TLS ENERGY

A Feasibility Study into the use of an Archimedean Screw Turbine for Hydroelectric generation at Knaresborough Lido, Project Number 858

Client:

Renaissance Knaresborough (Gillian Lacey)

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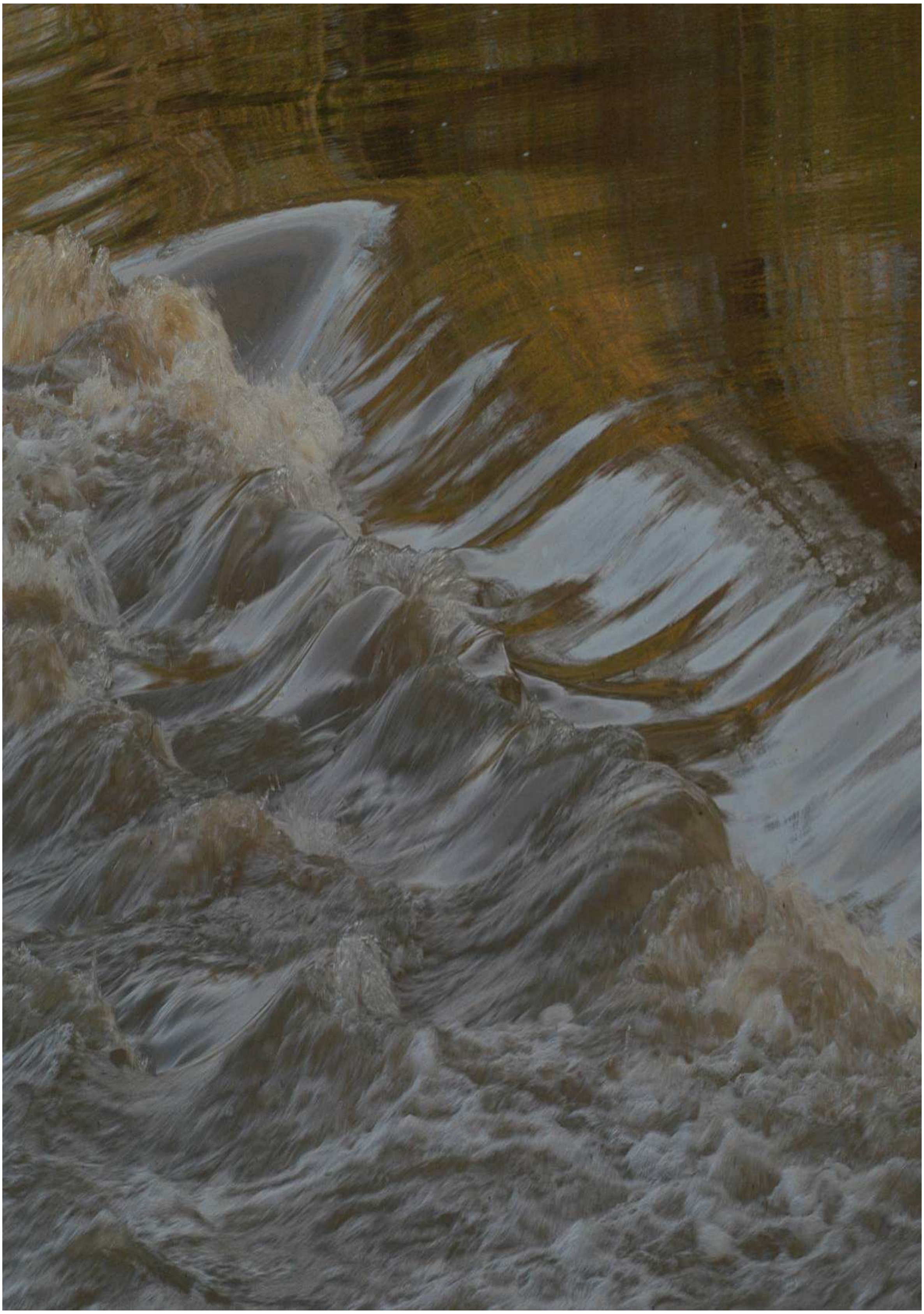

ANALYSIS DOCUMENTS

APPENDICES

Version control:

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Summary

TLS Renewable Consulting Ltd into was engaged to assess potential for installing a hydroelectric generating system at Knaresborough Lido Leisure Park, making use of the fall at the weir adjacent to a former watermill. Now known as the Watermill Café, historically this site has also been known as Lund's Mill, Haver Mill, and Plompton or Plumpton Mill.

Various different types of "low-head" hydropower system could be used at this site where the usable fall in height is no more than 2m; these are summarised in an Appendix. Independent cost / benefit comparisons have previously been carried out, identifying the Archimedean screw as likely to provide the best return at sites of a similar nature.

This study was commissioned to assess the potential for generation using an Archimedean screw device. Options are compared and summarised in Energy Capture and Cost/Benefit Calculations.

Figure 1: The mill and weir prior to 1909

Option 1 assesses the largest scheme possible without major modification of the wheelpit, which would be to install an Archimedean screw within or descending from the existing mill wheelpit. Generating at up to 40 kW, and running equivalent to full power for 55% of the year, this is predicted to cost approximately £495,000 to install, producing a net annual income of around £22,000, at a return rate of up to 4.4%, saving 48 tonnes of CO_2 emissions per annum.

Option 2 assesses a scheme sized to take the mean flow of the river – conventionally the maximum size permitted by the EA, and unlikely to raise significant issues during consenting - which would be to install an Archimedean screw downstream of the wheelpit, enlarging the wheelpit and taking flow via this into a new supporting structure. Generating at up to 80 kW, and running equivalent to full power for 39% of the year, this is predicted to cost approximately £745,000 to install, producing a net annual income of around £32,500, at a return rate of up to 4.4%, saving 69 tonnes of CO_2 emissions per annum.

Option 3 assesses a scheme sized to take 1.3x the annual mean flow of the river – the largest sizing likely to be permitted by the EA if they consider the scheme to be low risk - which would be to install an Archimedean screw downstream of the wheelpit, largely replacing the wheelpit with a new wider channel structure. Generating at up to 100 kW, and running equivalent to full power for 35% of the year, this is predicted to cost approximately £900,000 to install, producing a net annual income of around £36,000, at a return rate of up to 4.0%, saving 77 tonnes of CO_2 emissions per annum.

See appended Analysis Documents for detail. All predicted values are calculated as of date of this document. Incomes were predicted based on current purchase price of electricity at the local point of connection. FITs are no longer available (2019) and no other subsidy mechanism is in force. With no subsidy, the financial value of output now lies once more only in its price if sold onto the grid (which remains modest) or its worth in offsetting the need to buy electricity (which depends on the operator’s electricity needs). Electricity is here valued at an average of 15p/kWh for units consumed locally and 6p/kWh for excess exported to the grid, with local demand at the Lido having been modelled on real consumption during an example year. In all cases, benefit would improve if the site were to experience higher baseload in future, i.e. higher demand during periods where consumption is currently low.

Hydrology Assessment

Energy can be extracted from falling water and harnessed to provide mechanical or electrical power. The theoretical amount of energy available from any given site is directly proportional to two factors: the actual volume of water passing the site (the flow) and the height through which the water falls at the site (the head). In order to assess the actual potential of this site, it is necessary to have measurements of the changing flow over the course of several years, and ideally also the varying head which occurs across that range of flows, referenced to a topographical survey of the weir. This will determine what might be expected to be the average annual energy capture. For full methodology and results, please refer to the Hydrology Assessment presented among the Analysis Documents accompanying this study.

Cost/benefit calculation

This study was commissioned to assess the potential for generation with a focus on the Archimedean screw. Appropriate design sizings have been proposed to best exploit the available resource and these have been modelled to analyse performance in the likely range of flows. A full topographical survey of the site and formal civils & electrical costings will be required to produce more accurate figures, but the estimates presented for the client in the Analysis Documents are sufficient to form a decision to proceed with further design work.

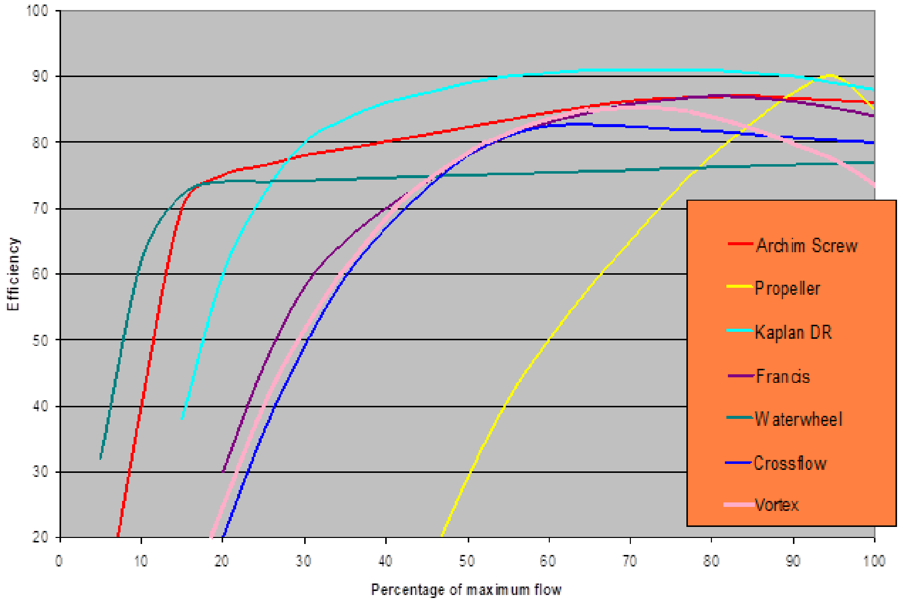
Archimedean screw, waterwheel, or other technology?

There are a number of quite different types of machinery that can be used to generate hydroelectricity at low head. The principal benefits of using a waterwheel would be: when one is already present; or that a new wheel can be assembled in-situ from more easily transportable components; or that the wheel shape is better suited to providing a like-for-like replacement in the space constraints of an existing mill wheelpit. Otherwise, a screw will offer an easier modular solution, and in general, slightly better efficiency, becoming significantly better in a very low-head site and/or where high tailwater conditions occur.

This report was commissioned to consider Archimedean screw options, but a summary of the available hydropower systems is provided in the Appendix to this document to show how the screw compares to other technologies. Archimedean screw technology is well proven, simple and robust to maintain, with the first hydropower screw system installed over 20 years ago, with many installations now operating in Europe and over 100 in the UK. The Archimedean screw is recognised as one of the most fish-friendly turbines available, as discussed in the Environmental section. Its competitive technical performance against alternative turbine types is illustrated below. Independent economic assessment has been done e.g. by Future Energy Yorkshire (now CO2Sense), which recommended a screw over a Kaplan alternative for a proposed community scheme at Copley Weir on the Calder. While the Kaplan's peak efficiency may be higher, its overall efficiency at this type of on-weir site is likely to be suppressed by rising tailwater and the need for fine fish screens, while also typically requiring more intrusive and expensive civil works than a screw. In the present context, where a machine is to be mounted in new or simple existing works directly within a flood-prone river corridor, the screw is easier to accommodate, maintain, and protect against damage. For other types, the main constructional differences would lie in these civil works (foundations and enclosures), additional pipework, and additional fish exclusion screens.

A further recent alternative, a Vortex-type turbine, was initially considered, but discounted. Exploiting the flow at this site would require using twin devices of a large diameter, which cannot continue to operate efficiently in lower flows, while the likely head variation here would reduce their efficiency in high flows. Vortex machines seem likely only to compete where: civils costs are low; ample footprint is available; the machine can be operated at its full flow for most of the year (i.e. the watercourse is unvarying, or the installed kW capacity is small for total flow resource); and the tailwater rise does not frequently reduce net head.

Efficiency comparison



This chart presents an indicative representation of the performance of different hydropower machines of a given size, showing how their efficiency changes against an increasing flow. As the aim is to maximise total generation over the course of a whole year, it is very important to consider how changing the flow affects the efficiency of the machine. A further benefit of the screw is that there is no need for pressure pipes or fine fish screens, which cause head loss, so it is possible to exploit more of the available gross head. The 'water to wire' efficiency, determining how much power can be extracted from the water, will thus remain high. This outcome is reflected in the energy capture calculation (see Appendix).

Vortex turbines are a recent new addition to this graph. While potentially fish-friendly, this design has not yet been evaluated or licensed by UK regulators. Efficiency is poorer than a screw, rotation speed is higher (a concern for fish). This example performance curve is from: http://www.zotloeterer.com/welcome/gravitation-water-vortex-power-plants/zotloeterer-turbine/

Proposed Site

Location description

The mill and weir are of long standing, with bedrock cliff at the left bank and the mill and Lido premises on alluvial slope rising to the right. The sloped masonry weir runs diagonally downstream from north to south bank, terminating against a massive wall of large stone blocks. This is the outer wall of a former wheelpit against the riverside elevation of the mill building, with the two walls formerly supporting the shaft bearings of a waterwheel.

The two walls contain iron stoplog slots at the upstream end of this channel, now occupied by wooden stoplogs forming a low dam, The walls then also contain curved iron guides where the paved upstream base of the channel gives way to the former wheelpit, these guides formerly accommodating the "sweep" or control sluice against the waterwheel, but now containing a second lower dam of boards. The shallow wheelpit bed below contains cobbles and its surfacing is uncertain. The offside wall terminates before the mill's downstream elevation. Dimensions indicate that the wheel was of low-breastshot design.

The historic stone mill building has been internally strengthened in its ground storey with breezeblock buttresses and steel joists supporting a concrete first floor to the café, the ground floor base being of uncertain (perhaps modern concrete) construction overlain with siltation, and this storey left unoccupied and allowing free throughflow of floodwater via upstream and downstream doorway grilles.

The alluvial right bank upstream of the mill shows two recent sinkholes of approx. ~0.5m diameter and apparent depth, and another depression on the same line, indicating a path of infiltration, possibly from beneath old stonework at a slipway close upstream. Downstream and in the lee of the mill is an area of still water against an old stone bank footway, where siltation has accumulated. At the mill's downstream wall is some erosion of this siltation, possibly due to escape of floodwater through or infiltration beneath the mill.

The author does not hold any inspection records of structures or machinery, therefore comments here relating to potential modifications are of a general nature only.

Figure 2: View from slipway downstream to mill

Figure 3: View downstream past mill, to proposed turbine installation

Figure 4: Weir, return view upstream from mill wheelpit wall

Figure 5: Mill, wheelpit, outer wall, weir - view upstream

Figure 6: Wheelpit, walls, and iron guides, looking downstream

Figure 7: Wheelpit, outer wall, and weir, looking upstream

Figure 8: Downstream wall of mill, stone footway, siltation and erosion

Figure 9: Silted area downstream – proposed site of turbine installation

Installation factors

Non-hydropower factors affecting the proposed options may also include:

- **Proximity of a suitable electrical demand / point of grid connection.** The main metered connection on this site appears suitably large to connect any likely scheme, with the potential (subject to confirmation by site electrician) to connect directly at a distribution point within ~50m of the hydro.
- **Land ownership and availability.** It is assumed so far that there are no issues with land ownership or maintenance access needed to pursue a scheme.
- **Construction access.** Site walkover indicates that the northern service track from the site's main gate is suitable for all construction access to a compound at the former farm buildings. During working hours, closure of or marshalled/gated access across the riverbank footpath will be required from the compound.
- **Trees.** The extent of clearance required for any works or access would have to be judged acceptable in terms of a planning application and any other preferences for retention. Scope of tree removal may include some of those immediately downstream of the mill, with trimming if required along the access track.
- **Listed buildings.** The site is not listed. Advice might be sought from a planning consultant as to whether Listed Building Consent may be required due to any potential impact upon St Robert's Cave, a listed at some 100m from the proposed site: https://historicengland.org.uk/listing/the-list/list-entry/1015540
- **Security and safety.** The site is accessible but supervised therefore with probably low risk of anti-social behaviour including vandalism. Any option would need to be designed to consider public exclusion fencing where necessary.

Further research at an early date is recommended to remove any uncertainty on the matters above, in case this closes off or opens up options. Consultations with the relevant statutory bodies would then need to be made as the scheme design evolves.

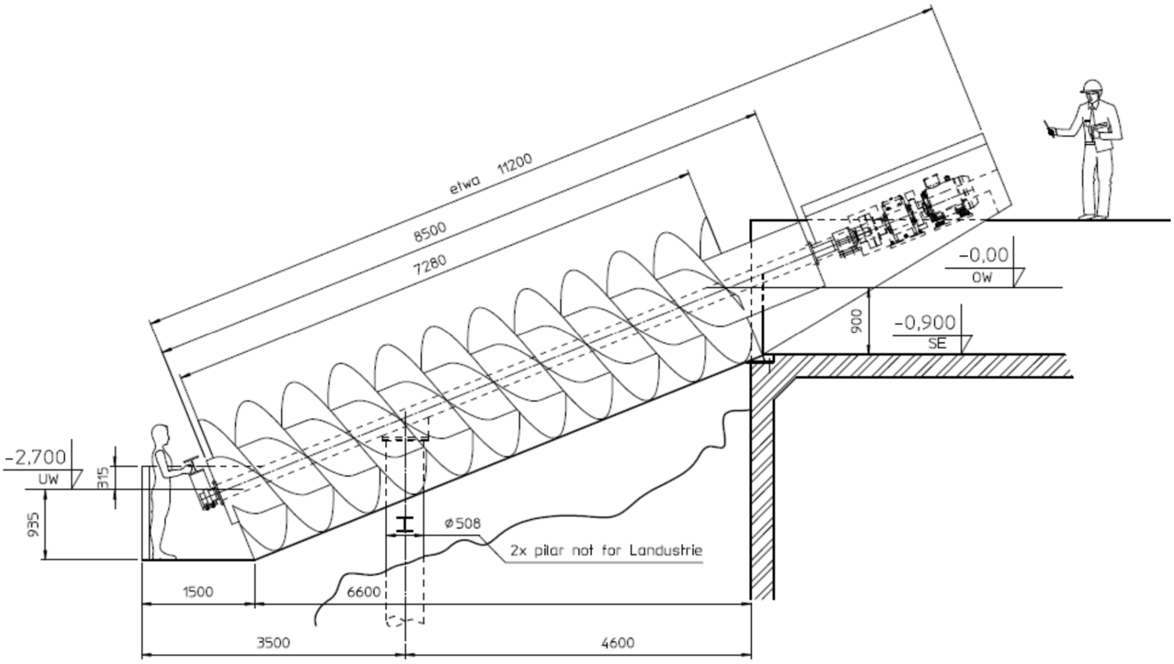


Figure 10: Schematic example of a screw installation (here for a head of 2.7m)

Figure 11: Installing a 30kW screw in an open compact trough

Any Archimedean screw turbine design would be installed at an inclination of 18 to 30 (typically 22 to 26) degrees from horizontal, depending on the parameters involved. The gearbox and generator at the top end of the screw must be secured against likely flooding, either in a concrete chamber or in a steel tank. Some form of secure weatherproof enclosure will be required for the control system, hydraulic units, etc: this need not be immediately adjacent, but would ideally be nearby and in line-of-site to facilitate future maintenance.

An automated sluice gate will be required immediately upstream of the screw, to close it off to flow when necessary. Upstream of the sluice gate, in order to protect the equipment, and prevent the ingress of large debris and mammals, a debris screen must be installed with a bar spacing as wide as is permitted. This can be up to 150-200mm but is often around 100mm. If horizontal bars are positioned across an intake at an oblique angle to the flow, this can add an element of self-cleaning to help prevent the flow being impeded by debris. To deflect more flotsam into adjacent flow paths, a floating boom might also be installed across the intake. Where there is no adjacent alternative cleansing flow route, and debris must instead be raked out, an upward slope of vertical bars is more practical.

Figure 12: The control system will require secure weatherproof enclosure

Licensing and Planning

EA licensing and permitting

The Environment Agency (EA) regulates many aspects of environmental protection and is particularly involved in the protection of inland waters. The EA recognises that hydropower proposals will need to be considered by several EA teams and will require a number of different permits. While there may be statutory periods for determining these permits (see below), in the case of hydropower the EA now expects most of the discussion process to take place within a pre-application period which is subject to no formal time limit. The EA will then provide a written response of any remaining concerns, giving confidence as to whether a formal application will be approved. When the formal application is submitted, there is a statutory period of 4 (or, more rarely, 3) months for determining this, though this limit may be extended or exceeded.

Realistically a period of about a year should be allowed for the end-to-end process. It is usually advisable to progress EA licensing as far as possible to achieve a firm design and address any substantive ecological issues before applying for planning consent.

The first 15 hours of EA pre-application advice is free of charge; charges apply thereafter (EA proposes £125/hour), though in practice these have rarely been invoked even where pre-app has continued for many months. Discussion does require that the applicant has or will have access rights to the abstraction point, and progress will be slow unless a well-developed design is submitted as the starting point for discussion. The EA aims to use the pre-app phase to dissuade applicants from submitting poorly-conceived schemes (not least to prevent them from gaining over any competing applicants at the same site who have followed due process to create a good design). As pre-app is not legally mandatory, applicants may not feel predisposed to refine all aspects in this phase, but the EA tends to respond more reliably if the pre-app process is respected.

During the pre-app process, the EA will decide which of the following are required.

Abstraction licence

An abstraction licence from EA Water Resources is typically required for removing water from a watercourse. This includes removing water from one “source of supply” to favour another, such as when proposing to divert flow between channels. Normally this will be issued to run until the common end date for all licences in the local catchment. While these renewal dates are intended in principle to recur every 12 years, a licence issued now for the EA’s local management area (Swale, Ure, Nidd and Upper Ouse) will run until the next cycle ends in 2029. Upon review, there is a presumption of renewal if three tests are met: continued need, efficient water use, and environmental sustainability.

Impoundment Licence

This is required where changes are to be made to structures which impound water, such as weirs and sluices, or if new structures are to be built. An impoundment licence lasts for the lifetime of the impoundment and is thus not time-limited.

Whether the proposed scheme requires an impoundment licence to impose conditions on the new works in the watercourse, a full abstraction licence (to remove water from an existing “source of supply”), and/or a transfer-type abstraction licence (if creating a new “source of supply”, or e.g. directing flow through a fish pass) may be difficult to predict. The EA will determine this based on the relevant legislation and on whether one or other permutation of these licences would add regulatory benefit. Either licence type is likely to attach similar conditions to the development (namely the protection of other water users’ rights in the river, as well as issues discussed in the Environmental section).

The application fee payable to the EA is now £1500 per licence application. A single application fee is charged even if the EA then determines that 2-3 different licences or licence types are required. This excludes any professional fees, and the costs charged by the EA for mandatory advertisement of the applications. The latter may amount to £1000 depending on local newspaper advertising rates, in addition to an EA administration fee of £100. Where the EA requires the additional creation of a legal operating agreement, this may incur another cost of £1750+. Pre-app advice is now also chargeable, as above.

Finally a word must be said on “licences of right” relating to milling operations which have continued in uninterrupted use since prior to Water Act 1963. In the author’s experience, where an abstractor has proposed to change the terms of an abstraction – including changing the use from milling to hydroelectric power generation - the regulators have sought wherever possible to use the proposed change as an opportunity to agree modern conditions on the abstraction. Unless an existing licence specifically permits abstraction for hydropower, the EA typically expects an application to be made to allow hydropower. If an ancient licence of right applies, it is to be anticipated that the EA will seek to refine / restrict its terms. It is certainly advisable to locate any existing licences or rights and review these before discussing proposals with the EA.

Fish Pass Approval

If a fish pass is to be installed or changed as part of the scheme, this has to be formally approved by EA Fisheries before operation. This process is subject to no time limit, and can be protracted over a number of occasional meetings of the EA’s National Fish Pass Panel. There is no application fee, but the costs of specialist design and negotiation with the EA should be allowed for. Eel-passes, and non-technical fish passes (e.g. new naturalistic streams, requiring a larger footprint), also go through a “light” version of this process.

Works-in-river consent / Flood Risk

Consents of this type are required for all works to be carried out in the watercourse or within a certain distance of the riverbank (set in local byelaws, or standardised by the EA). Consents consider the temporary impacts on the river of all construction works to be carried out for the scheme, for example by the release of concrete or oils during construction; and also permanent impacts of operation of the scheme, to ensure no detriment to third parties.

If the EA flood map shows the watercourse as a dark blue line, it is a “main river”. In this case, the permission is referred to as a Flood Risk Activities Permit (FRAP) under the EA’s Environmental Permitting (EP) regime. This is to be obtained by submitting a form, a cheque, and supporting documentation to the local flood risk team of the EA. This involves a shopping list of permitted activities with price tags which may add up to a cumulative fee of £1500-£2500.

The EA flood map for this site is found at:
https://flood-map-for-planning.service.gov.uk/confirm-location?easting=436053&northing=455953

A Flood Risk Assessment is often required to assess the potential impacts of a new in-river development. Such an assessment must be proportionate to the scale and risk: therefore an informal assessment is often sufficient in micro-hydro projects where no new obstruction is placed in the river corridor. In certain cases, particularly in urban flood corridors, a formal study will be required which may entail a cost of around £10k. Costs can be lower where the EA possesses good quality recent modelling which it is prepared to share.

Planning permission

Planning permission is required. The EA is a statutory consultee to the planning process in addition to its own licensing and consenting roles. The EA typically imposes planning conditions which *inter alia* prevent the operation of the scheme unless it has granted the appropriate abstraction and/or impoundment licence. Natural England and groups such as Yorkshire Wildlife Trust may be consulted on ecological impacts: their concerns will typically reflect those raised by the EA's ecology consultees. The usual planning concerns of general design and visual appearance and construction of the new elements may be extended to archaeology of the groundworks and cable route, safety protection measures and noise assessment. If necessary, a screw could be designed specifically to be masked from view, or it can be argued to form a modern and functional enhancement. Flood risk concerns (as above) will also be raised by the EA in its role as consultee in planning.

Planning application fees depend on the footprint of proposed works. Standard national fee is £401 per 0.1ha. New access routes and cable routes are sometimes included in the area. A smaller supplement may be payable later for discharge of any conditions.

Listed Building Consent, where applicable, generally attracts no additional fee. Where works are only in the curtilage of listed structures and not directly upon them, whether LBC is required will depend on the detail of the listing and the specifics of how the proposed works relate to the listed elements.

Environmental considerations

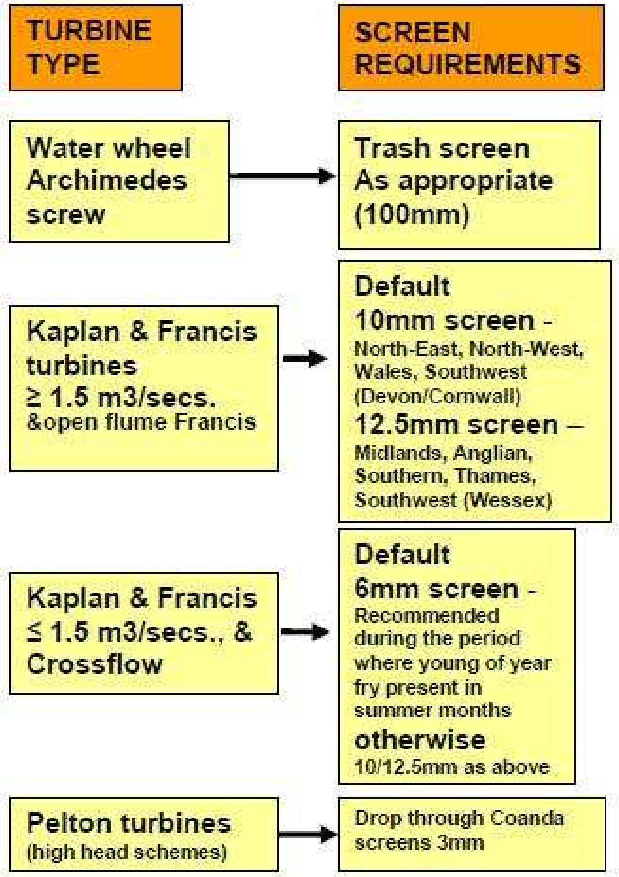
There are several potential environmental impacts which could arise from installing a hydro scheme, all of which will need to be considered before the abstraction licence is granted. The protection of local wildlife and ecosystems is important, and design should take account of the EA's best practice recommendations for the design of schemes which are "not expected to pose environmental problems" as set out in the EA's guidance 2013-2017. While subsequently withdrawn from formal status, this guidance continues to be found online and serves as the best available guide to the EA's likely response to a new hydropower proposal.

Fish protection

Current EA policy requires that the maximum protection must be given to fish, eels and lampreys; this is unlikely to change in the future. Legal protection is also provided through Water Resources Act 1991 (as amended) and compliance is regulated by the EA. To be able to comply with these requirements, there are two solutions:

1. If the machinery installed could potentially injure or kill aquatic vertebrates, then a screen can be installed to physically keep them out.
2. Machinery can be selected which is designed to permit the safe passage of aquatic vertebrates present in the river. There are two hydropower options which have been widely demonstrated allow aquatic vertebrates and debris to pass safely through them: the waterwheel and the Archimedean screw.

Archimedean screw installations have a proven track record of being fish-friendly and can cope with a large proportion of river debris. The EA's guidance confirms "Archimedean screw turbines have been demonstrated to cause minimal damage to fish" when appropriately installed. The EA's guidance since 2012 is based on research findings that screws with 4 or 5 blades pose no additional risk to fish over those with 3 blades, and that most screw designs require no mitigation beyond the application of standard rubber bumpers. This acceptance that screws are not harmful to fish is reflected in less demanding recommendations for screening (e.g. see the below from EA Good Practice Guidelines 2009) whereby Archimedean screws require only a coarse screen at the intake.



Angling Trust concurred with this in its Sustainable Hydropower Guidelines (November 2013): “Unless future evidence suggests otherwise, a simple trash screen is acceptable.” Further research since then has not led the EA to adopt stricter screening requirements.

The EA therefore allows that, in the case of screws exceeding a minimum diameter and not exceeding a maximum rotation speed, it is not necessary to exclude fish from the screw and its intake. Screening requirements are then typically limited to providing only a coarse screen which safeguards against larger debris and which excludes mammals.

(Note: At some sites with less flow than the current project, in cases with smaller diameters of turbine and faster rotation speeds, the EA did uphold a concern: not that the turbine may cause physical harm, but that deciding whether or not to enter the screw may cause delay to fish. In those cases, it may be obligatory to add finer screening and/or a downstream bywash so that fish can opt to pass around the screw rather than enter. This could mean that using a screw does not have the usual benefit of infrequent screen-cleaning.)

Similarly, some alternative systems also require the outflow to be screened, to prevent fish from swimming into the tailrace. Here, tests on Archimedean screw systems have shown that fish are not harmed by approaching the outflow from the screw. No screening is therefore likely to be required, though there may well be concern to ensure that onward upstream passage around the screw is available via some route (see also below).

Rubber bumpers are fitted to the edge of the screw blade as a standard mitigation. The EA requires a compressible rubber profile on screws with higher tip speeds, e.g. with diameter > 2.5m. In some smaller cases a simpler rubber profile has been accepted.

Effect of change in flow

The installation of a hydro scheme will divert water into the turbine. This creates a length of 'depleted reach' in the river, where there is less water when the scheme is operating. Hypothetically, a scheme could divert all of the water out of a river, so the EA sets limits on this – both by seeking to minimise the length of depleted reach created, and by agreeing a flow regime which does not have unacceptable impacts. This is achieved via the abstraction licence stating a minimum flow in the river and a maximum flow for the turbine.

Under EA guidelines, an amount up to the river's mean flow may be taken, or up to 1.3x as much if the system is installed on a weir. The EA's assessment of sensitivity in the bypassed "depleted reach" will then dictate how much of that amount may be taken at any time, after having always left an agreed minimum residual flow in the depleted reach. It can be as little as 35% of the total, if removed for more than a short distance. Some assumptions have been made and proposed flows are discussed in the Hydrology section.

Flow conditions on the weir will change when water is diverted around it by the hydro. The EA will take account of ecological concerns where they arise. This may also be of concern to canoeists if they are among the users of the site. The scope of flow changes could be set out for discussion if required.

Fish passage

Where changes are proposed to obstructions in any river, or flows in the river reduced, such as when diverting flows through a proposed hydropower scheme, EA guidance has increasingly emphasised that opportunities should be taken to restore or improve fish passage. In all cases, proposed changes should cause no deterioration in fish passage.

The EA has powers to require landowners to make changes to improve the fish passability of weir structures on their land. Applications to make changes for other reasons such as hydropower very often prompt requests for improved fish passage. Often the precise conditions and current or prospective fish populations have to be established via a site-specific fisheries study. Where there is already an upstream route for fish, understanding its operation (flows needed, etc) is necessary to hydro scheme design. Where the turbine is positioned at some distance from an existing route, the EA may require upstream fish passage to be provided at one or both locations. A new technical pass sited alongside the turbine will be expected to carry >5%-10% of turbine design flow. Allowance must be made in flow calculations and channel design for conveying this additional flow to the pass.

As an early step, therefore, the expectations of EA Fisheries at this particular site would need to be clarified. The worst case for the project would be that the EA would conclude that one or more new upstream fish passes must be included to compensate for the distraction caused by the turbine. As eels are present in the system, any change to flow distribution might cause the EA to ask for additional new eel passes in routes where the attraction flow is increased. Specialist consultancy is usually engaged to negotiate a level of mitigation which is not disproportionate.

Unlike other turbine types, a screw is usually not screened to exclude fish, as it provides a channel through which fish can pass unharmed downstream. It has therefore typically been agreed that there is no benefit in creating an additional bywash to help fish pass downstream around the turbine and/or weir site. If this case is not accepted, additional flow will have to be earmarked for a dedicated bywash and thus deducted from generation.

Design for flood risk

It is important that, whatever equipment or screens are installed, they do not impede the flow of the river while in flood; and this should also be the case even when the system is switched off. This issue is considered in planning and works-in-rivers consents (above).

At the locations considered in this scheme, it will have to be demonstrated that the new structures that are introduced in the flood plain do not present a significant overall reduction in flood storage or flow capacity. Options excavated within in-bank locations would have the benefit of not occupying the main river channel, though even here they may be deemed to lie within flood storage or transport routes, which may invoke a need to provide compensatory volume elsewhere. Options which involve new construction in currently unobstructed channels are likely to have greater implications than re-using an existing structure. Incorporating a new flow path to help dispel flood flows may serve as mitigation. If a proposal prompts a precautionary response, it may have to be formally flood-modelled.

It is also clearly necessary to ensure that any equipment installed is either waterproof or placed above the highest likely flood level. Most of the mechanical components are submersible or can be specified to cope with infrequent submersion. The generator can be mounted on the gearbox in the way most appropriate to avoid submersion, or, where this is impracticable, a submersible generator can be specified at a small additional cost; or the generator enclosure can be built as a watertight open box or closed tank. A suitable level of flood exclusion should therefore be chosen (in consultation with locally knowledgeable authorities) and the electrical equipment protected up to this level or positioned above it.

Pollution control

The hydro equipment must be designed and operated so as to prevent the discharge of potentially harmful oils, grease or other pollutants into the water, both when generating and when switched off during times of flooding. As a default precaution, use of environmentally-friendly industrial products is advised, e.g. biodegradable oil. Spill kits must be kept on site.

Electricity connection

The electricity generated is expected to be used locally with any excess sold into the supply network. Schemes above 11kW must comply with the G99 standard via a formal application process to satisfy the Distribution Network Operator (DNO), here Northern Powergrid.

A sizeable three-phase import supply (consumer unit) is already present on the Lido site, in which case, providing an export connection via an updated meter on this supply will incur no great expense. Location and condition of the existing infrastructure must be confirmed and possible options costed, in light of future plans for the wider site. It is understood that the Lido’s main meter (MPAN# S008452511592001039079) is the point of purchase for all of the site’s electricity. A connection at the customer side of this meter is therefore the most favourable point at which a hydropower scheme could be connected, in order to maximise the benefit of using hydro generation to displace purchased electricity. The connection could physically be made at a distribution point elsewhere on the customer’s supply provided that the cables and protection equipment are suitably sized. A junction box located opposite the Mill seems likely to be suitable: an electrician should be asked to confirm this.

Upgrading an existing import meter to an import-export meter is now likely to be required where any exports are sold. Further meter provision may be required in some cases. The new control panel will also be required to include a mains interface unit for safety protection.

Operational costs

Ongoing costs include insurance, rates, meter reading charges, machine overhaul and servicing costs, as seen in the Cost/Benefit Assessment. At a site which is already being managed, the labour component might be absorbed into existing site maintenance. If business rates or metering arrangements already apply, the net extra impact may be nil or small; but, if new costs, these must be quantified. Historically, Valuation Office Agency (VOA) is unlikely to take an interest in a “domestic”-scale scheme under 20kW, but above this, the Rateable Value allocated to a scheme can be key to its viability. Advice should always be sought from VOA. Using a screw dispenses with need for fine screens, which are needed in the case of turbine types which must be screened against fish. Omitting fine screens not only reduces operational costs of attendance for manual cleaning, but minimises debris build-up between attendances with impacts on flow and electrical output.

Income: importance of local demand

As of April 2019, the income from a new UK hydropower scheme is simply the value which can be realised by selling the electrical output. The previous subsidy regimes, namely the Feed-in Tariff (2010-2019) and Renewables Obligation Certificates, have now ceased.

The scheme which government proposed as a replacement, the Smart Export Guarantee (SEG, from Jan 2020), is not a subsidy. Its sole benefit was to close a loophole whereby large electricity supply companies could opt to pay nothing to or even charge renewable generators to dispose of their generated electricity (i.e. negative payment). Government does not set a market rate, but has chosen to specify only that the rate is above zero, leaving the supply companies to set their price. Participation has conditions, such as installing a half-hourly export meter.

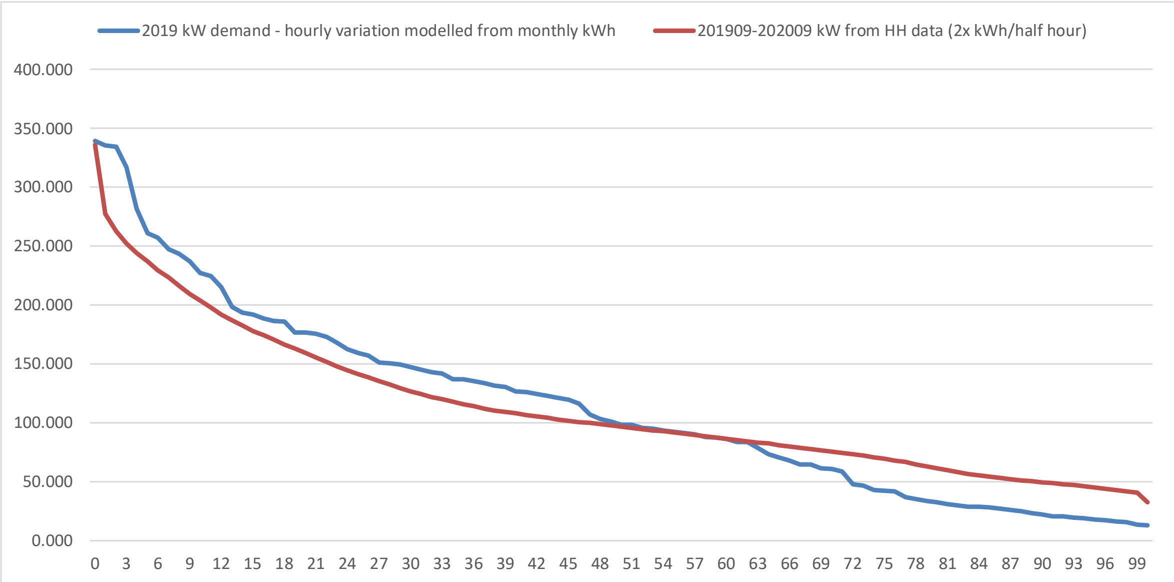
The value of any electricity exported to the grid is therefore set by whatever Power Purchase Agreement can be agreed with an electricity supply company. Be prepared to find that smaller specialist renewables-oriented supply companies may offer a more beneficial arrangement than the few familiar large national suppliers; weigh this against risk of business failure and default. In advance of SEG, some offerings are seeking to be smarter, with an ability to gamble on selling output at a higher rate when the grid has greater need.

Any scheme where the generated electricity is used to displace the need to import is likely to enjoy higher benefits, as it then substitutes for power which would otherwise have to be bought in at higher retail costs. Assuming that the scheme connects into the main metered supply, if the base load of power consumed by the site is high relative to the maximum potential generation, the scheme will rarely need to export. Up to 100% of the generated electricity might then be valued at the actual retail rate being paid for imports, as this is the cost saving by instead using this output from the hydro. It is more common that a portion of the hydro output can be expected not to coincide with demand, as the hydro will generate regardless of time-of-day, but site demand may dwindle e.g. during the night.

Where on-site demand is low, other potential local consumers could be approached. At this site, demand is large (as explored below), so this option is not explored further.

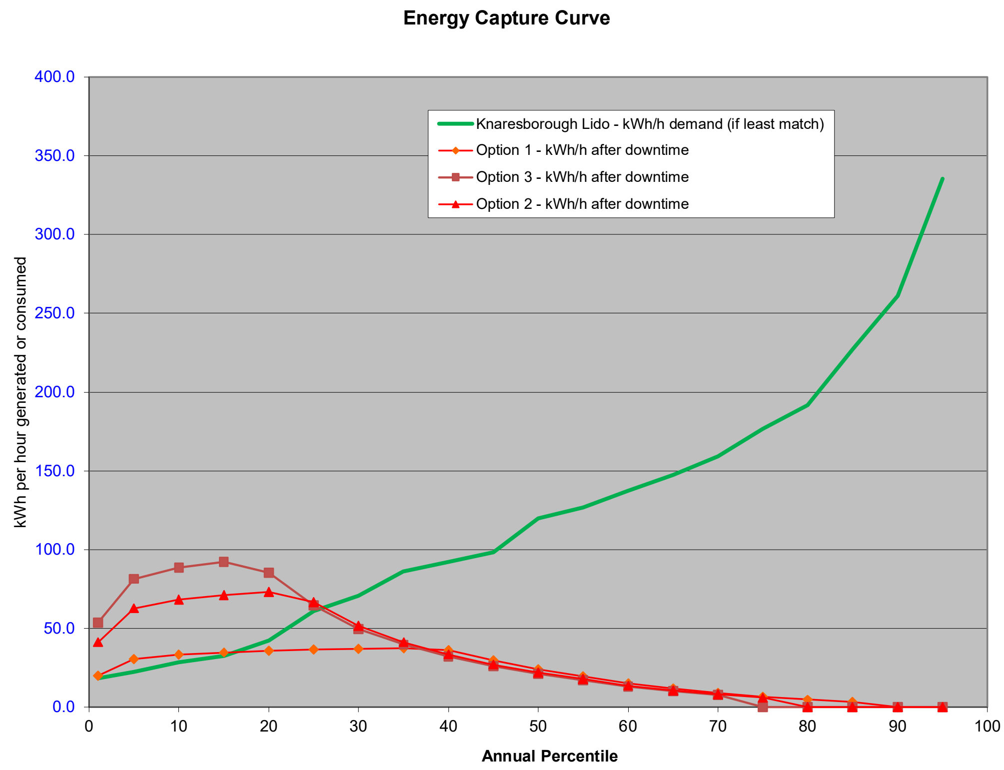
(Note: In the present analysis, the cost of all standing charges has not been taken into account: they are assumed to remain unaffected even if import consumption declines, though this should be checked against the current or potential import contracts.)

Electricity demand data from the Lido's main meter has been provided in the form of half-hourly consumption (kWh) for Sept 2019 to Sept 2020. A longer sequence of invoice totals (mostly monthly or quarterly) was also reviewed, covering the period from late 2005 to late 2020. The more detailed recent information allowed the creation of a percentile distribution of average electricity demand (kW) by half-hour of all days in the sample.



Present analysis has taken this consumption rate and has compared it with the output rate of the potential hydropower scheme options, in order to represent how well any given hydro output would match with the predicted Mill demand. The result of the exercise is that this predicted demand is modelled alongside predicted productivity, in **two graphs below**.

kW can also be expressed as kWh/h. This unit is used below, to remind the reader that this is the rate at which the paid-for units are generated and consumed.

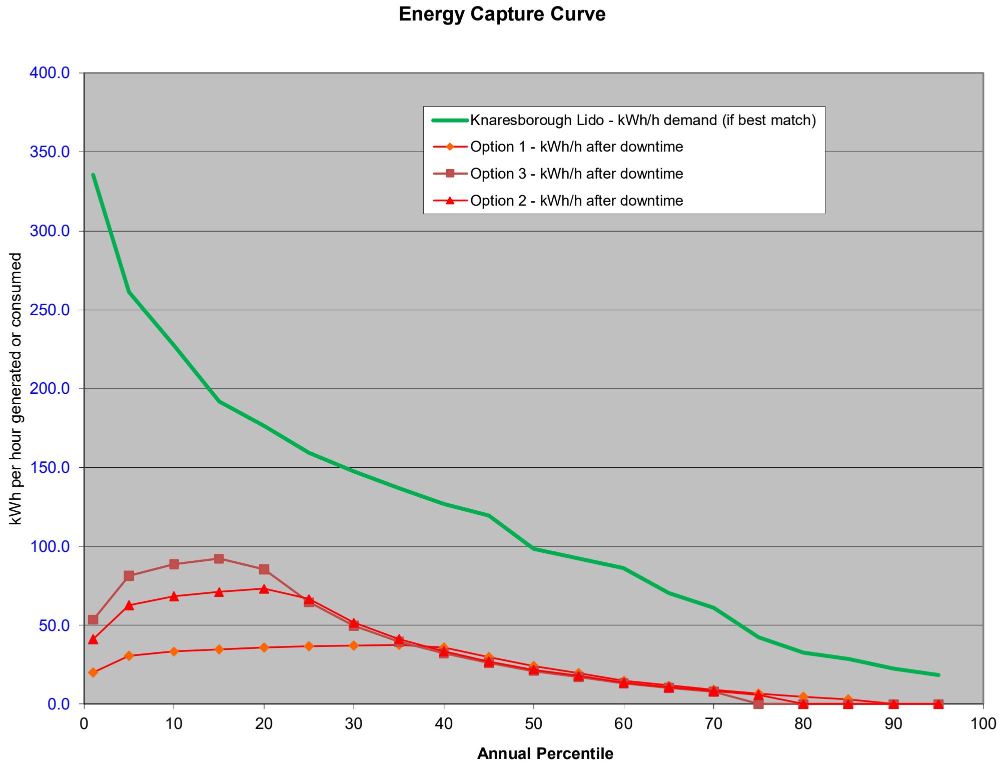


Here, the red lines represent the output of the three different hydropower options proposed, set against a percentile range of river flows (high-to-low). Outputs are low in dry conditions, on the right of the graph, peaking towards the left as river flows are high, then tailing off again at left in the very highest conditions.

The green line represents the site's demand data (in the same units). This occurs irrespective of river flow on the bottom axis - demand may happen even if the rain is not falling. **In this first graph**, the demand is arranged in ascending order, simply to show what would be the case if all of the site's historic demand occurred ONLY at the times most unsuitable to match the hydro output, with the highest demand in the driest conditions. **The green line in this first graph is therefore a worst-case match** for the predicted hydro output. All options could be producing electricity at times when this this site is unlikely to consume it (red lines higher than green line), but not producing enough on many other occasions when there is demand (red lines lower than green line).

This worst-case illustration is NOT a typical real-world scenario, as peaks of local energy demand at such a site would rarely coincide with the driest weather, unless the major demands are e.g. food chillers or seasonal catering appliances. The nature and seasonality of demands on the site meter should therefore be considered when interpreting this data.

The same applies to **the second graph** below, which takes the same output predictions, and simply reverses the demand predictions into descending order, so that **this green line shows a best-case scenario** – i.e. high demand coincides with high hydro output.



It is evident that in this best-case coincidence of site demand with hydro production, all proposed options are never large enough to satisfy the site demand. A real-world distribution of conditions will be somewhere between these two graphs, so it is likely that any of the schemes will find local demand for most of its output, with the smallest scheme being the surest of hardly ever needing to export anything into the grid.

Where desirable, demand might be increased sustainably by replacing any existing non-renewable non-electric heat sources with electric space heating or a common heat store, or by adding new sustainable demands (heat pumps, EV charging points). If opting for a larger hydropower option, the export sale value of any surplus would have to be weighed against its local value plus the cost of any specific method of using or storing any larger excess.

When calculating the relative benefit of generation, the unit cost of the on-site demand must be considered. A variable unit rate is charged during 10 night hours per 24-hour day. As it cannot be predicted whether rainfall and generation will coincide with day or night, this factor has been simplified by applying a modifier to the value of all units. It was found that the units consumed during night hours consistently account for around 30% of the total. Therefore this modifier was applied to give an average unit charge for any imported unit that might be displaced by hydro generation. From recent monthly averages, the figure used is 15p/kWh.

An indicative recent price of 15p/kWh is used in present calculations. The purchase price may well vary in future. Any general increase in purchase prices over time will incentivise the use of any available hydropower output.

Note on grant funding

Under the former Feed-In Tariff subsidy regime, accepting most forms of grant funding could make a scheme ineligible for the Feed-In Tariff subsidy. The closing of that regime to new applicants in 2019 means that this is no longer a constraint. It is therefore once again worthwhile pursuing any potential sources of grant funding.

As the majority of hydropower schemes can find some way to incorporate or facilitate environmental or ecological improvements, the project's potential for this should be assessed and any positive benefits should be explained in grant funding applications.

Recent initiatives such as local authorities declaring Climate Emergency may help to revive funding for local renewables projects, and should be monitored for opportunities.

A good recent source of development funding for hydropower assessment and pre-design activities has been the Rural Community Energy Fund (RCEF), now administered by Local Enterprise Partnerships (LEPs). However, this is only available to communitarian ventures in certain demographic or economic areas classified as “rural” under the scheme's rules.

The present site, lying administratively within Knaresborough, is unlikely to be considered eligible for RCEF; unless, for example, the LEP was able to find grounds to accept that the community interest and benefits fell within Plumpton parish.

Recommendations

The river at this site has technical potential for hydropower. The flow regime is well-understood, but it would be valuable also to collect measurements on the variability of tailwater levels during a range of different river conditions.

The economics of UK micro-hydro have changed markedly with the cessation of the FITs scheme. Commercial feasibility is now a question of what the generated output is worth, or may be worth in future, in terms of displacing the purchase of electricity from others. At this site, there is clear existing local demand for electricity at the Lido itself. Local demand will be particularly influential on the decision how to size a hydropower scheme for best efficiency. The values presented in this report provide a basis for concluding which if any scale of hydropower option is currently of interest.

For such a site, the Archimedean screw turbine has a proven track record of fish-friendly operation, efficient energy capture over a wide range of flows, and low running costs. A waterwheel shares some similar advantages over other turbine types, and the existence of a suitable wheelpit could facilitate this, but its capacity would be capped by the existing width, it would generate less due to tailwater rise, would place more load directly upon the mill structure and would be more exposed to debris damage. Vortex-type turbines are technically suitable, but will achieve lower efficiency in this flow regime, and will require more footprint for installation. If low risk to fish is among their claimed benefits, this has not yet been tested in the UK, which could be a costly exercise for a pioneer scheme. Other low-head turbine types are rarely considered except for large-budget developments at larger sites and/or where the entrainment and movement of fish is not a primary concern.

Further work would be required to confirm the estimates and assumptions of any of the options reviewed in this report, and to programme the process of obtaining a licence and procuring the necessary equipment. NB: A not-for-profit organisation may be able to obtain data from the EA or other authorities at a full or partial reduction against standard rates.

Next steps would include the following:

a) Low-cost and/or non-public investigative steps:

- Obtain any greater detail of potential local on-site demand for electricity (daily/seasonal phasing, type of demands, future plans for increased consumption), and predicted future changes to supplier charges
- If an excess is predicted, seek best locally-available deals for potential sale of any surplus electricity (unit rate)
- Measure to confirm head in a range of different flow conditions, especially when river is low-medium and medium-high. Make records of water level at proposed intake/outflow, with respect to a fixed datum, noting date and time. (Consider installing £25 gauge boards – or we can assist; and ask volunteers to keep a notebook of visual readings.)
- Discuss in outline with Harrogate BC Conservation Officer, and if necessary Historic England, regarding likely response to proposed changes to listed or heritage structures
- Discuss in outline with Harrogate BC or EA Flood Risk specialists, and if possible:
  - request values, for all available nearby points on this river, of the predicted flood level for the “1-in-100-year event plus allowance for climate change”
  - try to obtain all other available flood models and data relevant to your site
  - attempt to gain a view on what if any impacts on flood levels might be permissible.
- Approach local EA Fisheries technical specialist to attempt to gain a view on what fish protection measures would be sought, and what change they would or would not tolerate
- Contact DNO (Northern Powergrid) to confirm location and condition of existing grid supply/meter; make a G99 New Generation Connection enquiry to establish costs and terms of making a new export connection at this meter
- Consider any buried services, hazards, potential land contamination, ground stability
- Assess likely business rates - approach VOA to give an indicative Rateable Value for a standalone scheme, based on data given here: RV over £12k would begin to incur rates. Or, if owned by site operator, whether the extra plant would increase their business rates.
- Consider likely meter reading charges – may be an add-on to any existing fees
- Monitor any changing government policy with regard to restoring funding of renewables, or opportunities for support in light of e.g. Climate Emergency, HBC’s Carbon Reduction Strategy https://www.harrogate.gov.uk/downloads/file/1497/carbon-reduction-strategy
- Review the hydropower options and determine which if any scale of option to pursue further, considering cost-benefit and likely finances

b) More costly and/or public-facing development phase:

- Informed by previous steps, find budget for known necessary actions
- Commission a topographical survey (essential; c.£1k-2k+VAT depending on scope)
- Use topo data (of spills, channels, weirs, etc) to firm up performance assumptions
- Perform outline design and draw up detailed plans for chosen system
- Use the plans as the basis for informed discussions:
    - of environmental implications, with the EA - as early as possible
    - of planning and (if necessary) listed building implications, with planning & conservation officers, Historic England, and any other statutory consultees
    - with interested parties such as rivers trusts, angling organisations, parish councils, local history groups, ecology groups such as YWT, canoeists & other river users
    - to obtain budget quotations from suitably experienced civils contractors – the allowances here are estimates which it may be possible to reduce
- Allow time for both pre-application and application for EA licences, and for planning
- Be prepared to fund relevant fisheries and ecological assessments