A LAYMAN'S GUIDE TO

SMALL HYDRO SCHEMES IN SCOTLAND

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GENERAL INFORMATION ABOUT HYDRO TECHNOLOGY

General

Hydro electric schemes are the largest contributor of electricity from renewable sources worldwide and it is estimated that 20% of the world's electricity is generated from such schemes.

Scotland's wet climate and mountainous terrain, especially on the west coast, means it is well placed to make use of the technology on a large scale. Currently 10% of our electricity is produced from hydro power and most of the large hydro schemes in Scotland were constructed during the period from the 1930s to the 1950s. Whilst one major scheme is still being constructed at Glendoe most schemes to be developed in future would be in the range of 100 – 1500 kilowatts)kW. Schemes of less than 100Kw may still be developed; mainly for domestic consumption and the selling of any surplus electricity to the grid where possible. Hydro schemes may be classified as either 'impoundment' or 'run of river'. The majority of Scotland's large hydro stations are based around the use of a dam and impoundment reservoir.

Impoundment schemes have an advantage over other renewable energy technologies in that using a dam or weir to store water in a reservoir means it can be used when it is needed most.

Run of River schemes normally divert water from a river by the building of a diversionary weir which diverts water from a river into an intake which then passes through a generator and the water is returned some distance down the river. Hydro power is produced by simply using a body of moving water to turn a turbine. This is normally achieved by passing the water down a closed pipeline or through a closed culvert which then turns the turbine and the revolutions of the turbine convert mechanical energy through the generator into electricity.

Initial Considerations

Generation potential of a site is dependent on three overriding factors – the head, the flow of water available and the rainfall characteristics of the site.

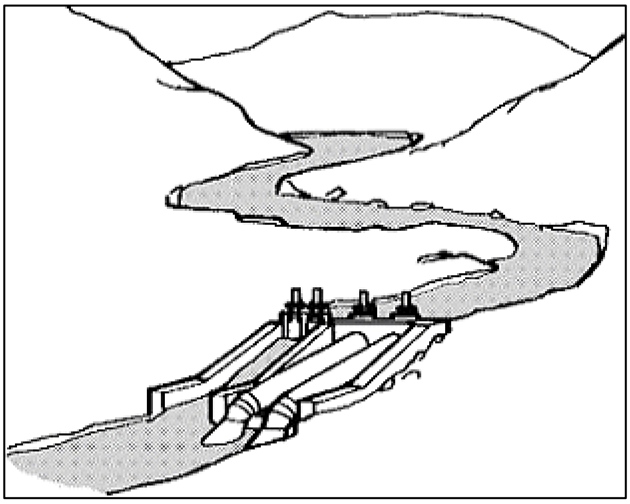
The head of water refers to the vertical distance from the intake at the top of the scheme and the floor level of the turbine at the bottom of the scheme. The flow of water is normally expressed in cubic metres per second or litres per second and refers to the quantity of water used by the scheme to turn the turbine. Water availability must be accurately measured before calculations regarding cost, compensation water availability and the energy generation potential of a scheme can be calculated.

High head schemes would normally be associated with an impoundment reservoir, impoundment can also be used for low head schemes. While it is possible to develop a high head run of river scheme they are more usually associated with low heads.

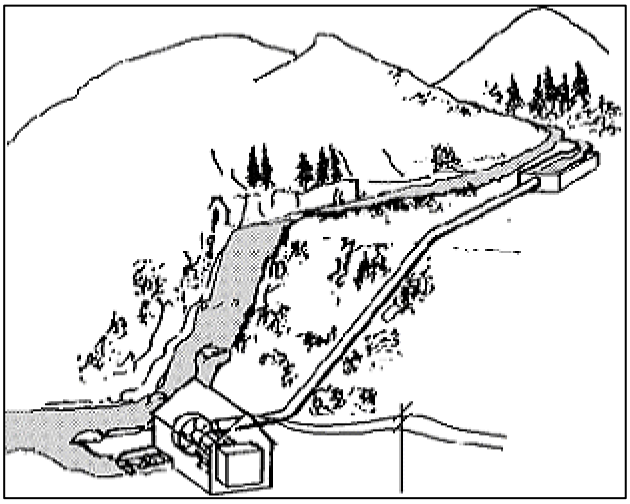
As mentioned earlier, hydro technology has been used for some 70 years for both large and small schemes and it is a credit to early turbine designers that even the most modern machinery has only increased in efficiency by a maximum of 3%. The machinery is therefore well understood and proven technology for generating electricity wherever there is sufficient flow in a river or burn. The type of scheme will determine the need to build a diversionary weir or a dam and reservoir.

Hydro electric schemes can be divided into three basic categories –

- low head schemes, which could be built using a head of between 5 – 25 metres
- medium head schemes, which would be in the region of 25 – 50 metres
- high head schemes, which would be 50 metres and over and have been built up to heads of 300m and more.



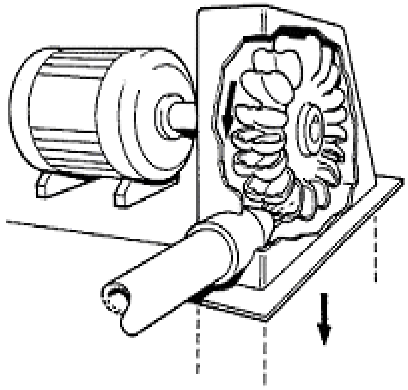
An example of one type of Low Head Scheme



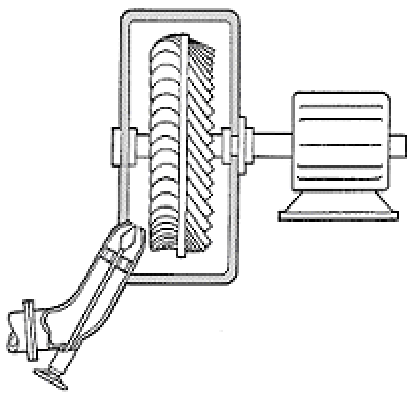
A typical Medium or High Head Scheme

Types of turbine usually associated with low head schemes would be Kaplan, in the case of medium head schemes it would be Francis or Crossflow and for high head schemes a combination of a Francis machine for 50-150m heads and a Pelton turbine for 100m and upwards.

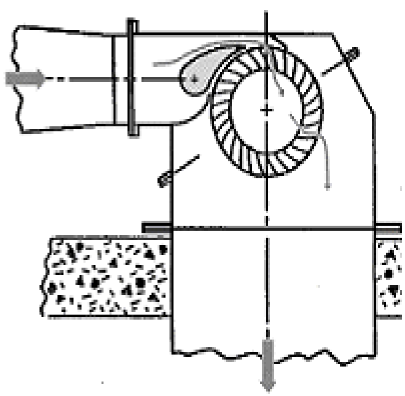
Impulse Turbines



The ***Pelton*** turbine consists of a wheel with a series of split buckets set around its rim; a high velocity jet of water is directed tangentially at the wheel. The jet hits each bucket and is split in half, so that each half is turned and deflected back almost through 180 degrees. Nearly all the energy of the water goes into propelling the bucket and the deflected water falls into a discharge channel below.



The ***Turgo*** turbine is similar to the Pelton but the jet strikes the plane of the runner at an angle (typically 20 degrees) so that the water enters the runner on one side and exits on the other. Therefore the flow rate is not limited by the discharged fluid interfering with the incoming jet (as is the case with Pelton turbines). As a consequence, a *Turgo* turbine can have a smaller diameter runner than a Pelton for an equivalent power.

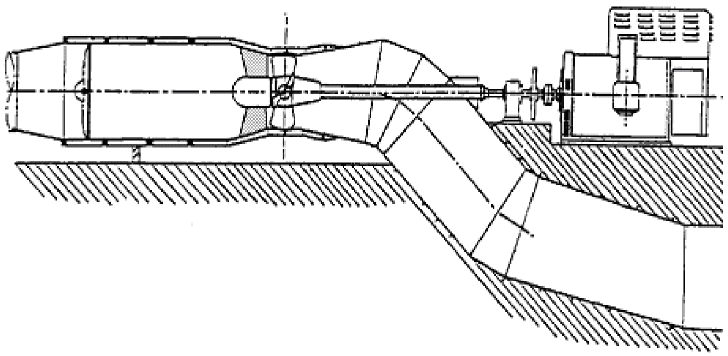


The ***Crossflow*** turbine has a drum-like rotor with a solid disk at each end and gutter-shaped "slats" joining the two disks. A jet of water enters the top of the rotor through the curved blades, emerging on the far side of the rotor by passing through the blades a 2nd time. The shape of the blades is such that on each passage through the periphery of the rotor the water transfers some of its momentum, before falling away with little residual energy.

Reaction Turbines

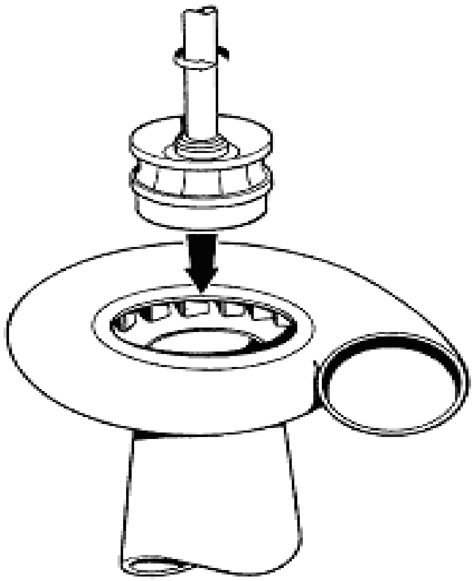
Reaction turbines exploit the oncoming flow of water to generate hydrodynamic lift forces to propel the runner blades. They are distinguished from the impulse type by having a runner that always functions within a completely water-filled casing.

All reaction turbines have a diffuser known as a 'draft tube' below the runner through which the water discharges. The draft tube slows the discharged water and reduces the static pressure below the runner and thereby increases the effective head.



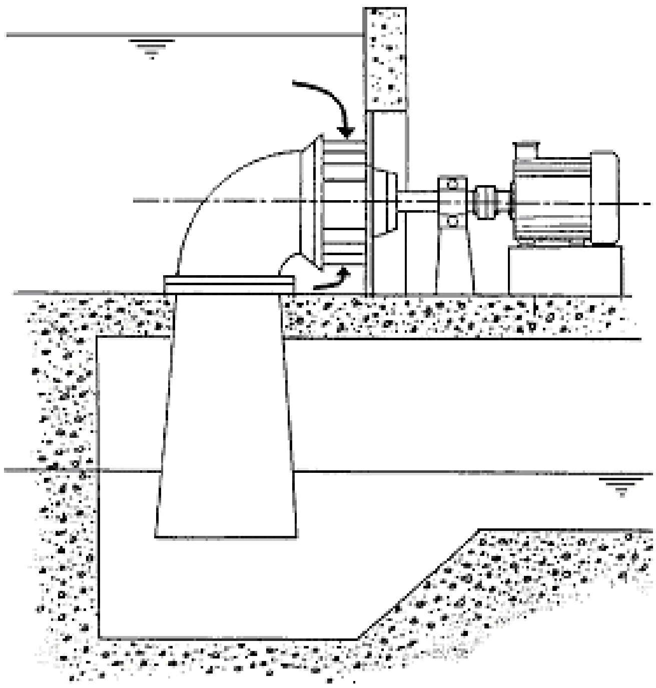
Propeller-type turbines are similar in principle to the propeller of a ship, but operating in reversed mode. Various configurations of propeller turbine exist; a key feature is that for good efficiency the water needs to be given some swirl before entering the turbine runner. With good design, the swirl is absorbed by the runner and the water that emerges flows straight into the draft tube. Methods for adding inlet swirl include the use of a set of guide vanes mounted upstream of the runner with water spiralling into the runner through them. Another method is to form a "snail shell" housing for the runner in which the water enters tangentially and is forced to spiral in to the runner.

When guide vanes are used, these are often adjustable so as to vary the flow admitted to the runner. In some cases the blades of the runner can also be adjusted, in which case the turbine is called a *Kaplan*. The mechanics for adjusting turbine blades and guide vanes can be costly and tend to be more affordable for large systems, but can greatly improve efficiency over a wide range of flows.



The **Spiral Case Francis** turbine is essentially a modified form of propeller turbine in which water flows radially inwards into the runner and is turned to emerge axially. For medium-head schemes, the runner is most commonly mounted in a spiral casing with internal adjustable guide vanes.

Since the cross-flow turbine is now a less costly (though less efficient) alternative to the spiral-case Francis, it is rare for these turbines to be used on sites of less than 100 kW output.



The Francis turbine was originally designed as a low-head machine, installed in an open chamber without a spiral casing. Thousands of such machines were installed in the UK and the rest of Europe from the 1920s to the 1960s. Although an efficient turbine, it was eventually superseded by the propeller turbine which is more compact and faster-running for the same head and flow conditions. However many of these **'open-flume' Francis** turbines are still in place, hence this technology is still relevant for refurbishment schemes.

Relative Efficiencies

A significant factor in the comparison of different turbine types is their relative efficiencies both at their design point and at reduced flows. An important point to note is that the Pelton and Kaplan turbines retain very high efficiencies when running below design flow, by contrast the efficiency of the Crossflow and Francis turbines falls away more sharply if run at below half their normal flow. Most fixed-pitch propeller turbines perform poorly except above 80% of full flow.

Step by Step Approach

Building a new hydro scheme can be an extremely costly exercise and the following guide sets out the steps a potential developer should go through to minimise upfront cost before deciding to proceed to detailed studies which heavily increase the costs involved even before planning is obtained.

If you consider you have a site available for development the following procedures should be undertaken –

1 Purchase of an Ordnance Survey map of the area from which you will be able to obtain an idea of the head available and some details of the site by an inspection of the contours on the map. Contours are at 10 metre vertical intervals.

2 Enquire where the nearest rainfall measuring station is for the area which will give an indication of the rainfall characteristics of the site. Information regarding rainfall can be obtained by contacting meteorology stations or Scottish Environment Protection Agency (SEPA).

3 Flow characteristics of a site can be measured by installation of an electronic flow recorder in the river or burn which will over a period of six months give you an indication of the flow characteristics involved. The biggest advantage is probably gained by measuring the flow in the driest six months of the year. Flow meters can be obtained relatively inexpensively and can be installed by seeking advice from a hydrologist.

4 Enquiry should be made as to the nearest point for a connection to the electricity distribution network as this can be a very important consideration in the economic viability of any scheme. Enquiries should

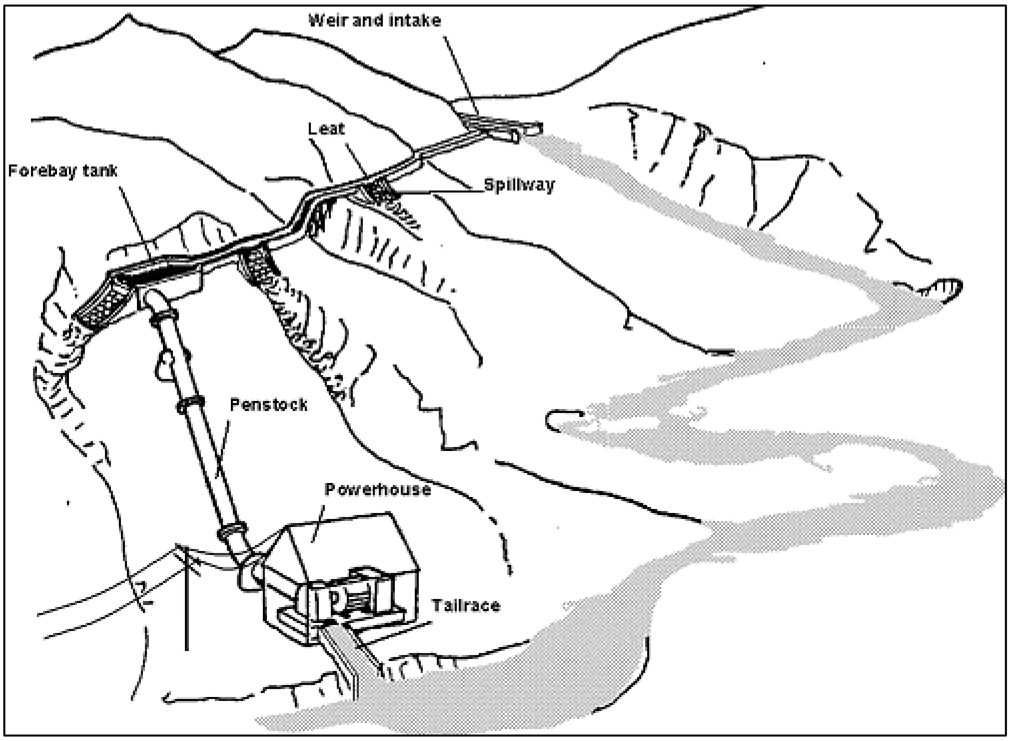
be made to Scottish and Southern Energy (for projects in the northern half of Scotland) or Scottish Power (for projects elsewhere in Scotland).

5 Enquiry should be made to SNH and the Local Planning Authority to establish whether there are any designations on the site such as National Park, National Scenic Area, Natura 2000, SSSI, SAC, SPA which may be affected by European Habitat Regulations and European Water Framework Regulations.

The foregoing five factors are important in determining the potential output of any proposed scheme from which calculations can then be made as to the potential viability of the development.

At this point in time you should seek the advice of a civil or mechanical engineering company to assist with the technical calculations and of a financial advisor to assist with the viability calculations. Contacts can be made through British Hydro Power Association (www.british-hydro.org).

Component Parts of any Scheme



All schemes are constructed with the following component parts –

a) Weir or diversionary weir
b) Intake
c) Penstock or pipeline which conveys water under pressure to the turbinehouse
d) There may be open leats which convey water to the intake pool from other streams or sources
e) Powerhouse in which the generation machinery is housed
f) Tailrace or outflow which discharges water to the river or loch as designed.

The penstock or pipeline can be short in the case of low head schemes, however depending on each scheme it could vary from around 100 metres up to several kilometres.

Further Development

Having at this point sought the advice of a civil or mechanical engineering company to advise on the technicalities of the scheme and of a financial advisor who has looked at the viability calculations, the next step would be a consultation process to find out planning requirements and also environmental and other considerations such as compensation water.

At this point in time it is important that an early meeting be held with the undernoted consultees –

- the Local Planning Authority
- Scottish Natural Heritage
- SEPA
- Fisheries Committee (over 1 megawatt)
- RSPB, if required and advised by SNH or the Local Planning Authority after consultation.

The foregoing consultations are carried out to establish any special considerations attached to the site which may indicate planning restrictions. It will also provide a guide on what would be required for the preparation of a planning application.

In Scotland a planning application for projects up to one megawatt would be handled as a local planning application by your Local Planning Authority. Developments over one megawatt are considered under Section 36 of the Electricity Act 1989 as amended and require planning application to be made to Scottish Ministers.

As a general guide, developments up to 500 kilowatts do not normally require a detailed environmental statement (ES) however developments over 500 kilowatts may require a full ES. The requirements for an ES should be discussed with the Local Planning Authority or with the Scottish Executive in the case of applications over one megawatt. Advice from the other consultees should also be sought during initial meetings with them about considerations of which they have knowledge which should be covered in an ES should one be required.

SEPA can advise on any special considerations for surveys to be carried out in the river or loch involved and advises what level of compensation flow would be required to maintain the flora and fauna within the water. For applications over 1 megawatt, it would also be necessary to apply to the Fisheries Committee for guidance and advice under Schedule 9 of the Electricity Act 1989, Subsection 5. It is also advisable when proceeding with the foregoing consultations that a prospective developer engages the services of a planning advisor, an environmental advisor, a landscape and visual advisor where necessary, a fisheries advisor and a hydrologist who would then assist in preparing a screening and scoping document, which is the precursor to a full ES. The screening or scoping document would be submitted to the Local Planning Authority or the Scottish Executive for approval prior to commencing the work for a detailed ES. It should be possible to engage one company or firm who can provide a range of services.

Financial Considerations

As the preparation of a full ES can take well in excess of a year to complete it is essential that the financial package is well in hand before committing to the detailed design and preparation of an ES as both the detail and the costs involved with environmental surveys can be high. Typically, schemes can be financed on the basis of 20 – 25% equity investment and 75 – 80% loan funding, repayable over a 10 year period. This could vary depending on the size of the scheme and the number of investors. Several banks will be willing to lend money to construct schemes and early enquiry would be advisable. As a general guide, low head schemes could cost between £4 –5k per kilowatt installed and as the size of the scheme increases costs can reduce to as low as £2.5-3k per kilowatt installed. These figures are given purely as a guide as they will vary considerably from site to site.

A financial advisor should also be able to advise on electricity prices inclusive of Levy Exemption Certificates (LECs), Renewable Obligation Certificates (ROCs) and other benefits attached to a contract with a licensed supplier and should also be able to advise on suppliers with whom you can make contact. Contracts with suppliers would normally cover sale of electricity generated plus ROCs, LECs and TRIADs associated therewith. See Appendix 1 for more information on electricity prices.

Lenders may look for long-term contracts, such as 3, 5 or up to 10 years if they can be obtained which gives them security in looking at the funding of such schemes. Normally the upfront costs in obtaining planning consent is the high risk element of any development and would be funded by equity with lending coming in at the latter end of the construction of the scheme.

In terms of the expected pay-back period investors and funders would normally look for a minimum of a 10 year pay-back with better schemes offering an even quicker return. Investors may be attracted by tax relief available through Enterprise Investment Scheme (EIS) funding although this may be very limited because of the time scale between planning application and completion of the scheme to commencement of operation which in the case of EIS would be a maximum of two years. In terms of timescale, securing planning consent and completing construction can take between 18 months and two years, with more complex schemes taking 3 – 5 years (for example, where an ES is required and survey work undertaken) and processing the planning application through either the Local Authority or the Scottish Executive.

In terms of equipment supply, as the turbines and generators are normally designed and built as a one-off for each site it should be expected that equipment supply may take a minimum of 9 – 10 months between ordering and delivery.

In terms of the civil construction, again depending on each site this can normally be completed within a maximum of two summer periods with smaller schemes being completed within one summer period. Contracts for the construction of such schemes can be done on a turnkey basis where one supervisor would be engaged to supervise the whole of the contract, which is known as a turnkey contract, or projects can be built and completed by self-supervision with the assistance of a civil engineering advisor and/or machinery supplier. A list of engineers and equipment suppliers can be obtained through the British Hydro Power Association which can also give advice should further information be required.

Operational Considerations and Operational Costs to be considered

The undernoted expenses may be incurred depending on whether a project is self-funded and operated or whether constructed for own use.

a) It may be necessary to enter into a lease agreement for ground and the use of water for which a rent would be paid.

b) Rates would be payable to the Local Authority and would be site dependent. Where the hydro scheme is rated as a separate business a 1000kW scheme could be rated on a valuation of between £15 – 20k depending on the output of each scheme. Small schemes can be rated pro rata.

c) Supervision – Although many schemes can be supervised electronically it would be normal to engage the services of a person to visit the site on a daily basis to check for any problems which may occur. Training should always be given to the person who visits the site however in cases where access is required for high voltage transmission of power only qualified engineers should be allowed on site and it would be normal to seek the assistance of qualified engineers in this case. As a guide, training could consist of an understanding of the low voltage operational side of the electronic control system and replacement of small components such as bulbs. This would also consist of operational training as to how to start, operate and stop the generator. This may also include an understanding of the control system where automatic starts and stops are employed. The operator would normally fill in a daily record of outputs, voltages, power factor, various temperature readings, daily total outputs and number of hours of operation. This should be taken only as a guide and is not exhaustive. It would also give the operator an understanding of levels to be recorded under the Reservoirs Act which requires weekly records to be kept of water levels in reservoirs and compensation water where applicable. In some cases it could also include training as to the recording of compensation water flows where independent electronic measuring devices are not used.

The person would also be responsible for clearing debris in the intake and reporting any malfunctions on a daily basis. For larger schemes removal of debris can be achieved by installing special machinery however this would only be done where the cost of installing the machinery can be justified.

d) Electricity Charges – The supplier who purchases the electricity will levy an administrative charge of £30 - £40 per month. In addition, a meter operator charge, which could average £25 –50 per month depending on the requirements, will normally be incurred. Suppliers will normally arrange to install half hourly meters at the site. It would also be normal to supply a telephone connection to your control system so meter data can be downloaded to the meter operator automatically on a monthly basis.

New schemes will also be liable for distribution use of system charges which is a charge based on kilowatt output for the use of the distribution system. Details on costs associated with this are not yet known but advice can be sought from your Distribution Network Operator (in Scotland, either Scottish Hydro Electric Power Distribution or Scottish Power Distribution Ltd) or Ofgem.

e) It would be normal to depreciate your project over a period of up to 25 years which would be its minimum expected life and would generally provide a flow of funds to assist with the reduction of any long term loan funding.

f) As security for your investors and yourself it would be normal to carry insurance against breakdown and loss of revenue as replacement of machinery and components can have a long lead time. Developers should carefully consider whether a stock of components with long lead times should be carried so that outages are minimised.

g) Any interest on lending would normally be written off on an annual basis and would reduce each year as reductions of loans are made.

h) Accounting and invoicing would be carried out on a monthly basis as the supplier company would advise monthly of the half hourly outputs on which an invoice can be raised. It would be expected that power would be paid for within 28 days of raising such an invoice. For the purpose of financing it would be wise to calculate cash flow on the basis of six weeks after the end of the month of delivery. Payment of ROCs, LECs and Recycle Payments can vary between three months and an annual payment in the case of Recycle or TRIADs.

Planning and Other Costs

As a guide, a developer would be expected to pay planning and other costs as follows –

a) Planning costs would be based on a minimum of £150 per 0.1 of a hectare affected, with a figure of between £1,300 - £1,500 but may be more in the case of larger sites.

b) Under CAR (Controlled Activities Regulations) which is administered by SEPA, costs could be incurred as undernoted –

Abstraction £2,944

Impoundment	£2,944
Engineering Fees	£1,209 per 250 metres of river or stream affected, plus an additional £1,209 for any river or stream crossings

It would be expected that CAR fees would be a minimum of £5 – 6k but for larger, more complex schemes can cost between £25 – 50k, all of which must be funded on application and is non-refundable. In terms of connection a fee of between £5 – 7,500k would be paid to Scottish & Southern or Scottish Power for a system review to consider whether the development can be connected within the existing distribution system or requires an upgrade. If a contract is signed for connection then you can expect to pay, up front, up to £100,000 in the case of small schemes or 50% of the fees over £100,000 at the date of signing the Connection Agreement. If the project does not proceed these fees are refundable, less any further costs associated therewith.

In the case of costs associated with preparation of environmental statements for small schemes of 500Kw and under these can cost between £30-50k depending on the complexity of the statement. Where a full ES is required costs of £100 – 200k can be incurred.

Early Warnings

a) It should be noted that under present planning guidance there are no presumptions in favour of construction of micro hydro schemes.

b) For Section 36 applications pre-consent development costs are high and consents can take in excess of 2½ years. Local Planning Authority consents usually take 6 – 9 months. Actual times will depend on the project and site being proposed.

c) As applications under Section 36 cover around 30 consultees including seven internal consultees, eight local authority consultees and 15 external consultees, normally 30 copies of the ES have to be submitted in respect of the application. Delays can be caused if statutory consultees do not reply by designated dates.

d) SEPA is responsible for administering CAR which is required under the European Water Framework Directive. Again, the process can take some time and impact on costs and risk associated with the project.

e) SNH and SEPA and the Fisheries Committee may require the same information and this can cause confusion for developers, particularly in relation to which of these bodies has overall responsibility.

f) For applications under Section 36 the demands of the Fisheries Committee are increasing and costs can be substantial in carrying out surveys for fish. Survey results are used as base line information which is subsequently monitored by the developer to measure the impacts on fish. They are also advisors to SEPA for any conditions to be included in the CAR licence.

g) When making an application to SEPA a developer should also consider whether there are any other types of generation other than hydro which could be developed on the site.

h) Grid capacity is becoming limited even for small hydro developments and connections may be delayed for several years in certain areas where only limited access is available.

i) All future hydro developments will be subject to Distribution Use of System Charges (DUOS) which is a new requirement, the details of which haven't been finalised. This is an additional cost of operation.

Legal Costs

It would also be important for any developer to engage the services of a lawyer to oversee the details of supplier contracts, lease agreements, connection agreements and any other agreements into which the developer may enter for delivery of his electricity.

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Appendix 1 – Electricity Prices

A scheme's power rating is normally referred to in kilowatts (KW). This is not to be confused with the electricity that the scheme generates which is measured in kilowatt hours (KWh). For example, a 100KW scheme will generate 100KWh for every hour it is operating, 2400KWh if it operates for a complete day. It is the output in KWh and associated benefits that are available to sell to a supplier.

Renewable source electricity prices are made up of a number of elements.

The electricity – sometimes referred to as the 'hard electricity', this is simply the power generated by a scheme. Prices vary hugely depending on the time of day, the season and overall market forces. As such a wide variety of power contracts are available and site specific issues will determine which one offers the best overall return. Income from generation is normally paid within 6 weeks of the end of any given month.

Levy Exempt Certificates (LECs) – these certificates relate to the Climate Change Levy (CCL). Renewable energy is exempt from the CCL and each LEC is evidence of exemption for 1000KWh. CCL is 0.43p per KWh or £4.30 per LEC, this price is fixed and unlike the ROC price is not indexed. A contract for the sale of LECs is normally expressed as 90 – 100% of the fixed price of £4.30. LECs must be sold with the hard electricity but income is normally received 3 months after the month end.

Triad Benefit – this is an annual payment made to generators in March/April who were operating during the 3 half hours (Nov-Feb) that had the highest demand for electricity (and hence highest price) as determined by the market. These prices can be incredibly high depending on peak demand. Prices of £4.00 - £8.00 per KWh are not unusual during these periods, in the South West of England Triad prices have reached £22.20 per KWh. If we compare these prices to the usual £0.02 - £0.05 per KWh in a contract this benefit is not insignificant.However, it is very difficult to quantify and should definitely not be relied upon. Prices vary year to year and the scheme must operate during some or all of the 3 peak periods to qualify. Unless the scheme is operating 24 hours a day for the 4 months involved there is no guarantee that it will be operating during the correct periods.

Renewable Obligation Certificates (ROCs) – for each 1000KWH a hydro scheme produces it receives 1 ROC. Suppliers need to surrender ROCs to meet their legal obligation to supply so much of their total output from renewable sources. That is, the ROCs are used as evidence of supply of renewable energy. Suppliers failing to surrender enough ROCs to meet their obligation must pay a 'Buyout Price', currently (2007) £34.20 but indexed by RPI, for every ROC they fall short of their obligation.

The monies paid by suppliers by way of the buyout are placed in a fund known as the recycle fund. This fund is then recycled to suppliers on the basis of how many ROCs they surrendered. That is, each ROC surrendered warrants a payment from the fund. This is known as the 'Recycle Payment'.

ROCs can be traded separately from the electricity but in most cases contracts will be for the total output of the scheme plus benefits. ROC prices are usually expressed as 90 – 95% of the Buyout Price plus 90 – 95% of the Recycle Payment, although some suppliers offer a flat rate per ROC. The Buyout portion of the income is paid some 3 months after the end of the month. The Recycle portion of the income is paid annually usually in the September following the end of a ROC year, which runs from April to March.

For the purposes of basic financial calculations renewable energy is currently (2007) trading at approximately £0.08 per KWh but with fluctuations in wholesale electricity prices this could vary by 25% even in the short-term, long-term fluctuations could be even larger. For more detailed financial calculations it is necessary to pay particular attention to cashflow. Due to the 5 elements of a contract having different timing for payment it is not outside the realms of possibility to have 35 – 45% of your annual income being carried as a debtor at a given date. This is extremely high for any industry and Ofgem are currently looking at ways of speeding up the issuing of LECs and ROCs which in turn will lead to faster payment.

Acknowledgement

British Hydropower Association for the various sketches used in the guide.

The foregoing guide should give a developer a basic knowledge of what is required in developing a small hydro electric scheme in Scotland and should more detailed information be required further information may be obtained through Scottish Renewable Forum, 93 Hope Street, Glasgow G2 6LD Telephone 0141 222 7920 or British Hydropower Association, 12 Riverside Park, Station Road, Wimborne, Dorset BH21 1QU Telephone 01202 880333, both of whom offer membership to developers.