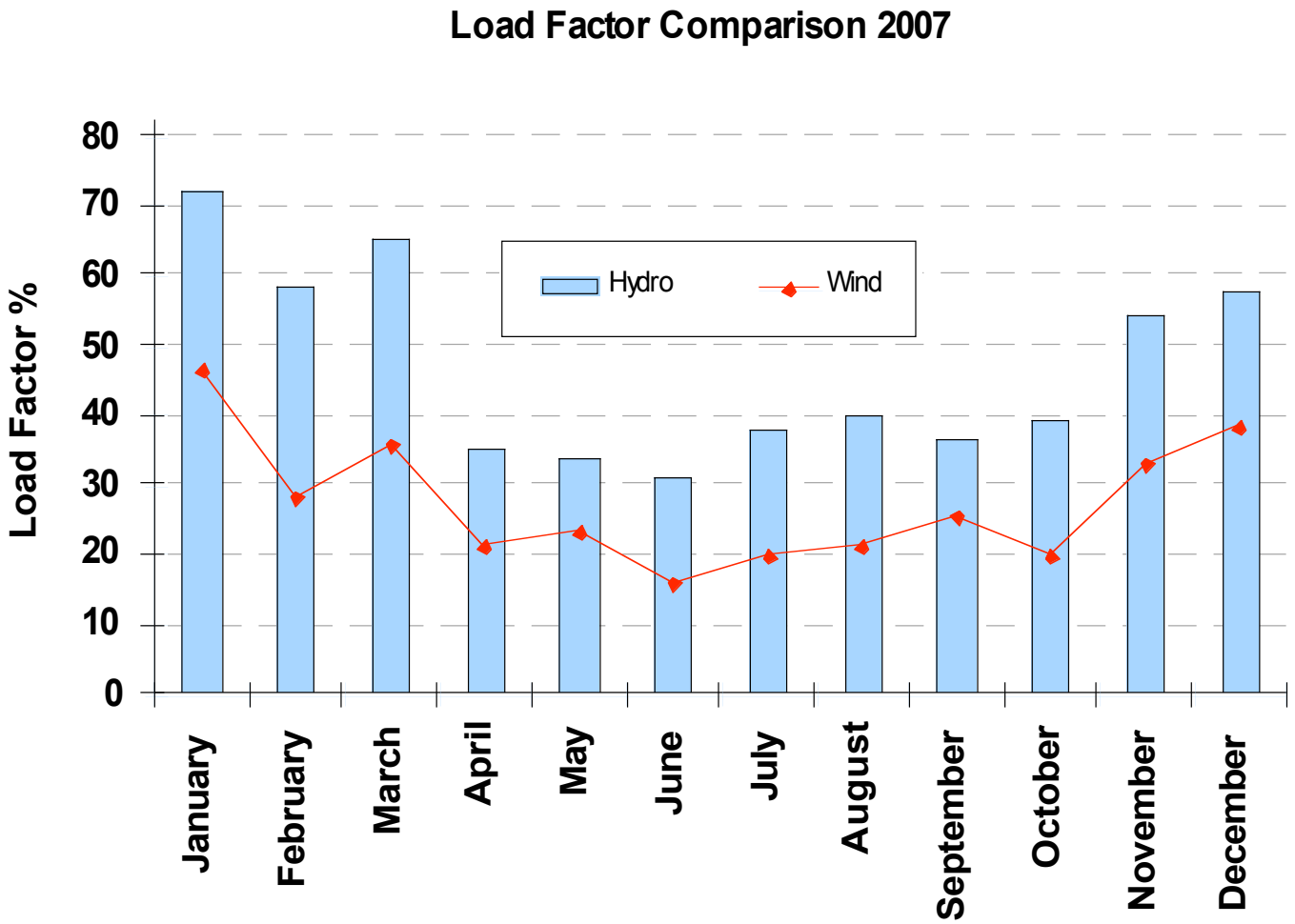
1. Clunie Damn Photograph from http://www.geograph.org.uk/photo/279864, licensing under creative commons http://creativecommons.org/licenses/by-sa/2.0/

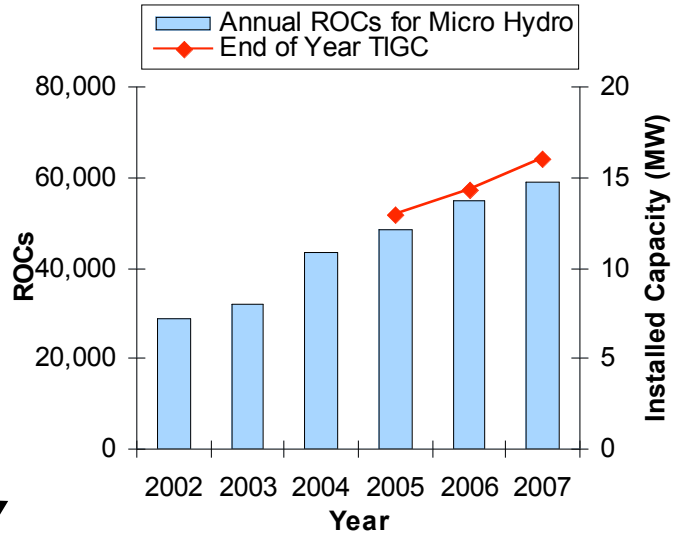
Wind and Hydro are Weather Dependent Renewables

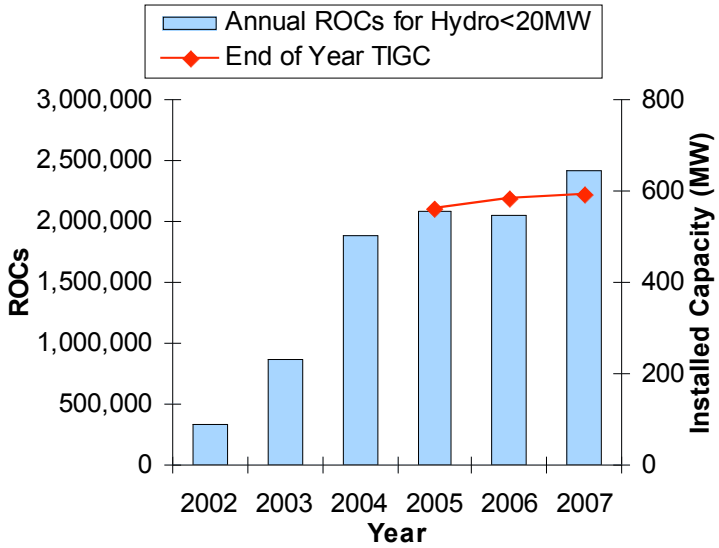


- Hydro plant shows a similar seasonal variation to wind – lower in the summer
  - Both wind and rain are dependent on low pressure weather systems moving across the country and these are weaker/fewer in summer

Micro Hydro Compared to Hydro <20MW

- To qualify for ROCs hydro plants must be less than 20MW. The sector is split into two groups:
  - Hydro < 20MW
  - Micro Hydro < 1.25MW (see Appendix B.1 for detailed definition)
- The total Installed Capacity for "Micro hydro" was only 16MW at the end of 2007, compared to "Hydro < 20MW" at 590MW





Conclusions

- There was a 176% increase in hydro station ROCs claimed in 2007 compared to 2003 (the first full year of the ROC system):
  - 0.9million ROCs in 2003; 2.5 million ROCs in 2007
  - Total number of hydro plants claiming ROCs in December 2007 was 218 compared to 186 in December 2005
- Hydro power output is dependent on the weather and strong variations occur. For example Jan 2006 provided 36% fewer ROCs than January 2007.
- Comparison of hydro load factor with that of wind shows a strong correlation (low pressure weather systems bring both wind and rain), limiting the degree to which hydro (without dams) can act to balance wind generation.
- This weather based variation can be smoothed by the use of dams and proper water flow management. However, this may interfere with the natural ebb and flow of rivers and effects wildlife and other river users. Contemporary environmental restrictions limit the future building of dams, which limits the economic return for significant new hydro plant.

Appendix A – Data, methods and calculations

1. ROCs & Ofgem
2. Data: ‘The Valid Set’
3. Load Factor & Installed Capacity

ROCs & Ofgem

- Renewable Obligation Certificates (ROCs) are granted for each MWh of electricity produced by an accredited renewable generator in the UK. The administration of the Renewables Obligation is conducted by Ofgem. Each ROC has a value to its owner and can be sold or traded. The average value of each ROC sold at auction in July 2008 was £53.27/MWh (see Non-Fossil Purchasing Agency Ltd http://www.nfpa.co.uk/).
- Ofgem publishes raw ROC claims data in their ROC Register and this can be accessed through their web site at:
  - https://www.renewablesandchp.ofgem.gov.uk/Reports/ReportManager.aspx?ReportVisibility=1&ReportCategory=0
  - While Ofgem publishes a valuable annual report on the RO, they do not summarise or interpret this data on a station by station basis, and the work here aims to present this data in a fair and concise way and then draw conclusions on the performance of the established renewables industry in the UK.
- Total Installed Generating Capacity:
  - For the purposes of this summary all RO data for renewable generation “stations over 50 kW” was downloaded from Ofgem in December 2005, May 2006, March 2007 and then monthly up to May 2008. This provides a complete set of ROCs from 2002 to December 2007 and also a detailed account of changes in total installed generating capacity (TIGC) for each generating station. This was downloaded from their website:
  - http://www.ofgem.gov.uk/Sustainability/Environmnt/RenewablStat/Documents1/Accreditation_**OVER50kw**.xls
- Cleaning up the data:
  - Once downloaded, it was found that some generators show duplicate entries for a month. Ofgem advised us that some accredited sites split their monthly ROCs for commercial reasons. They advised us to sum the monthly ROC values for these sites to obtain the total ROCs claimed for the site. Other records have been tidied such as removing revoked ROCs.

Data: ‘The Valid Set’

- The aim of this report is to fairly represent the performance achieved by generators in the UK, compare these and draw conclusions.
- With this in mind it has been decided to:
  - Exclude generators which were under construction during 2007 as these would have an unrepresentatively low output. This has been done by only including generators which first claimed ROCs prior to January 2007.
  - Exclude generators which were repowered during 2007. This was done by only including generators which had not changed the value of installed capacity during 2007, as recorded by Ofgem
  - Generators which pass both tests are termed ‘the valid set’ and are used to calculate Monthly and Annual Load Factors for the particular technology.
- Note that a generator which generates ROCs at the beginning of the year but suffers a failure later in year will be included in the valid set. This means the performance data such as National Annual Load Factor registers loss of availability.

Load Factor & Installed Capacity

- Load factor is the proportion of energy produced over a time period compared to the energy which would be produced if operating continuously at full power, e.g:

$$\text{Monthly Load Factor} = \frac{\text{MWh produced in month}}{\text{number of hours in month} \times \text{installed capacity}}$$

  - e.g. for a 10 MW generator which produced 3,000 MWh
    - LF = 3,000/(10 x 31 x 24) = 40.3%.
  - Load Factor is a clear and convenient way to summarise the output of a generator over a given time period such as an hour, a month or a year

- Total Installed Generating Capacity (TIGC)
  - The installed capacity for each generator was obtained from the Ofgem list of accredited RO generators which was downloaded from Ofgem web site in December 2005, May 2006, March 2007, and every month thereafter until May 2008. This provided the installed capacity recorded for each site on that date. It has not been possible to obtain the levels of installed capacity prior to May 2006 and so this capacity has been assumed to exist prior to that date. Best endeavours have been made to cross check the installed capacities with generators.

Appendix B – Description of the Technology

1. Description of the Technology
2. Operational Summary
3. Types of Hydroelectric Stations

Description of the Technology

- Hydro power is created by allowing a flow of water from a higher level to a lower level through a turbine where the potential energy of water is transferred to kinetic energy and the turbine drives a generator to produce electricity.

- The general rule for calculating power from hydroelectric plant:[1]

  Power = head × flow × gravity acceleration × efficiency.

  flow = the volume of water that can be captured and redirected to turn the turbine generator

  head = distance the water will fall on its way to the generator

- There are four types of turbines:[2]

  1. High head - above 100m
  2. Medium Head - 20m to 100m
  3. Low Head - 5m to 20m
  4. Ultra Low Head - below 5m

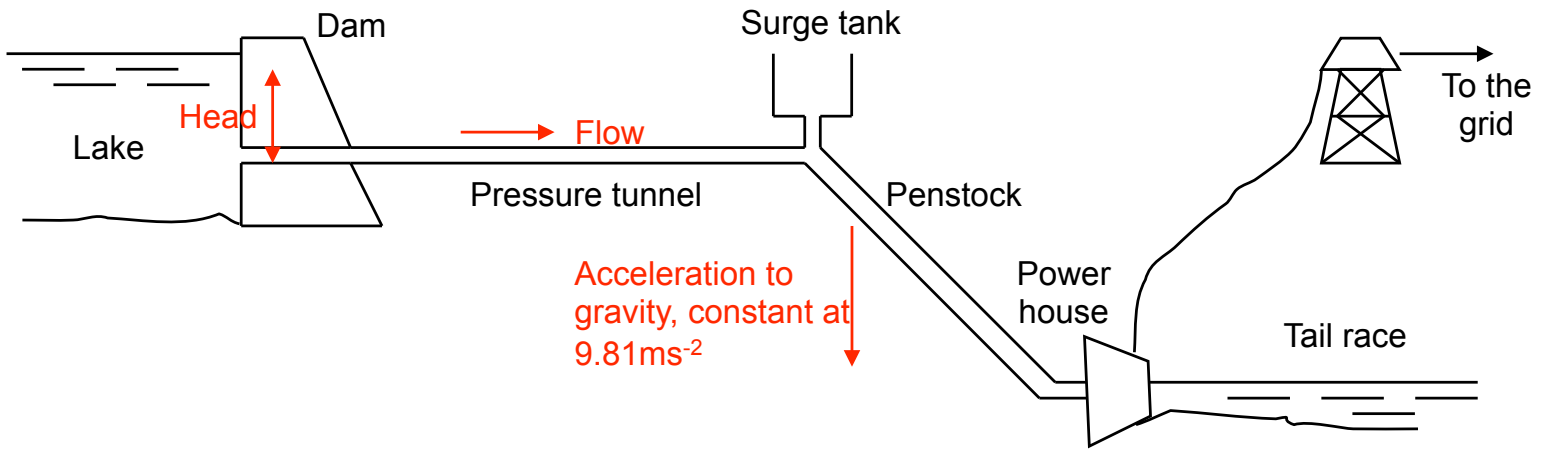
- The Renewable Obligation (RO) only accepts hydro generating stations which have or have had at any time since 1st April 2002, a declared net capacity (DNC) of 20 MW or below.
- The hydro generation plants in the UK that are entitled for ROCs (Renewable Obligation Certificates) are divided into two main categories by OFGEM (Office of Gas and Electricity Markets):

1. Micro hydro[3] (49 sites)
   - Micro hydro generating station means a hydro generating station that has a DNC of 1.25 MW or less and has always been in private ownership and operation and has never generated electricity under a Non Fossil Fuel Obligation (NFFO), Scottish Renewables Obligation (SRO) or Northern Ireland NFFO (NI NFFO) contract.
2. Hydro < 20MW DNC (172 sites)
   - All other Hydro sites <20MW (Hydro sites >20MW are not eligible)

- Energy White Paper 2007 proposed that as from from 1st April 2009, hydro is to remain on a banding of 1 ROC/MWh

1. Jog M.C., Hydro-Electric and Pumped Storage Plants,1988, John Wiley and sons
2. http://www.british-hydro.org/
3. Renewables Obligation: Guidance for generators over 50kW www.ofgem.gov.uk/Sustainability/Environmnt/RenewabelObligations

Operational Summary



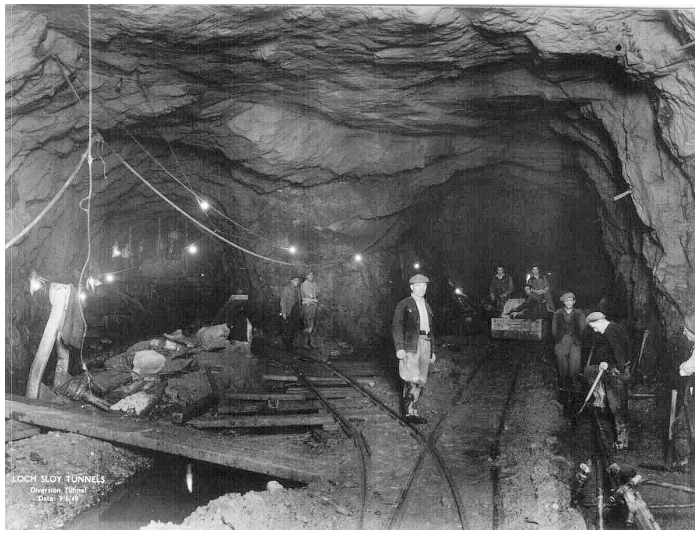
- The Dam: constructed on the river course resulting in an increase in the upstream water level due to the reservoir formation.
- The dam is built so that the reservoir will have sufficient volume of water for energy production from one season to the other (i.e. water is collected in the reservoir during winter for usage in the summer when rainfall is low).
- The Pressure Tunnel and/or penstocks are used to carry water from the reservoir to the power station (flow control valves and surge tanks – act as a pressure relief valve).
- The Power House accommodates the turbines, generator and the control equipment and sometimes the transformers.
- The Tail Race is simply the water after passing through the turbine and when discharged into the river itself.

Jog M.C., Hydro-Electric and Pumped Storage Plants,1988, John Wiley and sons

Types of Hydroelectric Stations

- Three Types
  - Baseload from reservoirs
  - Peaking from reservoirs
  - Peaking – Pumped storage
- All hydro plants (< 20MW) claimed 2.46 million ROCs in 2007
  - Plants over 20 MW can not claim ROCs
- The potential for growth is limited by environmental restrictions on the diversion of waterways

Loch Sloy tunnelling 1947



Sloy Power Station (> 20MW)

Four cast iron pipelines convey water down the steep hillside to the turbines.

The tailrace pool into which water from the turbines is discharged.