Reclaiming Lost Power

Kilkenny's Potential Hydro Power Sites

This project was part funded by the
European Fund for Rural Development Investing in Rural Areas
through Kilkenny LEADER Partnership

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Kilkenny's Potential Hydro Power Sites

January 2010

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Jane Wickham, Carlow Kilkenny Energy Agency

Foreword

Kilkenny Leader Partnership
Kilkenny LEADER Partnership (KLP) commissioned this report on hydro-power in the county as a result of its recognition of the potential of the technology to be a driver of rural development. The company has identified hydro-power as one of the renewable energies with significant potential for development. KLP and its partners on the *Kilkenny Sustainable Energy Forum* (KSEF) were familiar with a number of modern facilities in Kilkenny which have successfully adopted existing river mill facilities to produce electrical power.

It might be expected that untapped hydro-power potential would exist in a county which is geographically defined by its rivers – the Barrow, Nore and Suir, of course, but also their major tributaries, the Blackwater, Kings, Dinnen, Arrigle and others. The county's rivers were once a thriving source of enterprise and commerce, with a surprising number of mills of all types (grain, stone cutting, etc) crowded on their banks. Why should we turn our backs on their neglected resource when looking at renewable energy?

What KLP wished to achieve in commissioning the report was to research and analyse which of the older or, indeed new sites, offer the best opportunities for development in the immediate future. The report was asked to take into account the available technology and regulatory system. On behalf of KLP and KSEF, I'd like to thank the contracted consultants *Carlow Kilkenny Energy Agency* (CKEA) for their excellent report. It is clear, concise and – above all, a usable document. It is very much a 'users manual' aimed at the layman with an interest in development – be that a site owner, a community group, officials or enthusiasts for the technology. The partners do not see it as an end in itself, but rather as the start of a process. In the coming months we will be considering the options to move toward development in some of the identified sites.

Declan Rice
CEO, Kilkenny LEADER Partnership

Kilkenny Sustainable Energy Forum

It gives me great pleasure as chairman of *Kilkenny Sustainable Energy Forum* to have been part of the development of this report. A principal purpose of the Forum is to promote the development of Renewable Energy in Kilkenny. As a representative of Kilkenny Chamber of Commerce the publication of this report gives me particular pleasure as it should attract considerable investment and economic activity to Kilkenny.

The development of Renewable Energy in Europe generates huge capital investment and is a preferred focus of EU regional funding programmes. This report identifies specific sites that may be suitable for development either by owners or investors and offers the prospect of significant commercial activity, and long term economic and environmental benefits for the owners and the county.

We are grateful to all those who worked on and facilitated the report.

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Michael Boyd
Chairman, Kilkenny Sustainable Energy Forum

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Executive Summary

Hydro power currently contributes to approximately 1.6% of Ireland's total electricity production (Energy Statistics Databank, 2008) with high head schemes contributing to the vast majority of this. Many of the high head schemes around the county have been developed but there exists potential to develop low head schemes at a local level.

County Kilkenny, due to its geographical location, has a potential of low head hydro resource existing in disused mill sites, weirs and untapped areas around the county that could be utilised to generate electricity. These low head sites (< 10 m) owned by local land owners, community groups and industries could create employment, revenue and further enhance the green economy for County Kilkenny.

This report presents an overview of the process involved in developing a hydro project and identifies a number of sites that may be suitable for future development. The report was funded by Kilkenny LEADER Partnership (KLP).

Guidelines and recommendations from the report include the following;

- The power output from a hydro turbine varies directly with the head or vertical decline of water from headrace to tailrace and the available flow of water. Power output will be limited by the efficiency of the system being used. Energy output depends on the availability of the site. The head can be physically measured and flow rates can be obtained using a velocity method.

- For gauged sites, hydrometric data can be obtained from the Environmental Protection Agency (EPA) Hydro-net database (http://hydronet.epa.ie/hydronet.html) or from the Office of Public Works hydro database (http://www.opw.ie/hydro/). For ungauged sites, a hydro calculation tool has been developed as part of this project; this is based on catchment area, annual rainfall and measured head, and can be used to calculate the potential power and energy output.

- Twenty-seven hydro sites in County Kilkenny were assessed using the calculation tool. A map illustrating potential power output was produced. For new projects, the hydro calculation tool can act as a valuable starting point for potential hydro projects not identified in this study. This tool will be made available on the KLP website.

- The appropriate turbine type can be selected initially by referring to the turbine selection graph and efficiency comparison chart in this report, and then by consulting with a reputable engineer. Francis and propeller type turbines are generally used for low head sites but recently there has been increased interest in the Archimedes Screw turbine because of its noticeable fish friendliness. However, for all turbines, including the Archimedes Screw, it is essential that a fish pass and screens are placed in such a way as to protect fish from entering the turbine.

- Hydro sites are subject to planning permission and Kilkenny County Council (KCC) should be consulted in relation this. As hydro power developments can have a potential negative impact on the fisheries / ecology aspects of the river, it is advisable that some type of environmental assessment is prepared for all proposed hydro developments.

- A screening stage will assess the requirements of an Environmental Impact Assessment (EIA). For sites where an EIA is required, the Central Fisheries Board document on *Guidelines to the construction & operation of small-scale hydro-electric schemes and fisheries* and the Environmental Protection Agency documents on *Guidelines on the Information to be contained in Environmental Impact Statements* and *Advice Notes on Current Practice in the preparation of Environmental Impact Statements* should be consulted.

- For any development, one of the main concerns will be in relation to the impact the development will have on the local fish population. Under the Fisheries Act, 1959 a fish pass and screening will need to be installed. The Southern Regional Fisheries Board (SRFB) should be consulted on a case-by-case basis to review this.

- The Barrow and Nore Rivers are designated Special Areas of Conservation, so any proposed development along these rivers will require an fish impact study to be preformed. Again, a screening stage will assess the requirements of this study. The National Parks & Wildlife Service (NPWS) and SRFB should be consulted on this. The requirements for a fish impact study are presented in *Guidelines to the construction & operation of small-scale hydro-electric schemes and fisheries.*

- Some sites are listed as designated protected structures and a pre-planning meeting should be arranged with the conservation officer at KCC for sites of this type.

- Hydro generators can connect to the national grid, operate as an auto-producer or charge a battery bank; this will depend primarily on the electricity load on-site and the proximity to the grid. ESB Networks and the Commission for Energy Regulation (CER) should be consulted on grid connection.

- Revenue can be obtained by securing a power purchase agreement from an energy supply company, or for micro-generators obtaining an export payment. Alternatively, auto-production allows a site owner to offset their electricity demand.

- Grants may be available from KLP or Sustainable Energy Authority of Ireland (SEAI). Both organisations should be consulted on the relevant grant assistance available. Factors such as community development / involvement will need to be considered for funding under KLP Rural Development Strategy 2007 – 2013.

Recommendations are made in this study for potential hydro developments based primarily on proximity to the grid of sites with a capacity less than or equal to 50kW. These are listed in the table below.

No.	River	Location	Structure	Potential kW	Potential MWh
Generation capacity (11 – 50kW)					
10	Dinin	Castlecomer	**Weir*	29	154
11	Dinin	Ballyhimmin, Castlecomer	**Corn Mill*	22	115
16	Kings	Killinny, Kells	**Killinny Mill*	34	177
17	Kings	Kells	Corn Mill	41	217
18	Kings	Stoneyford	Corn Mill	48	253
29	Blackwater	Kilmacow	Corn Mill	25	133
Potential micro-generation (< 11kW)					
22	Little Arrigle	Jerpoint	**Corn Mill*	16	85
23	Douske	Graiguenamanagh	Corn Mill	12	63
24	*Arrigle*	*Ballyduff*	**Flour Mill*	15	76
25	Arrigle	Ardshinnan, Inistioge	Saw Mill	15	81
27	Blackwater	Ballyhomuck, Mullinavat	River	15	80
28	Blackwater	Dangan, Mullinavat	Corn Mill	16	86
32	Unnamed	Smartscastle, Dunkitt	Corn Mill	13	70

** protected structures*

Sites with a large potential output should also be considered but it is advised to keep with in the maximum export capacity of approximately less than 50kW.

No.	River	Location	Structure	Potential kW	Potential MWh
2	Barrow	Castlecomer	Weir	148	776
3	Barrow	Goresbridge	Weir	116	608
4	Barrow	Graiguenamanagh	Weir	215	1,130
13	Nore	Dukesmeadows, Kilkenny city	Ormonde Woollen mill / Marble mill	75	392
19	Nore	Thomastown	Greenan Flour mill	105	549
20	Nore	Thomastown	Corn mill & Island Flour mill	111	584
21	Nore	Thomastown	Dangan Flour mill	139	731

This study has identified a hydro resource in County Kilkenny that can be tapped into by local community groups, land owners and local industries. Under the KLP Rural Development Strategy 2007 – 2013, funding is available for the development of renewable energy resources in the county. The next step for anyone considering developing suitable projects should be to contact Kilkenny LEADER Partnership to determine if their project would fulfil the requirements of the development strategy.

Acknowledgments

The Authors would like to thank Kilkenny LEADER Partnership for funding the project and the following people and organisations who were consulted throughout the project;

- Aine Doyle, Conservation Officer, Kilkenny County Council
- Alan Cullagh, The Southern Regional Fisheries Board
- An Taisce
- Aoife Dowling, Kilkenny County Council who helped with the GIS maps
- Central Fisheries Board
- Dearbhala Ledwidge, Heritage Officer, Kilkenny County Council
- ESB Networks
- Jimi Conroy, National Parks & Wildlife Service
- Planning Department, Kilkenny County Council
- Martin Rafter, Kilkenny Leader Partnership
- Micheál MacCárthaigh, Environmental Protection Agency
- Office of Public Works
- Rick McGrath, Arcogen Limited
- Rory McConnon, Carlow Kilkenny Energy Agency
- Patrick Kilfeather, The Southern Regional Fisheries Board
- Waterways Ireland

In addition, the author would like to thank the people that participated in the site visits.

Abbreviations

CER	Commission for Energy Regulation
CHP	Combined heat and power
CKEA	Carlow Kilkenny Energy Agency
DCENR	Department Communications, Energy & Natural Resources
DEHLG	Department Environment, Heritage & Local Government
EIA	Environmental impact assessment
EPA	Environmental Protection Agency
EU	European Union
GPS	Global positioning system
KCC	Kilkenny County Council
KLP	Kilkenny LEADER Partnership
kW	kilowatt
kWh	kilowatt hour
MEC	Maximum export capacity
MW	megawatt
NPWS	National Parks & Wildlife Service
OPW	Office of Public Works
PPA	Power purchase agreement
REFIT	Renewable energy feed in tariff
SAC	Special area of conservation
SEAI	Sustainable Energy Authority of Ireland
SPA	Special protection area
SRFB	Southern Regional Fisheries Board

1 Introduction

In Ireland, around 70 years ago, hydro power represented an important source of mechanical and electrical energy for domestic, agricultural, industrial and municipal supply. At the beginning of the 20^{th} century over 1,800 mill sites were operating with waterwheels or small turbines. Its relative importance has declined since then because of advances in centralised generation of electricity using oil, coal, peat and gas. Today hydro power installed capacity comprises approximately 211 mega-watts (MW) of large scale hydro projects, 292MW of pumped storage and 26MW of non-centrally dispatched hydro generation plants, representing approximately 10% of installed dispatchable capacity (Transmission System Operator, 2005). Of the non-central generation, approximately 0.175MW of capacity is currently installed in County Kilkenny (Appendix 1: Hydro schemes in commercial operation).

Small and micro hydro power has a number of inherent benefits both as a technology and to the wider environment and community, these include;

- Free source of fuel
- Displaces fossil fuel generation
- Environmental impacts negligible
- Consistent and dispatchable generation over long periods of time
- Good correlation with demand – more hydro available in winter
- Long lifetime for systems
- Reasonable payback
- Local projects connected to the distribution system or at a customer’s site
- Create employment and revenue feeding back into the local economy

County Kilkenny, due to its geographical location and historic trade has an available hydro resource existing in numerous old mill sites owned by local land owners, communities and industry. New technology, less stringent regulation of grid-connected generators, support mechanisms and standardised turbine designs are now encouraging more widespread interest in developing these hydro sites.

This aim of this study is to present the process involved in developing a hydro project from conceptual idea to completion, along with a review of potential sites which may be suitable for further development in County Kilkenny with funding though Kilkenny LEADER Partnership.

In addition, developing sites will contribute to Irelands 2020 renewable energy targets of 40% of total final electricity consumption from renewables.

2 Basic theory

The *flow rate* in the river is the volume of water passing per second, measured in m^3 sec^{-1}. For small schemes, the flow rate may also be expressed in litres sec^{-1} where 1,000 litres sec^{-1} is equal to 1 m^3 sec^{-1}.

The *gross head* is the maximum available vertical fall in the water from the upstream level to the downstream level. In real hydro systems the water delivered to the turbines will lose some energy as a result of frictional drag and turbulence as it flows in channels and pipes. Thus, the effective head will be less than the available head.

Hydro turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator, or other machinery. The power available is proportional to the product of *head* and *flow rate*. The general formula for any hydro system's potential power output is:

$$P = \eta \rho g Q H$$

P: mechanical power produced at the turbine shaft (watts)
η: hydraulic efficiency of the turbine
ρ: density of water (1,000 kg m^{-3})
g: acceleration due to gravity (9.81 m s^{-2})
Q: flow rate passing through the turbine (m s^{-1})
H: effective pressure head across the turbine

The most efficient turbines can have hydraulic efficiencies in the range 80% to over 90%. Hydraulic efficiency refers to the amount of mechanical power that the hydro turbine extracts from the water flowing through it. In addition to the hydraulic efficiency, the mechanical to electrical generation process also incurs efficiency losses, which can be up to 10%. The efficiency over the whole process, water-mechanical-electrical, is often referred to as the "water to wire" efficiency"

Micro-hydro systems (<100kW) tend to have a water-to-wire efficiency range of 60% to 80%.

If we take 70% as a typical water-to-wire efficiency for the whole system, then the above equation can be simplified to:

$$P = 7\ Q\ H\ (kW)$$

The energy output from a turbine over a year can be estimated using a capacity factor (C_f), which is a ratio between the actual energy generated and the potential generation capacity, and the number of hours per year, i.e. 8,760.

$$E = P\ C_f\ 8{,}760\ (kWh)$$

The capacity factor for hydro turbines ranges from 50% to 70%, and is determined by, inter alia, downtime for maintenance and the range of flow rates available over the year.

3 Types of hydro schemes

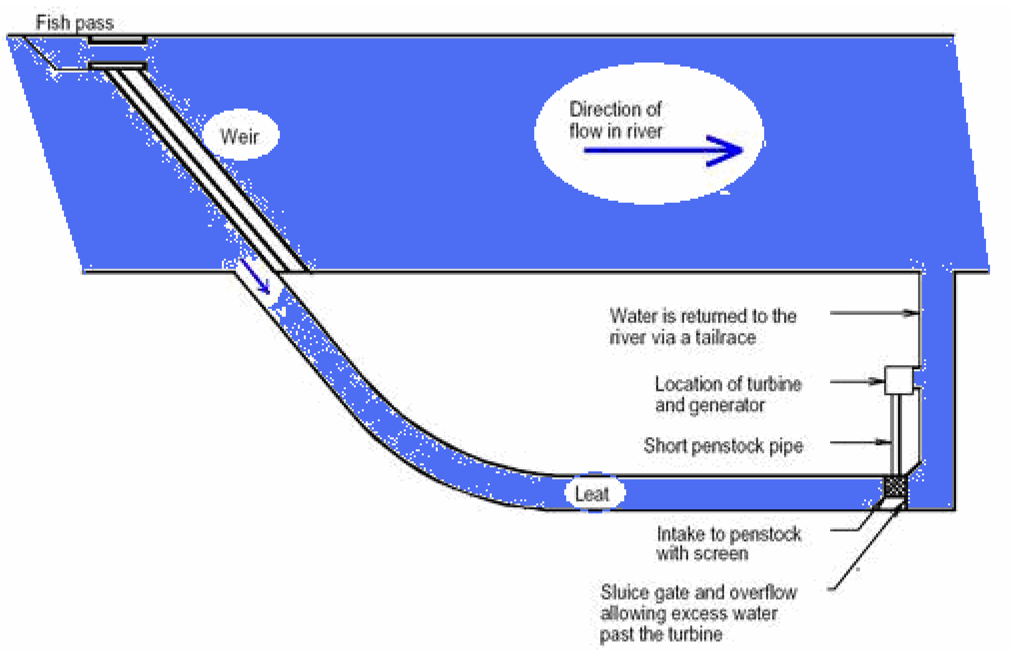
Two hydro projects with the same power output could be very different; one using a relatively low volume of high-speed water from a mountain reservoir and the other using a high volume of water in a slow flowing river. As such, hydro schemes are classified as low, medium or high head schemes.

3.1 Low head schemes

Low head systems typically have a gross head of less than 10m. Types of sites which are particularly worthy of consideration include;

- Historic water mills
- Weirs

Low head systems are generally located in lowland areas, abstracting water from rivers through the use of weirs with diversion of a proportion of river flow to a leat (millrace) and from there to a turbine house. Water is returned to the river downstream of the turbine through a tailrace. Low head schemes are very dependent on flow, and may shut down during periods of low rainfall. This study will primarily focus on low head sites.



Source: Hydro Generation, 2009

Figure 1: Typical layout for a low head scheme

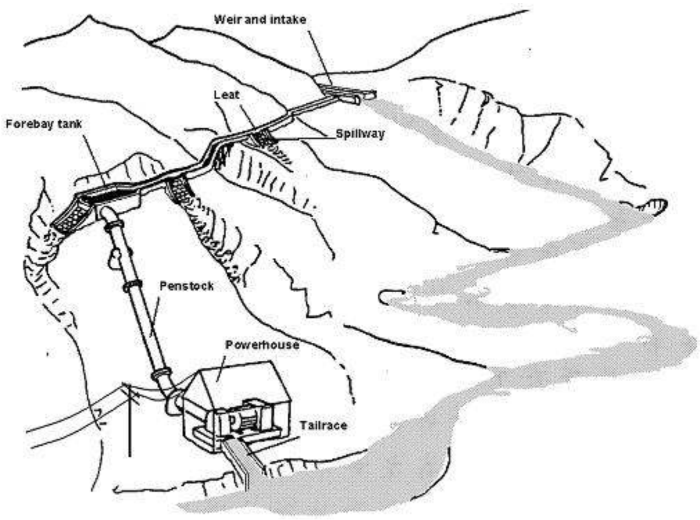
The operation of this type of system can be summarised as follows:

- The weir raises water height to the necessary level to fill the leat which conveys water to the penstock intake.
- At the intake, water is passed through a screen which prevents the entry of fish and debris.
- A pressure pipe or 'penstock' of suitable diameter conveys water to the turbine.
- The turbine converts hydro power into rotating mechanical power and the generator converts rotating mechanical power into electricity.
- The tailrace returns the water to the river.

The overflow allows unhindered passage of excess water in the leat back to the river. The fish-pass allows passage of migratory fish.

3.2 Medium / high head schemes

While there is no explicit definition, medium head systems typically have a gross head of between 10 – 50m, and high head schemes typically have a gross head of >50m. Medium and high head schemes typically, but not always, are larger in terms of installed generation capacity. In any case, there is little scope for development of these types of schemes in County Kilkenny.



Source: British Hydro, 2009

Figure 2: Typical layout for a medium / high head scheme

The operation of a medium / high head scheme can be summarised as follows:

- Water is taken form the river by diverting it through an intake at a weir.
- Water is carried horizontally to the settling or forebay tank by a small canal or leat.
- Water is passed through the tank where the water is slowed down sufficiently for suspended particles to settle out. The forebay is usually protected by a rack or metal bars which filters out debris.
- A pressure pipe or 'penstock' conveys the water from the forebay to the powerhouse where the turbine, generator and control equipment is housed.
- The turbine and generator convert hydro power into electricity.
- After leaving the turbine, the water discharges down the tailrace canal back into the river.

4 Hydro – power generating technologies

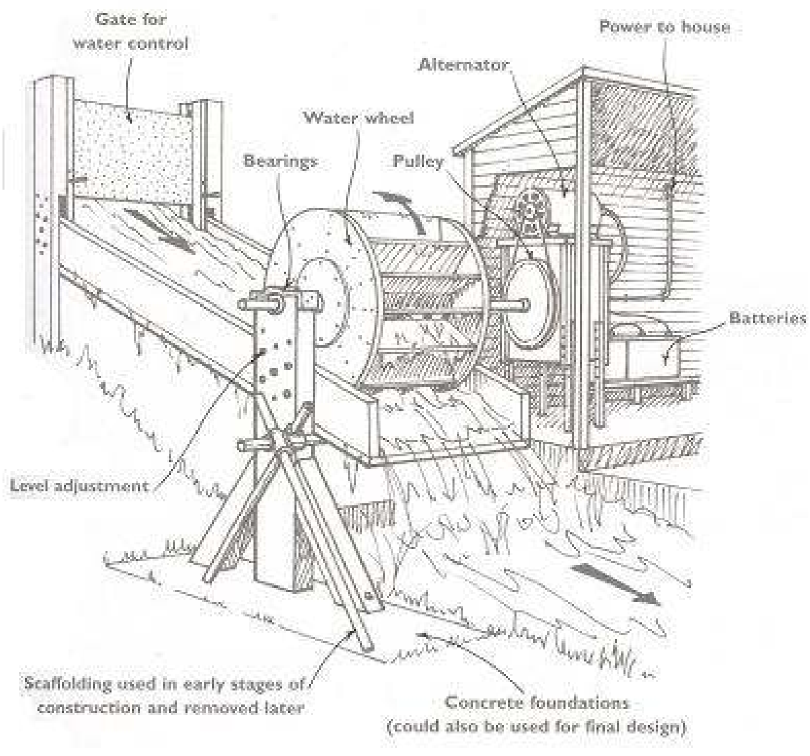
Hydro power is a mature technology and has been used as a source of energy for centuries. The earliest water mills appeared around the first century BC in the Middle East and a few centuries later in Scandinavia. Between 1650 and 1800 there were major advances in designs, and from 1800 the traditional waterwheel was used widely into the late 1900s. Further advances are continually being made in hydro electricity generating turbines in terms of capacity factors, maintenance requirements and costs. The following section of this report describes the main types of low head hydro systems which may be suitable for projects in County Kilkenny in terms of their application, operation, advantages and potential disadvantages.

4.1 Waterwheel

Waterwheels are wooden or metal wheels that spin slowly as water passes through them. The wheel spins slowly but with lots of torque. Waterwheels have been used to power flour mills and other industries for hundred of years.

Advantages:

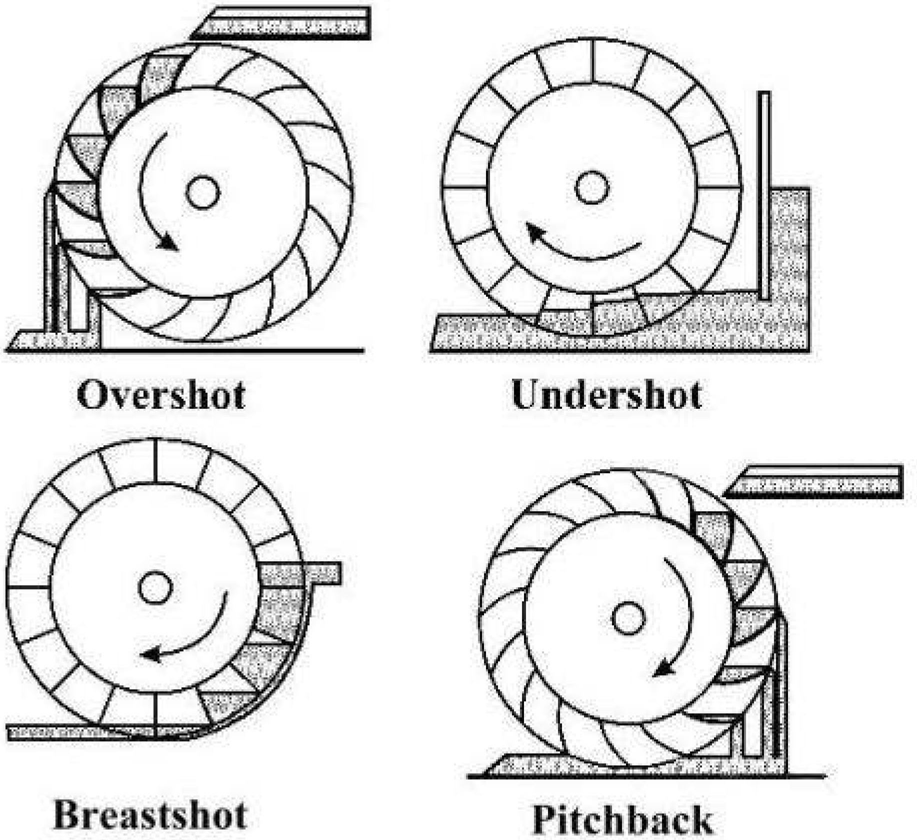
- Low maintenance
- Large buckets of water allow fish and debris to pass through
- Minimum dependency on water level
- Very good part flow efficiency allowing it to operate at most times of the year
- Robust and reliable technology



Source: Bridgewater, 2008

Figure 3: Systematic set-up for an undershot waterwheel

There are four main types of waterwheels – the overshot, the undershot, the breastshot and pitchshot (Fig. 4).



Source: Ford End Watermill, 1996

Figure 4: Types of waterwheels

- The 'overshot' water enters the buckets at the top
- The 'undershot' water flows underneath the wheel
- The 'breastshot' water enters the buckets at about the middle of the wheel
- The 'pitchback' water enters the buckets at the rear of the wheel beneath the penstock

Overshot and pitchback wheels are more efficient than the other two because they are driven both by the weight of water and by the force or pressure of water directed into the buckets by the penstock but require a higher head of water.

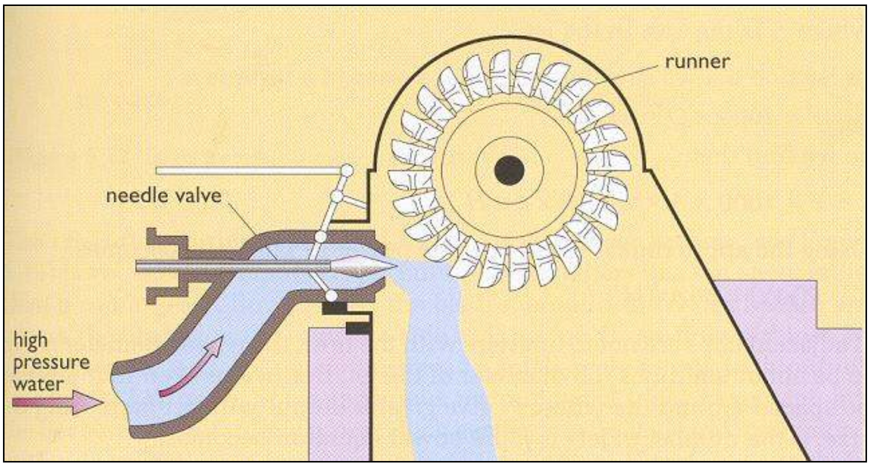
4.2 Hydro turbines

Turbine selection depends on a number of factors…

- Site characteristics
- Head of the hydro scheme
- Available flow rate
- Desired runner speed of the generator

There are two main categories of Turbine: Reaction & Impulse

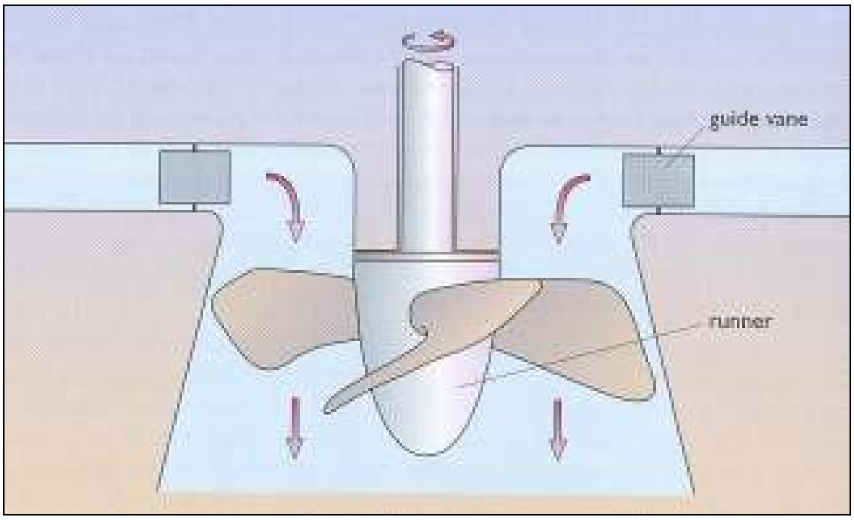
Generally, impulse turbines are high head, low flow machines which convert the kinetic energy of a jet of water into mechanical energy by striking buckets or blades (Fig. 5). The power can be varied by adjusting the jet size to change the volume of flow rate or by deflecting the entire jet; [→ kinetic energy to work].



Source: Boyle, G., 2004

Figure 5: Impulse turbine

By comparison, the blades of a reaction turbine are totally immersed in the flow of water; the angular and linear momentum of water is converted into shaft power. Reaction machines operate at lower head and higher flow rates (Fig. 6); [→ pressure to work].



Source: Boyle, G., 2004

Figure 6: Reaction turbine (Propeller)

4.2.1 Turbine descriptions

The following gives a description of a range of modern turbine types. Table 1 gives operating range, Figure 7 gives turbine selection graph and Figure 8 gives efficiency range. Using this data a suitable turbine selection can be made for any given flow and head range. All turbines will require the installation of fish passes and screening.

Table 1: Classification of turbines and operating range

Head classification	**Impulse**	**Reaction**
High (> 50m)	Pelton Turgo	–
Medium (10 – 50m)	Crossflow Turgo Multi-jet	Francis (spiral case)
Low (< 10m)	Crossflow (< 20kW)	Propeller Kaplan Francis (open flume) Archimedes screw turbine

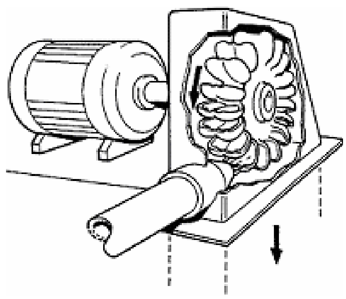
High/medium head Turbines

Pelton

- Discharge of water from a nozzle striking bucket and deflecting the jet through 160°.
- Vertical shaft.

Multi-jet

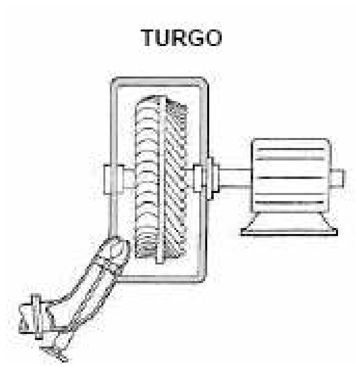
- Similar operation to pelton but with multi-jets instead of a single jet.



Source: British Hydro, 2009

Turgo

- Similar operation to pelton but discharge of water strikes a plane at an angle and deflects without interference.
- Operate at a lower specific speed and hence over a wider range of speeds.
- Smaller diameter than pelton
- Horizontal or vertical shaft.

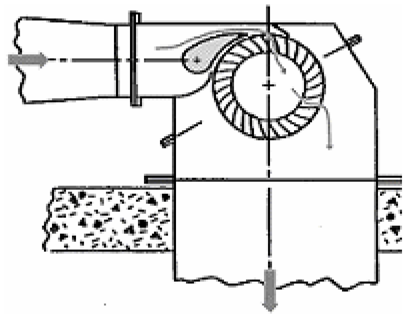


Source: British Hydro, 2009

Low Head Turbines

Crossflow

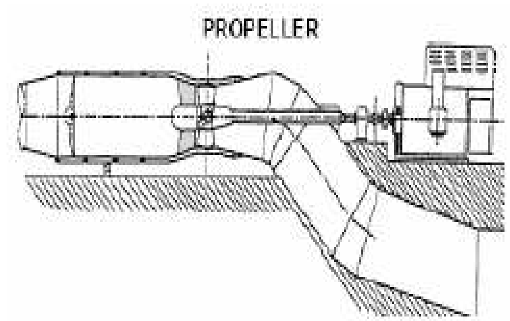
- Jet of water directed onto curved blades with double impact before leaving the turbine.
- Horizontal shaft.



Source: British Hydro, 2009

Propeller

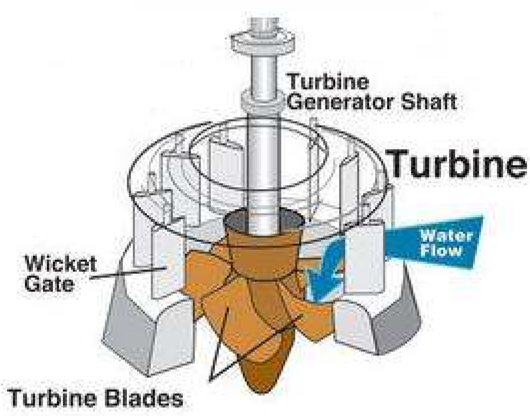
- Fitted inside a tube and similar to a ship's propeller (Fig. 6).
- Usually contains 6 blades.



Source: British Hydro, 2009

Kaplan

- More sophisticated version of the propeller.
- Pitch of blades can be adjusted to handle variation in flow.
- High specific speed which reduces losses.



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Francis

- Spiral casing with adjustable guide vanes to direct water at correct angle. The water exists axially from the centre of the turbine.
- Horizontal shaft for smaller diameters / vertical shaft for larger diameters.

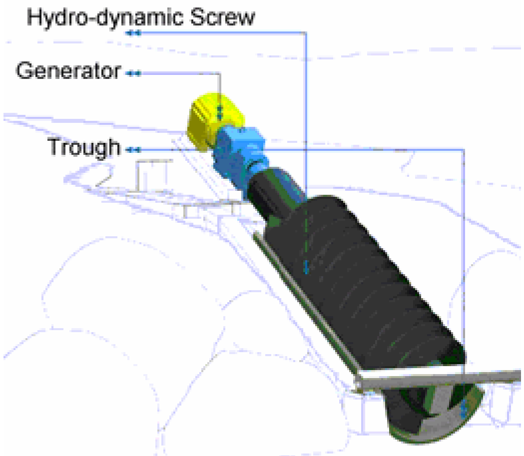
Source: Electrical & Electronics, 2009

Archimedes screw turbine

- The Archimedes Screw has been used for pumping water for over 2,000 years. Applying the principle in reverse, the same equipment can be used for generating power from water.

- It is becoming increasingly popular for lower head (1 to 10m) sites over a high range of flow rates (0.1 to 10 $m^3 s^{-1}$) and offering an operating range of 1 to 350 kW and a high efficiency across large variation in flow.

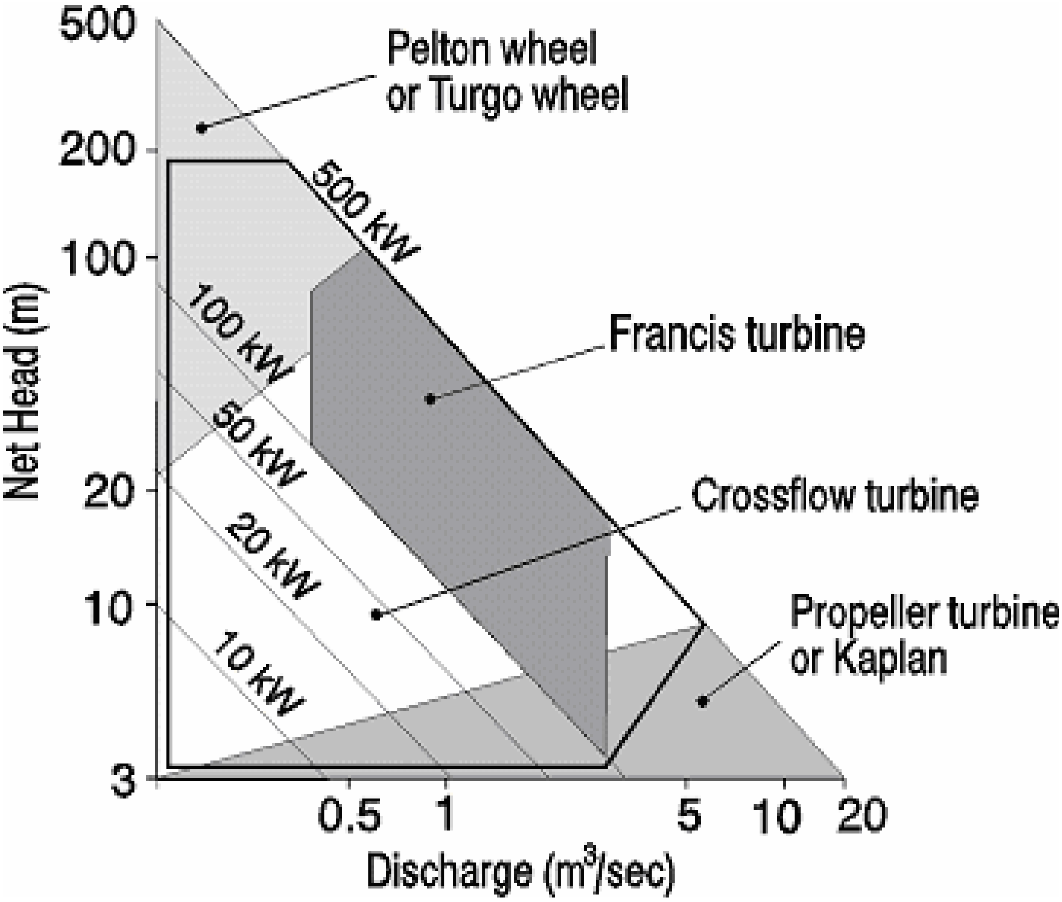
- The slow turning screw turbine is considered more fish friendly as there are no trapping points or pressure discontinuities and fish can pass through freely; some have been installed with screening. However, the Fisheries Board in Ireland may require fish passes and screening to protect against fish entering the screw.



Source: UNIDO, 2009

4.2.2 Turbine selection

Knowing the head and flow rate at a site, Figure 7 can be used to select a suitable turbine. Some interchangeability is possible at certain flow/head combinations.

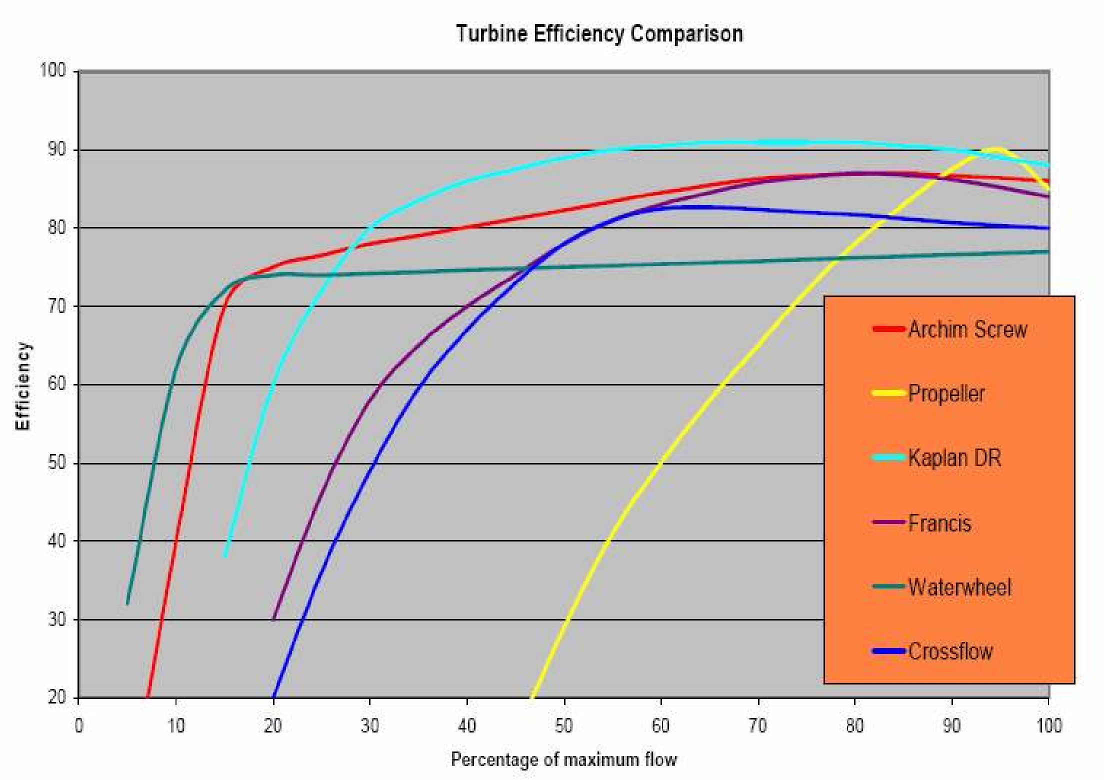


Source: British Hydro, 2009

Figure 7: Turbine selection graph

4.2.3 Turbine efficiency

A significant factor when comparing turbine types is their relative efficiencies both at their design point and at reduced flows. Typical efficiency curves are shown below (Fig. 8).



Source: *Source: Eco Evolution, 2009*

Figure 8: Efficiency comparison chart at reduced flow rate

An important point to note is that Archimedies screw; waterwheel and, kaplan turbines retain very high mechanical efficiencies when running below design flow. In contrast, the efficiency of the francis and crossflow turbines fall sharply if run below half of the design flow. Most fixed-pitch propeller turbines perform poorly expect above 80% of full flow.

5 Current relevant legislation

Water Framework Directive
The Water Framework Directive, (formally 2000/60/EC), is an initiative aimed at improving water quality throughout the EU. It applies to rivers, lakes, groundwater, and coastal waters. The Directive requires a co-ordinated approach to water management in respect of whole river basins with a view to the following;

- Maintaining high status of waters where it exists
- Preventing any deterioration in the existing status of waters
- Reducing chemical pollution
- Achieving at least "good status" in relation to all waters by 2015

A comprehensive programme of activities is currently underway by the Department of the Environment, the EPA, local authorities and other relevant bodies for full implementation of the Directive.

Habitats Directive
The Habitats Directive, (92/43/EC) requires that an assessment of that impact on the habitat is done for projects that are likely to have an impact upon a protected habitat. Protected areas refer to areas within a Special Area of Conservation (SAC) set out in the Directive.

Fisheries Act
Fisheries Act, 1959 sets out the primary fisheries legislation in relation to hydro power, dams, fish passes, screening etc. Experience has shown that fish passage through turbines does infer a mortality factor and for all new hydro-electric developments fish passes and screens must be implemented. These are approved individually by the Department of Communications, Energy & Natural Resources.

Fish Passes
Current legislation requires that every dam in or across any river shall be constructed so as to allow, in one or more parts, the free and uninterrupted migration of all fish at all periods of the year. Good practice requires that fish are capable of negotiating fish passes without undue effort, and fish passes should be easily located by the fish and should not expose the fish to risk or injury. The flow of water from the downstream end of the pass must have sufficient velocity to attract fish. Harming of fish and the failing to preserve a fish pass is considered an offence.

Screens / Gratings
To prevent downstream and upstream migrating fish from entering a headrace or tailrace, legislation stipulates that bar screens with gaps not greater than 2 inches are fitted at the points of divergence from and return to the river channel. During the months when the brood of salmon or trout are descending, the legislation requires a wire lattice (10mm spacing) to be stretched across the gratings at entry to a headrace to prevent the entry of smolts into the headrace. All screens must be regularly inspected and maintained to ensure that they are operating effectively.

Unsuitable schemes

The following types of scheme are likely to be detrimental to the fisheries resource and may be rejected by the planning authority:

- New low head schemes that may cause significant obstacles to fish movement.
- In catchments / sub-catchments of importance such as a spring salmon fishery.
- Placing structures / weirs at the outlet of lakes or creating new impoundments.
- The transfer of water from one catchment to another.
- River channel sections of high fisheries value where the impacts of the proposed hydro scheme development would be unacceptable from a fisheries perspective, i.e. in an area of important spawning or nursery area
- Where there are existing competing uses of the water resource, such as water abstractions, dilution of licensed discharges etc.
- Where there may be an impact on river continuity, fish migration, or fish mortality.

Flow duration curve and flow regime

The current legislation regarding hydro schemes relates primarily to fisheries and ecology aspects. It does not address issues such as compensation flow and allowable level of water abstraction in the river. The *Guidelines on the Construction & Operation of Small-Scale Hydro-Electric Schemes and Fisherie*s provides guidance on this.

The flow-duration curve represents the flow that is equalled or exceeded *n*% of the time. For example, in Figure 9, the flow rate is approximately equal to or exceeds $1.5 m^3 s^{-1}$ for 90% of the time.

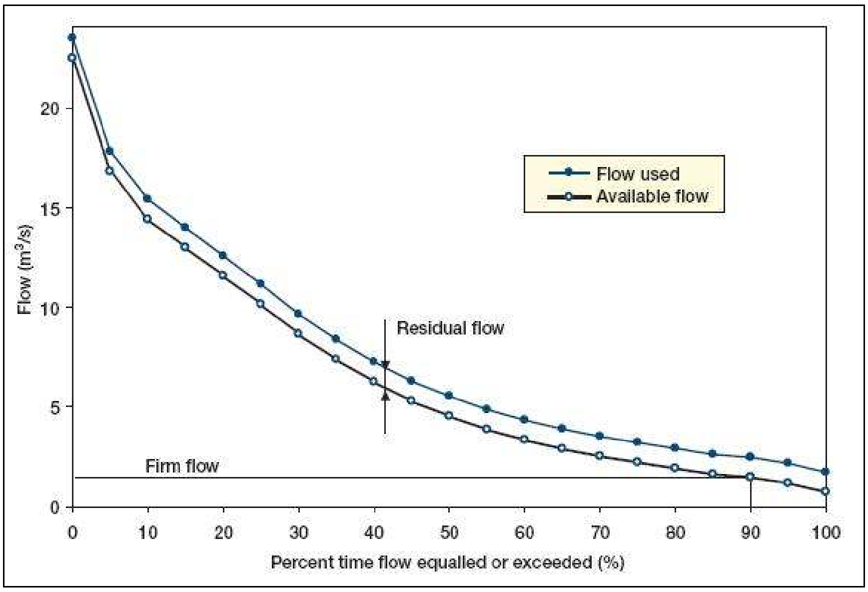


Figure 9: Flow duration curve

The *long term mean flow (Q_m)* is the mean flow rate in a natural river course equal to or exceeding approximately 30% of the time (Q_{30}) over a period of greater then 10 years for gauged sites.

The *base compensation flow* is a minimum flow that must be maintained at all times in the natural channel to ensure a sufficient flow regime is maintained (usually 12.5% of Q_m where Q_m is the long term mean flow).

The *available flow* is the actual flow in the river at intake point before abstraction takes place.

The *residual flow* is the (varying level of) flow remaining in the river when abstraction is taking place. To ensure an adequate residual flow remains in the river, the planning authorities may stipulate that the hydro station throughput should never exceed 50% of the available flow.

Guidelines on the measurement of water abstraction and residual flows
A sufficient means of measuring and recording how much water a hydropower scheme abstracts must be installed.

There should be a notch in weirs designed to take 12.5 % of the long-term mean flow (Q_m). A staff gauge should be inserted to measure the compensation flow at all sites.

For low head schemes, fish passes should be designed as to discharge the residual flow when the head water is at the lowest level**.** In addition, there may be a need to install properly calibrated flow sensors to automatically turn the turbine off when the river level falls below the minimum residual flow level.

6 Stages of development & stakeholders

Outlined below are a number of stages in the development of a hydro project;

- Conceptual idea & consideration of location
- Feasibility study
- Pre-planning & initial stakeholder consultation
- Planning application
- Environmental impact assessment
- Fish assessment study
- Turbine selection
- On-grid / off- grid
- Selling electricity
- Commissioning & operation

Presented below is a condensed step-by-step approach to developing a project along with the relevant stakeholders that need to be consulted. The Central & Regional Fisheries Board and the Department of Communications, Energy & Natural Resources have published *Guidelines on the Construction & Operation of Small-Scale Hydro-Electric Schemes and Fisherie*s. This document provides guidelines which should be followed for proposed small scale hydro-electric schemes and should be consulted for a more in-depth analysis.

6.1 Feasibility study

An initial feasibility study should be conducted in order to assess the technical and financial viability of the project and establish if the project should proceed.

Initial study should identify;

- Location of scheme – ordnance survey map highlighting the proposed development
- State of existing structures – water wheel, weir, headrace, tailrace, fish pass etc.
- Is the proposed development in a Special Area of Conservation?
- Uses including bathing, angling etc.
- Electrical / heating load on site
- Three phase / single phase electricity
- Distance to nearest grid connection point

Technical aspects should identify;

- The potential turbine locations and orientations
- Hydrological analysis i.e. determination of 'flow' and 'head'
- Calculation of potential power and energy output
- Initial costing and economic analysis

6.2 Pre-planning & initial stakeholder consultation

Hydro power developments have the potential for significant impact on the aquatic resource and it is essential that the fisheries resource is adequately protected, without interference to fish movement, habitat or water quality (Central Fisheries Board, 2005). The initial contact when developing a project will be with the *Southern Regional Fisheries Board (SRFB)* and the *National Parks & Wildlife Service (NPWS*) (if the proposed scheme is located in a Special Area of Conservation).

Regional Fisheries Board
The Central & Regional Fisheries Boards are the statutory bodies charged with the protection, conservation, development and management of inland fisheries (Fisheries Act, 1980). The Fisheries Board can advice both the developer and the planning authority in relation to proposed hydro schemes.

The SRFB should be contacted in relation to hydro developments in Kilkenny on a case-by-case basis. They will be able to advice on fish passes, screening, level of abstraction and be able to provide data on fish stocks, flora and fauna, habitat and fish migration.

National Parks & Wildlife Services
The National Parks & Wildlife Service (NPWS) is part of the Department of the Environment Heritage and Local Government and is charged with the conservation of a range of habitats and species in Ireland. Important activities for the NPWS include the designation and protection of Natural Heritage Areas (NHAs), Special Areas of Conservation (SACs) and Special Protection Areas (SPAs).

Under the Habitats Directive a *Fisheries Impact Assessment Study* is required in SAC areas to estimate the ecological interference of the proposed development along with a mitigation plan. Each development is unique so this is done on a case-by-case basis. The NPWS should be consulted if the development is located in a SAC area.

It is advised that both of these bodies are consulted before a planning application is submitted to KCC as a pre-consultation will determine the critical issues relating to each individual project.

6.3 Planning application

Kilkenny County Development Plan, 2008 – 2014 states that *"all proposed hydro developments will be assessed having regard to current capacities in the national grid to accommodate such inputs. Kilkenny County Council will consult with all relevant service providers in this regard at a very early stage in the assessment of such proposals. Appropriate proposals for the reinstatement of mills and associated power generation will be welcomed by the County Council subject to amenity considerations"*.

Small hydro schemes are subject to planning regulation and planning applications should be submitted to the planning department of KCC. Planning application forms can be obtained from the planning department of KCC. The planning department will require best practice to ensure that the proposed hydro development does not present a negative impact on amenity or on the indigenous fish population, including seasonal migration.

Planning applications will be forwarded by KCC to a prescribed list of external and internal consultees for review. Further consultation may be required between parties if a development appears that it may cause the following;

- Significant abstraction or addition of water either to or from surface or ground waters whether naturally occurring or artificial
- Significant discharges of polluting matters or other materials to such waters which could cause serious water pollution or the danger of such pollution
- The carrying out of works in, over, along or adjacent to the banks of such waters, or to any structures in, over or along the banks of such waters, which might materially affect the waters

The relevant bodies that the planning authority may need to consult and why they may need to be consulted:

- Regional Fisheries Board – fish populations, fish pass, screening, flow regime etc.
- National Parks & Wildlife Service (part of the Department of the Environment Heritage & Local Government (DEHLG)) – if the development is located in a SAC and if a fish impact study is required under Habitats Directive.
- The Office of Public Works – hydrological data and if the development relates to any implications which may cause land drainage and flooding.
- Environmental Protection Agency – hydrological data and environmental impact assessment.
- The Heritage Council (part of the DEHLG) – if the development is considered a protected structure.
- The Department of Communications, Energy & Natural Resources (DECNR) – technical engineering advisors within the department can provide technical advice on the development. Application for renewable energy feed in tariff (Refit).
- An Taisce (non-governmental organisation) – consulted if the development is in an special area of conservation and / or if the development will have an impact on the architectural heritage or ecology of the existing structure.
- DCENR – to ensure that the project is in line with the EU Water Framework Directive, (2000/60/EC). The Directive prevents further deterioration in aquatic ecosystems.
- An Bord Pleanála – consulted if the planning application is refused or there are some concerns about the development.
- Public consultation – consulted from the beginning so the implications and benefits of the proposed project are fully understood.
- Land owners – consulted to discuss ownership, access, leasing and way-leave issues.
- Energy supply companies – to obtain a power purchase agreement.

Under the provisions of the Environmental Protection Agency Act, 1992, planning authorities may require that an Environmental Impact Statement is submitted for projects deemed likely to have a significant effect on the environment. Because of the potential negative impact of hydro power developments on fisheries / ecology of the river, it is advisable that some type of environmental assessment should be prepared for all proposed hydro developments.

6.4 Environmental impact assessment

An Environmental Impact Assessment (EIA) is a process for anticipating the effects on the environment caused by the development. An Environmental Impact Statement (EIS) is a document produced as a result of the process.

The Environmental Impact Assessment Amendment Regulations (99//EC), states that an environmental impact assessment (EIA) is required for *"installations for hydroelectric energy production with an output of 20 megawatts or more, or where the new or extended superficial area of water impounded would be 30 hectares or more, or where there would be a 30% change in the maximum, minimum or mean flows in the main river channel"* (Planning & Development, Act 2006).

Most proposed small scale hydro schemes would have an output well below 20MW and may not impound any water. However, a change in 30% of mean river flow is likely to occur and it is in this context that an EIA is required.

For hydro projects, the EIA procedure commences at the project design stage where it is decided if a full EIS is required. The Environmental Assessment Directive, (97/11/EC) sets the thresholds of certain classes of projects (Annex 1 or Annex 2)[1] which require an EIA. Installation of hydroelectric energy production is considered an Annex 2 project and the requirements for an EIA for these types of projects are done on a case-by-case basis.

An initial environmental *screening* and *scoping stage* can determine the requirements of the EIA.

Screening stage
Screening is a process which examines whether or not any development, hydro or other, should require an EIA. However, because of the potential negative impact of a hydro project can have on the fisheries and the environment it is recommended that an EIA or some type of Environmental Appraisal is prepared for all proposed developments.

Scoping stage
The scoping stage determines what is to be included in the EIS. This should draw on the impacts of the hydro development on issues relating to hydrology, habitat, fish

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[1] Annex1: Crude-oil refineries, thermal power stations, inland waterways and port for inland-waterway traffic which permit the passage of vessels over 1,350 tonnes etc.
Annex 2: Installations for the production of hydro electrical energy production, Agricultural; projects for the restructuring of rural land holding etc.

movement, flow, efficacy of fishpasses where present etc. and should following format:

- The proposed development
- The existing environment
- The impacts of the proposed development
- The measures to mitigate adverse impacts
- A non-technical summary

Baseline data will be required to make an accurate comparison. *Guidelines on the Construction & Operation of Small-Scale Hydro-Electric Schemes and Fisherie*s should be consulted for further details to be included in the EIS.

The scoping stage provides an opportunity to consult further with the relevant stakeholders to determine the level of information required on their part. It some cases it may be decided that the development is unacceptable.

All EIA's should be carried out in accordance with Irish Legislation relating to Environmental Impact Statements and in accordance with the Environmental Protection Agency's *Guidelines on the Information to be contained in Environmental Impact Statements* and *Advice Notes on Current Practice in the preparation of Environmental Impact Statements*.

6.5 Fish assessment study

The Habitats Directive, (92/43/EEC) requires that an assessment of that impact on the habitat is done for projects that are likely to have an impact upon a protected habitat. Protected areas refer to areas within a Special Area of Conservation (SAC) set out in the Directive[2].

There are 8 SACs in County Kilkenny; of which the following two relate to hydro projects (see Fig. 11);

1) The rivers Barrow & Nore
2) The lower river Suir

Old mill / hydro sites to be developed along these rivers would require an assessment to be preformed of the likely impact on ecology and species specific to each site for each project. Baseline data on fisheries resource, fish migration and flow, habitat, efficacy of fish passes where present will be required. The SRFB and NPWS should be consulted for the detail required for this study. Each development is unique so this is done on a case-by-case basis.

As a guide, requirements for a fisheries impact assessment include the following;

- Description of the existing environment including fisheries information and hydrological data

[2] Irish habitats include raised bogs, active blanket bogs, turloughs, sand dunes, machair (flat sandy plains on the north and west coasts), heaths, lakes, rivers, woodlands, estuaries and sea inlets. The 25 Irish species include salmon, otter, and freshwater pearl mussel.

- Description of the proposed development including site features and turbine description
- Prediction of likely impacts
- Evaluation of the significance of impacts
- Proposed avoidance / mitigation measures
- Monitoring programme

The Eastern Regional Fisheries Board produced a useful document on the *Requirements for the protection of Fisheries Habitat during Construction and Development Works at River Sites.* This should be consulted along with *Guidelines on the Construction & Operation of Small-Scale Hydro-Electric Schemes and Fisheries* for further details to be included in the fish impact study.

6.6 Turbine selection

River flow rate and head can give a good indication for selecting a turbine based on the previous chapter in this report, however, consultation with reputable turbine supplier or adviser is advised.

6.7 Electricity generated

The electricity generated by the hydro turbine can be used on site or exported to the grid but this will depend on the load on-site and proximity to the grid. Options include;

- Direct current (DC) generation; connect to battery bank to store generated DC electricity. When the battery is fully charged electricity can be diverted to a secondary load e.g. to heat water. Suitable for off grid applications.
- Alternately current (AC) generation; connect to existing on-site electricity supply; a transformer and two-way meter will be required. Required for grid connected micro-generation and smaller units.
- Auto-production; use all electricity generated on site, where the maximum export capacity (MEC) is less than the site base load.
- Alternatively, connect to medium voltage 10kV / 20kV network; a connection line, a transformer and two-way meter will be required. A grid interaction study will need to be preformed. [*For grid connection where the generator size is less than or equal to approximately 50kW, an interaction study may not be necessary*].

A detailed map of the 10/20kV network is available from ESB Networks at the following web address:
http://www.esb.ie/esbnetworks/en/about-us/our_networks/index.jsp

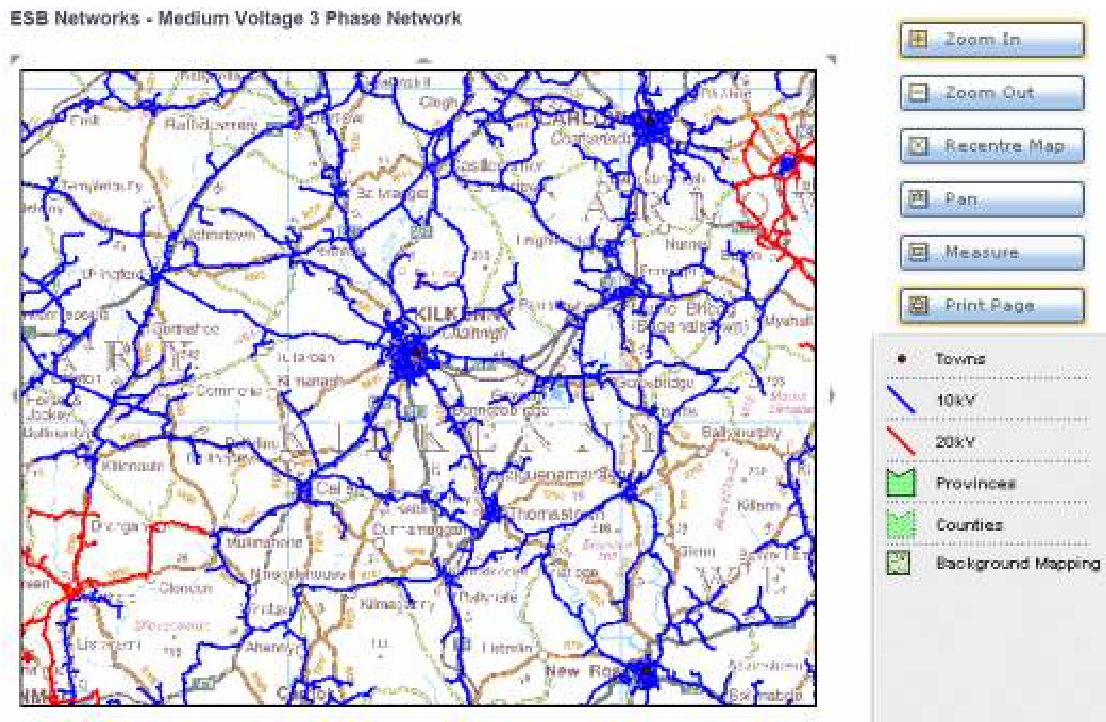


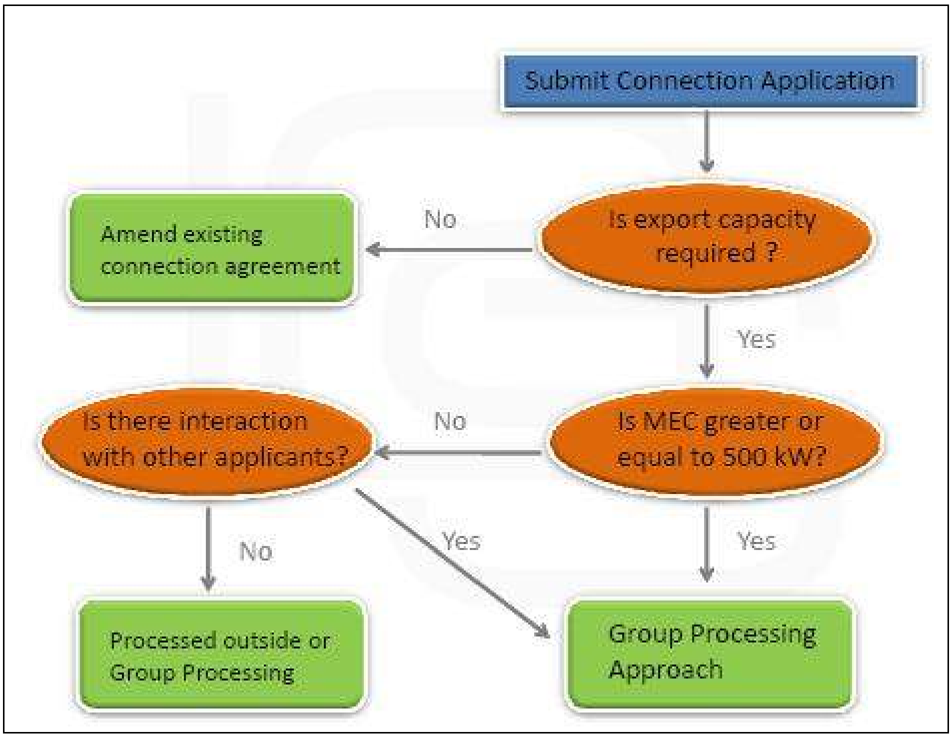
Figure 10: Medium Voltage Network

Connecting to the grid

For information on connecting to the grid, Sustainable Energy Authority of Irelands report on *A Guide to Connecting Renewable and CHP Electricity Generators to the Electricity Network* should be consulted. Detailed procedure for connecting a micro-generator to the grid is available from ESB Networks: http://www.esb.ie/esbnetworks/generator_connections/micro_gen_connections.jsp

Since December 2004, large scale commercial renewable generators (> 0.5 MW) wishing to connect to the transmission or distribution systems have been subject to the “group processing approach” (GPA) where applications are considered in a series of successive “Gates”. There can be considerable delays in this process and for smaller projects it is desirable to be processed outside of the GPA.

The Commission for Energy Regulation (CER) is the regulator of the electricity sector in Ireland. The CER allows renewable generator applications with a maximum export capacity (MEC) less than 0.5MW (500kW) to seek exemption from the GPA. Any such exemption requires approval from the CER; refer to CER/09/099. Hydro sites considered in this study will have an MEC less than 0.5MW.



Source: Sustainable Energy Authority of Ireland, 2008

Figure 11: Connection process

ESB networks are responsible for connecting generators to the distribution network and applications should be submitted to ESB networks. Renewable generators wishing to connect to the grid and who seek to be processed outside the GPA should submit the NC5 form to ESB Networks, http://www.esb.ie/esbnetworks/downloads/Application_Form_for_Embedded_Generators.pdf (ESB Networks, 2009).

Authorisation to construct / licence to generate

Generators wishing to construct a new generating station or reconstruct an existing generating station with a MEC greater than 1MW must obtain the following from the CER prior to commencing work;

- Authorisation to construct a generating station
- Licence to generate electricity

Projects with an installed capacity less than 1MW are not required to obtain authorisation or licence; of which is the main interest in this study. However, projects must notify the CER of the proposed project.

6.8 Sale of electricity

When designing a hydro plant, the electricity generated may be used directly on-site to displace electricity imports or the electricity may be exported in order to receive a fixed payment from an electricity supplier. It may be desirable to use the power on-site to displace the cost of imported electricity (approximately 15c/kWh).

Two types of support mechanisms are in place depending on the size of the generator; the first is for generators greater than 11kW – *Renewable Energy Feed-in Tariff Scheme,* and the second is for generators less than 11kW – *Micro-generation Scheme*.

Renewable Energy Feed in Tariff Scheme
For larger scale projects (<11kW), the Government support scheme, referred to as the Renewable Energy Feed in Tariff (REFIT) provides 8.05c per kWh (in 2008) for electricity exported to the national grid from hydro generators. This tariff is partially indexed linked to inflation and is valid for 15 years.

To receive a REFIT, a developer must secure a Power Purchase Agreement (PPA) from either a Government source or a private energy supply company.

Micro-generation Scheme
ESB Customer Supply provides renewable micro-generators with a power rating of less than or equal to 11kW for three phase or 5.75kW for single phase with a financial support mechanism for electricity exported to the national grid, these include;

- An export payment of 9 cents per kWh.
- An extra support payment of 10 cents per kWh for the first 3,000kWh exported annually. This payment will be given to the first 4,000 micro-generators connected in the next 3 years and will be paid over a 5 year period.
- An import / export meter free of charge to the first 4,000 domestic customers installing micro-generators in the next 3 years.

The ESB extra support payment will be available to all electricity suppliers who offer an export tariff for micro-generation. The supplier who buys exported electricity from a micro-generator will also sell them their imported electricity. For further details see, http://www.esb.ie/esbnetworks/en/generator-connections/micro_gen_connections.jsp.

7 Existing mills & structures

In 1985, the Department of Energy published a document on *Small-scale Hydroelectric Potential of Ireland*. In this, 568 potential hydro sites were identified across Ireland; 32 were identified in County Kilkenny (Table 2: Potential hydro sites in Kilkenny). These sites mainly consisted of old mills, weirs and locks.

This publication provided data on for each site on catchment areas, annual rainfall, flow rates and head. Using more up-to-date data from the EPA Hydro-net and OPW hydro site on flow rates and rainfall, the potential power (kW) and energy output (MWh) from each site was calculated (Table 2: Potential hydro sites in Kilkenny).

Since abstraction should not exceed the available flow rate (Q_{30}) in the river and stipulation may require abstraction level to be 50% of the available flow. This value was used to calculate potential power output for mill sites. For weirs along the River Barrow and larger mills along the River Nore 25% of the available flow was used. The SRFB should be consulted on a case by case base for the allowable abstraction level.

[Note: Headrace capacity can be calculated and percentage of available flow worked out; this was not done in this report.]

Table 2: Potential hydro sites in Kilkenny

	River	Easting, Northing	Available flow m^3/s	Head m	Potential Power kW	Potential Energy MWh
1	Barrow	268800, 157600	28.22	1.55	81	423
2	Barrow	268600, 155500	30.86	2.6	148	776
3	Barrow	268700, 153400	32.23	1.95	116	608
4	Barrow	272600, 145500	35.09	3.33	215	1,130
10	Dinin	253600, 173000	2.75	2.9	29	154
11	Dinin	253500, 171500	2.84	2.1	22	115
12	Nore	250000, 158000	24.21	1.83	82	428
13	Nore	251200, 155800	25.31	1.6	75	392
14	Nore	253200, 154550	25.96	1.4	67	351
15	Nore	255250, 149200	26.66	2.0	98	515
16	Kings	248000, 143200	4.82	1.9	34	177
17	Kings	251200, 143700	6.06	1.85	41	217
18	Kings	252300, 143700	6.08	2.15	48	253
19	Nore	258500, 141600	35.51	1.6	105	549
20	Nore	258300, 141500	35.51	1.7	111	584
21	Nore	258500, 141600	35.51	2.13	139	731
22	Little Arrigle	257150, 140300	0.90	4.85	16	85
23	Douske	270830, 143780	0.34	9.5	12	63
24	Arrigle	260800, 138300	0.86	4.6	15	76
25	Arrigle	260600, 137600	0.84	5	15	81
26	Clodiagh	267550, 135000	0.19	9.3	6	34
27	Blackwater	253500, 122100	2.18	1.9	15	80

28	Blackwater	257000, 120000	2.28	1.95	16	86
29	Blackwater	256500, 118200	1.92	3.58	25	133
30	Blackwater	256900, 118250	2.28	11.9	100	526
31	Blackwater	257000, 117200	1.99	2.1	15	81
32	Unnamed	259400, 115700	0.78	4.6	13	70
					1,658	8,716

The potential (kW) power output in table 2 is based on estimations and in practice more or less flow may be allowed through the turbine. As such these figures should only act as a guide for anyone wishing to peruse a development. The SRFB should be consulted on the suitable level of extraction from the flow in the river on a case-by-case basis.

A map of County Kilkenny was generated illustrating the location and potential output at these sites (Fig. 12).

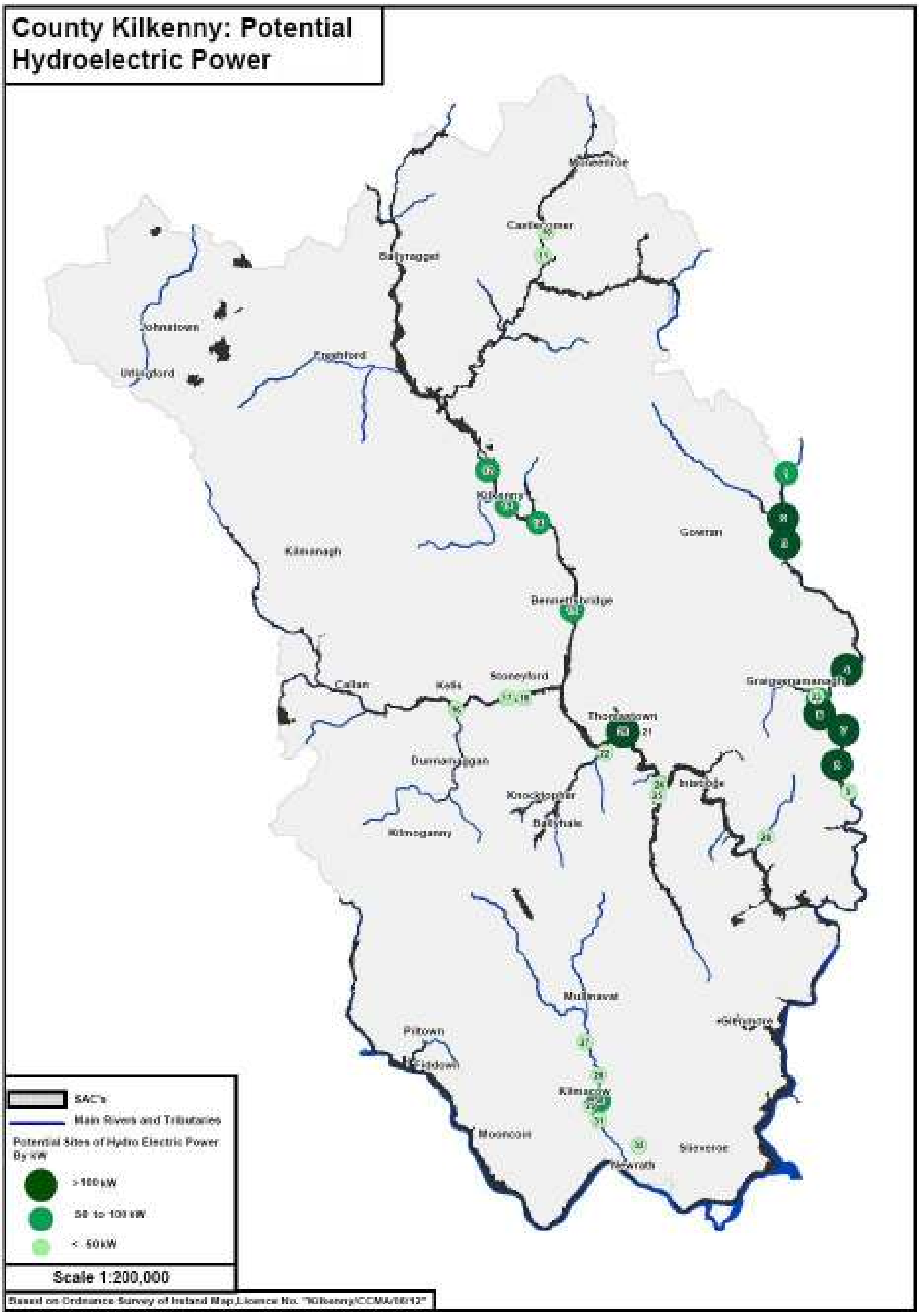


Figure 12: Hydro site locations and potential outputs

Not all sites will be suitable for development or redevelopment into hydro generating stations and consideration needs to be given to prioritising sites. The following criteria should be considered;

- Sites with a capacity of less than or equal to 50kW as a grid interaction study will not be required.

- Proximity to the national grid; further consultation with ESB Networks will be required.
- Protected structures (*italics* in Table 3: Sites with potential capacity between 11 – 50kW); a preplanning meeting should be arranged with the conservation officer in KCC for these sites.

Based on these criteria, sites were prioritised and are listed in table 3. In addition, factors such as community development and involved will need to be considered for funding under KLP Rural Development Strategy 2007 – 2013.

Table 3: Sites with potential capacity between 11 – 50kW

No.	River	Location	Structure	Potential kW	Potential MWh
10	Dinin	Castlecomer	**Weir*	29	154
11	Dinin	Ballyhimmin, Castlecomer	**Corn Mill*	22	115
16	Kings	Killinny, Kells	**Killinny Corn Mill*	34	177
17	Kings	Kells	Corn Mill	41	217
18	Kings	Stoneyford	Corn Mill	48	253
29	Blackwater	Kilmacow	Corn Mill	25	133

** protected structures*

Sites with a capacity less than 11kW (three-phase) and 5.75kW (single-phase) should be consideration under the Micro-generation Scheme as per table 4. Site capacity can be tailored to meet Micro-generation Scheme and avail of micro-generation tariff.

Table 4: Micro-generation (< 11kW)

No.	River	Location	Structure	Potential kW	Potential MWh
22	Little Arrigle	Jerpoint	**Corn Mill*	16	85
23	Douske	Graiguenamanagh	Corn Mill	12	63
24	Arrigle	Ballyduff	**Flour Mill*	15	76
25	Arrigle	Ardshinnan, Inistioge	Saw Mill	15	81
27	Blackwater	Ballyhomuck, Mullinavat	River	15	80
28	Blackwater	Dangan, Mullinavat	Corn Mill	16	86
32	Unnamed	Smartscastle, Dunkitt	Corn Mill	13	70

For sites with a larger capacity, the abstraction rate can be adjusted to accommodate a turbine with a capacity of 50kW or less so sites in table 5 can be considered.

Table 5: Sites with larger capacity (<50kW)

No.	River	Location	Structure	Potential kW	Potential MWh
2	Barrow	Castlecomer	Weir	148	776
3	Barrow	Goresbridge	Weir	116	608
4	Barrow	Graignamanagh	Weir	215	1,130
13	Nore	Dukesmeadows, Kilkenny city	Ormonde Woollen Mill / Marble Mill	75	392
19	Nore	Thomastown	Greenan Flour Mill	105	549
20	Nore	Thomastown	Corn Mill & Island Flour Mill	111	584
21	Nore	Thomastown	Dangan Flour Mill	139	731

8 New projects

8.1 Site survey

A site survey should be conducted for all new sites. See Appendix 2 for procedure of initial on-site assessment.

8.2 Calculating resource

When a site has been identified as topographically suitable for hydropower, the first task is to investigate the head and flow rate at the site. Retscreen can be used to calculate the viability of a project.

8.2.1 Measuring head

Head is the difference between the headrace and tailrace elevations. The following are some ways to determine head;

1. Pressure Gauge

If there is a pipeline installed with flowing water, then connect a water pressure gauge to measure the pressure. The head can be worked out from the measured pressure. This pressure should be measured with the pipe completely filled with water.

2. Using a Level

The use of a dumpy level is the conventional method for measuring head. A simplified version of this method, without the specialist equipment is outlined below.

- Starting at the lowest point (e.g. where the hydro turbine may be situated) view a point at eye level (horizontal) on the ground ahead.
- Walk up to point.
- Repeat this step until your eyes are level with the water source (where the pipeline would begin).
- Measure the distance between your eyes and feet (in meters) and multiply by the number of times you walked. The cumulative total of the vertical measurements is the head.

3. Altimeter

Altimeters are used to measure the altitude of an object above a fixed level and these can be used for high head sites.

4. Ordnance survey map

Locate the water source and the potential site for your hydro project on a reasonably accurate contour map. Count the contours lines; this method is useful for high head sites.

5. Global positioning system (GPS) receiver

An accurate GPS receiver may be used to measure the headrace and tailrace elevations above sea level.

8.2.2 Measuring flow

1. Velocity method

For an ungauged watercourse, where observations of discharge over a long period are not available, the flow rate can be measured by physically measuring the flow. Throw a floatable devise in the river and measure how long it will take to flow over a particular distance (m sec^{-1}). Multiply this by an average cross section of the river (m^2) to determine the flow rate in m^3 sec^{-1}.

2. Gauged site

For gauged sites the *long term mean flow rate* can be obtained from hydrometric records or from hydrological data for the river in question from local authority (EPA Hydro-net) or OPW measured data. The period of record should preferably be in excess of 10 years and be a full number of hydrological (or calendar) years.

3. Ungauged site

Where long term flow data is unavailable the long term mean flow is estimated on the basis of catchment area and long term rainfall records (preferably 30 years record) and evaporation and transpiration data.

A calculation tool was developed for this method (Figure 13: Hydro calculation tool) and available as an excel spreadsheet with this report.

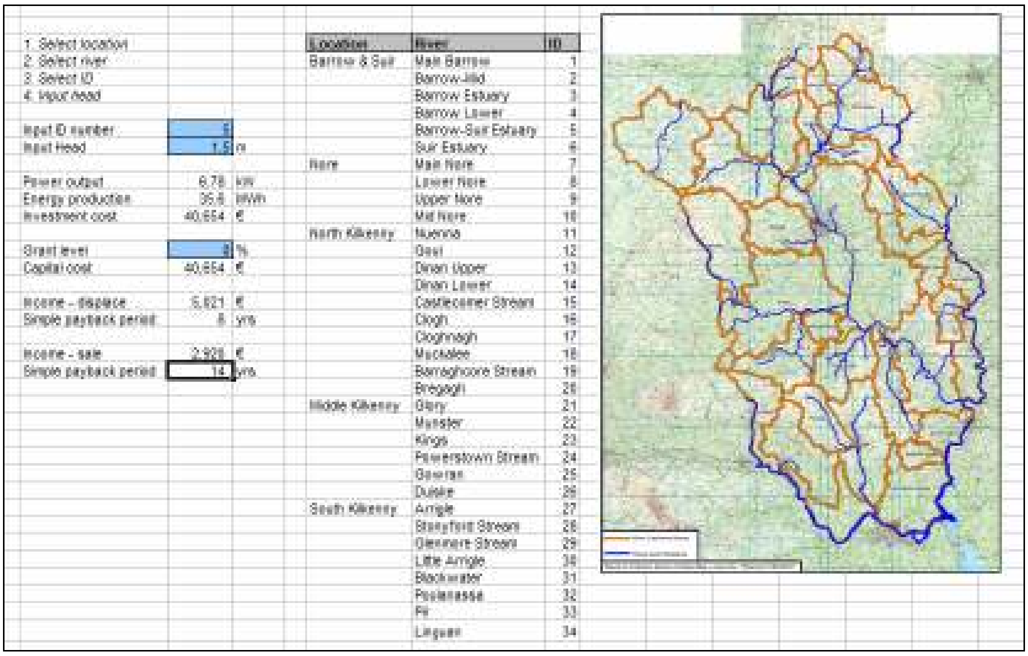


Figure 13: Hydro calculation tool

Steps involved;

1. Identify the catchment area for the river from the map (Figure 14: Map: Catchment areas in County Kilkenny).
2. Identify the ID number for the catchment area.
3. Input ID number along with the measured head into the calculation tool.
4. Potential power and energy output calculated.

This methodology does not take into account the following and should only be used as a guide;

- Does not take into account the effects of particular local conditions.
- Does not take into account effects of catchment geology and soil type.

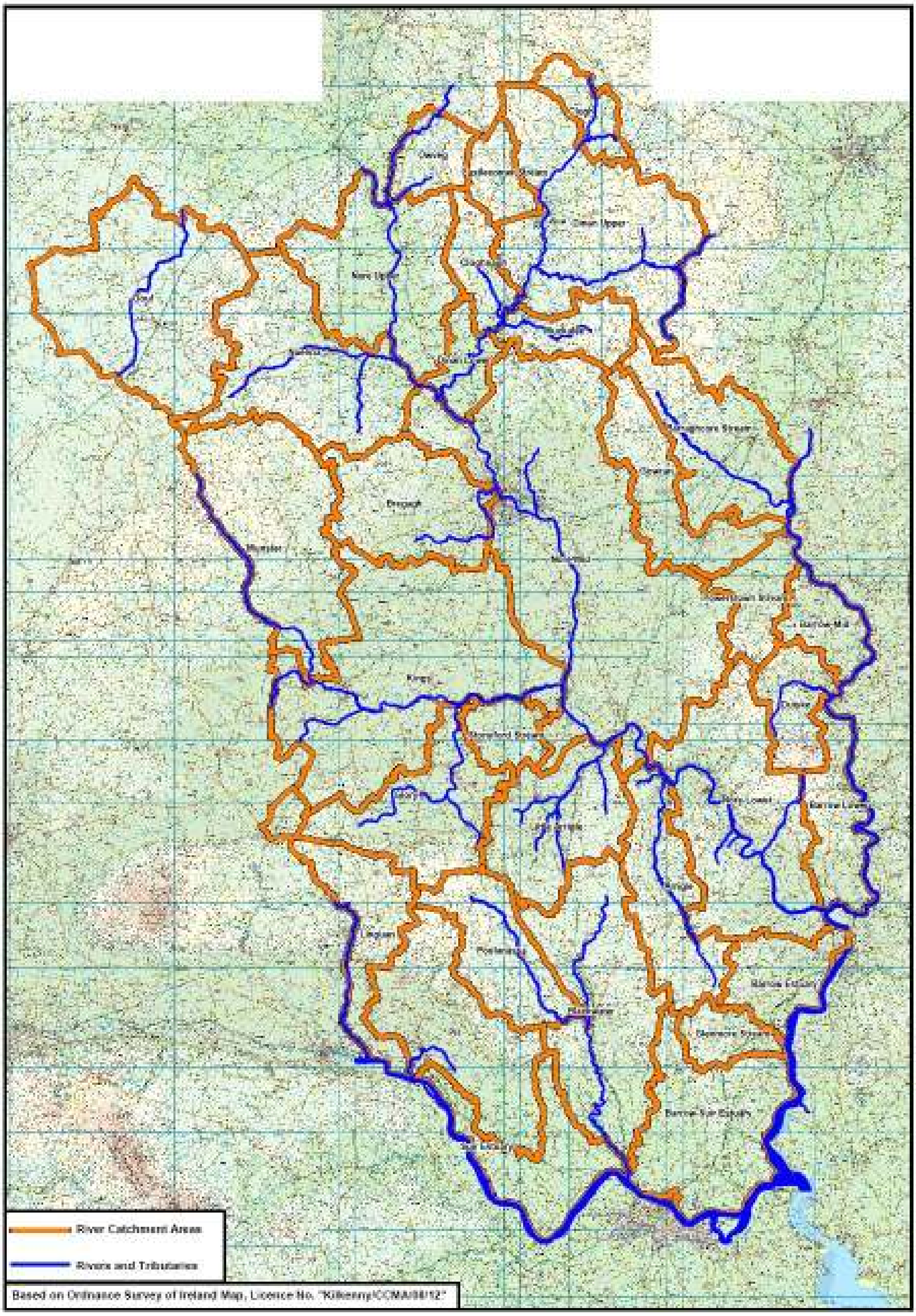


Figure 14: Map: Catchment areas in County Kilkenny

8.2.3 Retscreen hydro model

The Retscreen Software is a decision support tool developed to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of renewable energy and energy efficient technologies (RETs). The software can be downloaded from the RETSCREEN website and can be a useful first step tool for calculating the viability of a project.

8.3 Economics

Most of the costs incurred in a hydro scheme will usually occur at the building stage of the project. Once the project is operational it can run for several years without substantial further expenditure.

Investment costs include;
- Machinery
- Civil works
- Electrical works
- External costs including planning application, engineering services etc.

Environmental costs include;
- Repairing weir
- Fishpass & screening
- Environmental impact assessment
- Fish impact assessment

Running costs include;
- Leasing
- Metering
- Rates
- Maintenance
- Insurance

Grants may be available from Kilkenny Leader Partnership or Sustainable Energy Authority of Ireland. Both organisations should be consulted on the relevant grant assistance available.

9 Conclusion

This report presents an overview of the process involved in developing a hydro project and provides recommendations and support for future developments in County Kilkenny. Some of the main points and conclusions are summarised below.

- The potential power output from a hydro turbine is proportional to the head and the rate of flow available from the river. Power output will be limited by the efficiency of the system being used. Energy output depends on the availability of the site.

- The head is the vertical drop in water entering the turbine. This can be physically measured using the level method.

- Flow rates can be obtained from hydrometric data for gauged sites from the Environmental Protection Agency Hydro-net database (http://hydronet.epa.ie/hydronet.html) or from the Office of Public works hydro database (http://www.opw.ie/hydro/).

- For ungauged sites a hydro calculation tool was developed. This uses measured head and selected catchment area to calculate the potential power and energy output.

- Turbine selection can be done by referring to the turbine selection graph and efficiency comparison chart, and consulting with a reputable engineer.

- Hydro sites are subject to planning permission and KCC should be consulted in relation this.

- For any development, one of the main concerns will be in relation to the impact the development will have on the local fish population. The SRFB should be consulted on a case-by-case basis to review this. It is essential that fish passes and screens are placed in such a way as to protect fish from entering the hydro turbine.

- The Barrow and Nore Rivers are designated as SACs so any proposed development along these rivers will require an impact study to be performed. The SRFB and the NPWS should be consulted on this.

- It is recommended that a preplanning meeting is arranged with the conservation officer at KCC for sites designated protected structures.

- ESB networks should be consulted in relation to grid connection. Sites with a capacity of less than or equal to 50kW do not require an interaction study.

- Revenue can be obtained by securing a power purchase agreement from an energy supply company, or for micro-generators obtaining an export payment.

Alternatively, auto-production allows a site owner to offset their electricity demand.

- Grants may be available from Kilkenny Leader Partnership or Sustainable Authority of Energy Ireland. Both organisations should be consulted on the relevant grant assistance available. Factors such as community development and involvement will need to be considered for funding under KLP Rural Development Strategy 2007 – 2013.

It was concluded that there exists an untapped hydro resource in County Kilkenny that has the potential to be developed to provide revenue and employment in local areas. A map illustrating sites with potential output and a calculation tool were produced; these will act as an initial guide for anyone starting a project.

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Appendix 1: Hydro schemes in commercial operation

Table 6: Large scale hydro projects in Ireland

Generating station	Address	County	Operator	Capacity (MW)
Ardnacrusha	Ardnacrusha	Clare	ESB	89
Lee	Carrigadrohid	Cork	ESB	8
Lee	Inniscarra	Cork	ESB	19
Erne	Cliff	Donegal	ESB	20
Erne	Cathleens Falls	Donegal	ESB	45
Liffey	Pollaphouca	Wicklow	ESB	30
			Total	**211**

Source: Department of Communications, Energy & Natural Resources, 2009

Table 7: Medium scale hydro projects in Ireland

Generating station	Address	County	Operator	Capacity (kW)
Lodge Mills	Bagnelstown	Carlow	International Trailers Ltd	110
	Milford	Carlow	Strongstream Ltd	340
Ardnacrusha	Parteen Weir	Clare	ESB	600
Derryclogher	Bantry	Cork	Hibernian Hydro Ltd	370
Weir Street	Bandon	Cork	Bandon Charitable Resources	66
Glenlough	Adrigole	Cork	Glenlough Generations Ltd	375
Owenbeg	Bantry	Cork	Owenbeg Natural Power Co.	850
Clady	Ballyshannon	Donegal	ESB	4,000
Meenachallow	Glenties	Donegal	Hibernian Hydro Ltd	325
Barnesmore	Barnesmore Gap	Donegal	Hibernian Hydro Ltd	485
Lowreymore	Barnesmore	Donegal	Hibernian Hydro Ltd	550
Anarget Upper	Donegal	Donegal	Saporito Ltd	840
Lough Belshade	Edergole, Barnesmore	Donegal	Edergole Energy Ltd	650
Hills Mills	Lucan	Dublin	Munslow Ltd	104
Flesk Mills	Killarney	Kerry	Flesk Mills Restoration Project	150
Ferta River	Cahirciveen	Kerry	Trafalgar Consultants Ltd	300
Inchinanagh	Kilgarvan	Kerry	Hibernian Hydro Ltd	490
Ashgrove Mill	Kenmare	Kerry	Sandview Ltd	650
Cottoners	Killorglin	Kerry	Trewell Ltd	1,032
Liffey	Leixlip	Kildare	ESB	4,000
River Liffey	Celbridge	Kildare	Energy Control Systems Ltd	55

Athgarvan Grain Co	Athgarvan	Kildare	Michael Keogh	20
Inch Mills	Sion Road	Kilkenny	Inch Hydro Ltd	40
Greenville Mill	Kilmacow	Kilkenny	Benedict Behal	75
Drying Plant	Bennettsbridge	Kilkenny	Nicholas Mosse Pottery	28
Milling Plant	Bennettsbridge	Kilkenny	Nicholas Mosse Pottery	42
	Askeaton	Limerick	Aeroboard Ltd	240
Tarmonbarry Weir	Tarmonbarry	Longford	Riverview Electric Ltd	444
Nadirckmore	Tourmakeady	Mayo	Nadirckmore Energy Ltd & PCAS	560
Springvale	Ballinrobe	Mayo	Langan Springvale Ltd	100
Millbrook	Navan	Meath	Paulson Investments Ltd	200
Belmont	Ferbane	Offaly	Wilmour Holdings Ltd	400
	Boyle	Roscommon	Stewart Hydro	132
Collooney Hydro	Collooney	Sligo	Baydeen Ltd	500
	Ballisodare	Sligo	Rockygrange Hydro Electric Ltd	2,190
Cahir Mills	Cahir	Tipperary	Cahir Commercial Enterprises	140
Holycross	Thurles	Tipperary	Michael Dawn	200
Castlegrace	Clogheen	Tipperary	Nicholas de Grubb	80
Kilmacow Mill	Kilmacow	Waterford	Dominic Behal	22
Clohamon Hydro	Kilmacow	Waterford	Millstream Power Ltd	135
Coola Mills	Kilbeggan	Westmeath	Coola Mills Ltd	110
Liffey	Golden Falls	Wicklow	ESB	4,000
			Total	**26,000** ***(26MW)***

Source: Department of Communications, Energy & Natural Resources, 2009

Appendix 2a: Initial site survey

Hydrological and structural assessment

1. Date…
2. County….
3. Townland…
4. Grid reference number…
5. Catchment area (km2)…
6. Annual rainfall (m)…
7. Flow rate (m3/s)…
8. Head (m)…
9. Existing features…
10. Weir… Existing / needs repair / needs major repair
    a. Height
    b. Length
11. Headrace… Existing / needs repair / needs major repair
    a. Length
    b. Width
    c. Depth
12. Penstock… Existing / needs repair / needs major repair
13. Powerhouse… Existing / needs repair / needs major repair
    a. Length
    b. Diameter
14. Distance to nearest ESB network…
15. Tailrace… Existing / needs repair / needs major repair
16. Access…
17. Amenity…
18. Fisheries…

Appendix 2b: Requirements for a detailed project development assessment

FEASIBILITY TO ASSESS
THE POTENTIAL TO
DEVELOP HYDRO-POWER TO GENERATE RENEWBLE ENERGY
AT THE RIVER BARROW (AT ….)

Location details and description of site

1. Obtain an Ordnance Survey map (scale 1:2500-1:10560).
2. Obtain a detailed site plan (scale 1:100-1:500).
3. Provide an overview description of the proposed development.

Power and energy potential

4. Obtain historical flow rate data available for the site from EPA Hydro-net database (http://hydronet.epa.ie/hydronet.html) or from the OPW hydro database (http://www.opw.ie/hydro/).
5. Carry out on-site sampling or calculations of available flow rates based on volume of water to be diverted from the main channel.
6. Provide measurements of gross and net head available.
7. Determine appropriate Turbine Type and Rated Output.
8. Determine expected Capacity Factor and annual energy output.

Equipment Requirements and draft design

9. Provide schematic diagrams for Civil Works including fish pass details.
10. Identify likely disruption to existing infrastructures.
11. Provide specifications and wiring diagrams to include electrical generator, inverter, protection, controls, data monitoring equipment, and grid interface equipment to comply with CER and ESB Networks requirements.
12. Provide details of proposed construction schedule.
13. Provide a maintenance schedule for the proposed generator system identifying service intervals and requirements and requirements for automatic alerts.

Grid integration

14. Determine details necessary for access to the Grid.
15. Complete relevant Grid connection application forms based on information available from the findings of this study, and identify relevant sources for any inputs not available:
    a. E.g. Form NC5 or NC5A: ‘Application for a New Grid Connection’ as appropriate based on reference to CER direction CER/09/099 or any update;
    b. E.g.: CER Authorisation to Construct Application Form & CER Licence to Generate Application Form

Environmental and planning

16. Identify full List of Stakeholders and determine level of engagement required.
17. Obtain initial feedback from consultation with the Central Fisheries Board.
18. Planning Requirements - Obtain initial feedback from consultation with the local planning authority including environmental impact assessment screening and scoping analysis.
19. Determine appropriate Health and Safety requirements.

Financial details

20. Provide full details of expected development costs:
    - Planning - Environmental Impact Assessment;
    - Equipment & Materials - Hydroelectric Turbine, Civil Works including fish pass and site remediation, Mechanical works, Electrical Works, cables and connections, etc;
    - Installation: Electrical, Civil, and Mechanical and including commissioning costs;
    - Specify any other likely costs.
21. Provide a projected (10-15year) Cashflow analysis for the system based on development costs, operational costs and expected incomes (e.g. REFIT).
22. Provide an outline of expected warranties and guarantees for equipment.

Other

23. Provide comparison with models of best practice, i.e. identify reference sites.
24. Reference any relevant hydroelectric turbine and other standards e.g. IEC 60041 - Performance test, IEC 60193 - Model acceptance tests.

Next Steps

25. Provide a schedule of further requirements up to construction stage.