Appendix 11

Hydro Report

Refurbishment Of Existing Hydro-Electric Scheme And Addition Of A Power Distribution System For The Lammas Settlement At Pont-Y-Gafel

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Assessment of needs

An average UK dwelling consumes 4800kWh/yr, although typical demand varies between 1500 -15000 kWh/yr. The disparity is indicative of different lifestyles and consumer habits.

Families should not be expected to make major compromises to their lifestyles, particularly when living with children. A two bedroom dwelling using energy efficient lighting (not left on unnecessarily), washing machine (3 washes a week), laptop computer, radio, DVD player, fridge and freezer and occasional power tools should be able to maintain their consumption below 2000kWh/yr.

From the Lammas management plans, expected electricity requirements are as follows:

Plot Number	**Annual Expected Consumption (kWh)**
1	1200
2	1086
3	2000
4	600
5	2200
6	2200
7	1200
8	1333
9	4500
Hub	2500
Average	**1882**
Total	**18819** **or 18.8 MWh/yr**

The demand throughout the year will not be equally distributed. In the winter months there is more requirement for lighting and higher occupancy levels. This is suited well to hydroelectricity which produces many times more power in winter when water levels are high.

There is quite a large disparity in figures, less than national consumption patterns but again indicative of different needs. In particular plot 9 expects to use 2000kWh for domestic purposes and 2500kWh in the plot's workshop. They estimate requiring a 6kW max supply for 48 days of the year and will keep the use of the workshop to times of year when power is most available.

In addition to the Lammas settlement, Pont-y-Gafel farm and water bottling plant are retaining an option to use surplus electricity when available.

Existing Hydro-Electric System

There is an existing hydro-electric scheme included in the arranged land purchase. Water is taken from the Afon Gafel by way of a boulder weir at SN19273097 from where it flows through a predominantly earth leat for nearly 1mile. This system was initially constructed to serve the old mill at Pont-y-Gafel Farm. Some decades ago, the water was diverted through a hydro-electric turbine in a powerhouse at SN19252952. The turbine is a large single jet turgo built by Gilkes in 1935. This system has been fully operational within the last few years but fell out of use due to the maintenance requirement of cleaning leaves from the intake screen at the top of the penstock, where water is taken from the leat.

Hydro-electric generation is dependant on the weather, requiring rainfall to supply water to a turbine. The nature of water run-off from the land means that the available resource is much less variable throughout the year than photovoltaic solar or wind generation. Reduced flows in summer reduce the available power significantly or may prevent generation entirely in many installations. Hydro-electric generally shows a high correlation between available power and demand, i.e. generally producing maximum power in the winter when demand is highest. The existing turbine is clearly the best choice of renewable electricity sources for the settlement and will be shown to provide adequate power for the projects needs.

Study

Further to previous studies by Dulas and Derwent Hydro, a survey of the existing hydroelectric installation at Pont-y-Gafel was carried out on the 19th October 2007, and enquiries made with the Environment Agency regarding requirement for licensing.

The principle findings were as follows:

- The turbine is in reasonable condition; bearings, centrifugal governor, spear valve, isolator valve all operational.
- The turbine was originally installed on a lower head installation, and subsequently ran slower. It currently runs at 700rpm, which is well within the speed limit of the bearings.
- The turbine ran satisfactorily for many years before the work involved in cleaning the intake screen caused discontinuation of use.
- The 3 phase generator has a fault, either caused by moisture in the windings or failure of the automatic voltage regulator.
- There is no electronic load controller, the preferred method of regulating the turbine to ensure good quality output.
- The maximum output of the turbine is around 28kW using 100 litres of water per second
- The turbine performs inefficiently when running at low part load capacity, i.e. below 10kW.
- There is no automatic system to adjust the turbine in accordance with the flow available.
- The leat and pipeline are in serviceable condition.
- There is no self cleaning screen on the intake, necessitating continual cleaning throughout the winter
- The coarse screen at the upper spillway on the leat will need regular cleaning in the winter (probably weekly).

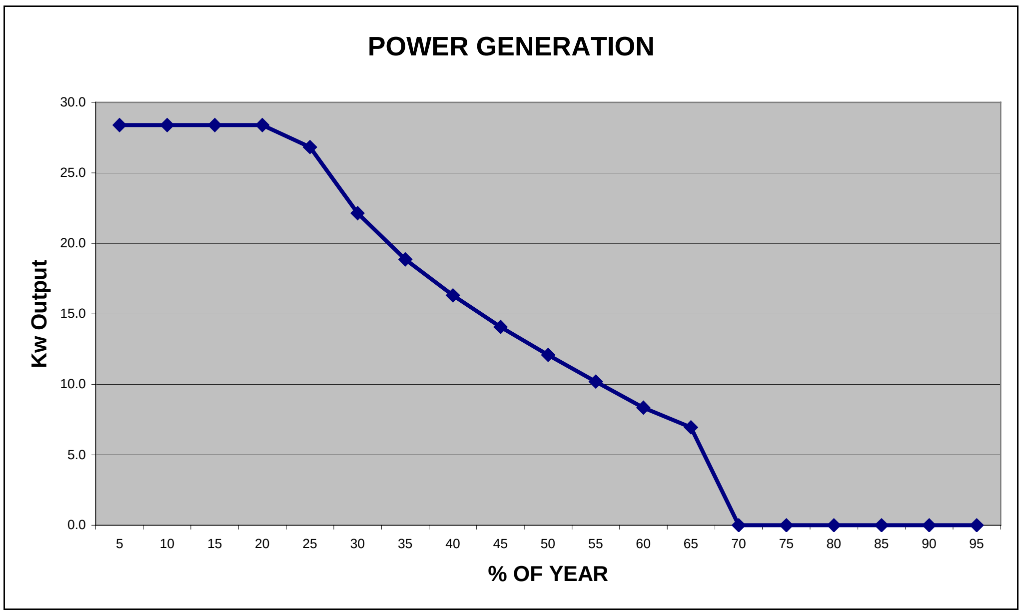
Consideration

The Dulas study made an estimation of annual capture based on a computer model of flow in the stream and assuming standard Environment Agency guidelines on how much water can be abstracted from the stream.

> *"The catchment upstream of the existing weir was digitised and assessed to give a total catchment area of 4.96 km2. Rainfall data from "Engineering Hydrology" by Eric Wilson indicated a gross annual rainfall for the area of 1600mm, with estimated losses due to evaporation and transpiration of 450mm, leaving a net runoff of 1150mm. This catchment was then scaled to the long term flow duration curve for the Afon Hafren, produced from 30 years of15 minute data collected by the Institute of Hydrology. This gives a predicted flow duration curve for the Afon Gafel catchment which feeds the existing weir."*

This involves what is termed a 'hands off flow', which effectively means there is a portion of the year in which you cannot generate.

Presented Graphically, the power generation throughout a typical year was suggested:

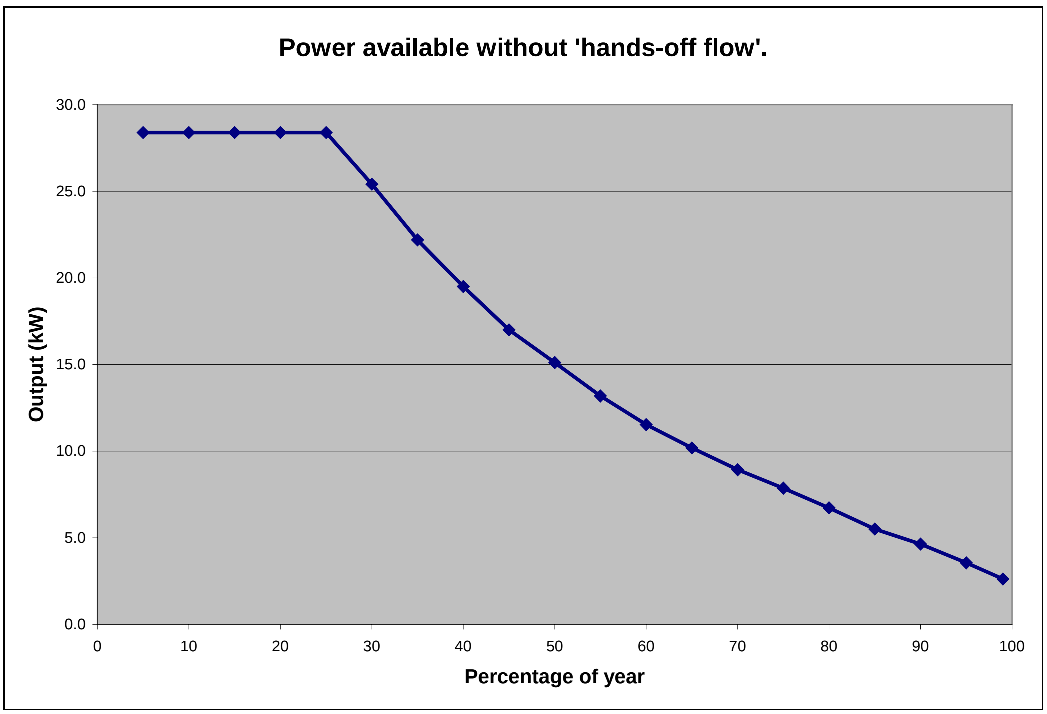


The turbine produces 28kW for 3 months of the year, equal to 672 kWh per day. Under these conditions the installation would generate **95,000 kWh** per year, this is **5 times the estimated energy demand**. Furthermore, the excess energy could be used to provide some degree of space and water heating thereby reducing consumption of biomass fuel.

However, the right hand end of this graph shows that for 30% of the year there would be no power generation, as there would be no water available.

James Slowgrave of the Environment Agency Wales has confirmed that the leat has Riparian Rights (pre-dating the Environment Agency), and that as such, no abstraction licence exists. It was also confirmed that no abstraction licence would be required as long as no changes or alterations are made to the leat, weir and inlet This means that no 'hands-off flow' exists. This is important at Pont-y-Gafel because it will significantly extend the generating season. Without the 'hands-off flow' the expected power generation is as follows:

Days/Year Flow Exceeded	% Time Flow Exceeded	Available flow (l/s)	Turbine flow (l/s)	Residual Flow (l/s)	Generated Power (kW)	Available Energy (kWh/yr)
18	5	590	100.0	490.0	28.4	12436
37	10	397	100.0	297.0	28.4	12436
55	15	305	100.0	205.0	28.4	12436
73	20	250	100.0	150.0	28.4	12436
91	25	212	100.0	112.0	28.4	12436
110	30	179	89.5	89.5	25.4	11130
128	35	153	76.5	76.5	22.2	9722
146	40	133	66.5	66.5	19.5	8542
164	45	116	58.0	58.0	17.0	7450
183	50	102	51.0	51.0	15.1	6621
201	55	89	44.5	44.5	13.2	5777
219	60	77	38.5	38.5	11.5	5051
237	65	68	34.0	34.0	10.2	4460
256	70	59	29.5	29.5	8.9	3910
274	75	52	26.0	26.0	7.9	3446
292	80	44	22.0	22.0	6.7	2946
310	85	36	18.0	18.0	5.5	2411
329	90	30	15.0	15.0	4.6	2029
347	95	23	11.5	11.5	3.6	1556
361	99		8.5		2.6	1150
					Total	**138382**



Under these circumstances the resource is able to maintain over 2kW in all but the driest conditions. This would provide 50kWh per day. The low flow situation is most likely to occur in the summer when demand is at it's lowest, so 50kWh/day should be sufficient. Whilst a continuous output of 2kW would be unlikely to meet the maximum instantaneous demand of the dwellings, a short term battery storage facility with inverter(s) would bridge this demand.

Without the 'hands-off flow' the expected annual generation will be 138MWh. This is over seven times the predicted annual demand of 18.8MWh.

Unsuitability of Turbine for Low Flow conditions

For generating power in low flow conditions (i.e. below 30 litres/second or 9kW generated power), the large Gilkes turbine currently installed is unsuitable. This turbine is design to use much larger quantities of water and in such conditions the efficiency will become very poor.
An additional turbine and generator would be required to extend power generation for the remaining 30% of the year. Fortunately the existing infrastructure has a facility which will allow easy connection of another small turbine to the existing hydraulic system. This means that the only additional requirement would be a turbine, generator, manifold, controller and changeover switching. It is probable that changing from one turbine to the other will be a manual duty, performed perhaps 6 times a year, depending on major fluctuations in the river flow.

Remedial Work required to the existing system

The turbine itself is in generally good condition. With repairs to the generator the system will work but require constant maintenance and adjustment to suit available flow.
To modernise the system and reduce the maintenance requires the following recommendations;

- Install a self cleaning aquashear screen at the intake to reduce the requirement for cleaning.
- Recondition the existing generator or replace with new.
- Install an electronic load controller with 'load shedding capability' that will turn off non priority loads when generation levels are particularly low.
- Install level sensor in intake tank, with controller and automation on the spear valve to continually adjust the turbine in accordance with the availability of water.
- Install cabling from the turbine house to the settlement.
- Install battery bank and inverter system to maintain continuity of supply when large peaks in demand occur.
- Install a second turbine and generator for low flow conditions.

Power distribution and management

Cabling

The power will be carried by three phase cabling to a distribution point in the community hub. From the distribution point this will split into three single phase spurs with additional signal cabling. The spurs will serve the following:

1. The terrace, plots 1-4
2. Plots 5,6 and the community hub.
3. Plots 7,8 and 9

Load Control

A requirement of hydroelectric system is that the load must be constantly matched to the production of the generator in order to maintain a stable voltage. This can be achieved by mechanically deflecting the flow to the turbine. The turbine still ‘consumes’ the same quantity of water, but some of the potential energy is wasted.

A more prudent approach is to maintain electricity production of the generator whilst dumping the excess power into (a) variable consumption dump load(s).

This is achieved by the electronic load controller (ELC) positioned at the distribution point in the hub building. The ELC maintains a nominal 240V output and diverts any excess generated power to the dump load, or ballast, at a variable voltage.

Dump Load

The ELC in the hub will direct all unused power to variable voltage dump loads which in combination are capable of safely using the maximum power output of the generator for an indefinite period. The dump load will be split into 10 x 3kW dump loads at the nine dwellings and the hub. These could be used to power space heating as long as provision is made to direct the heat to outside if not required. If individual residents do not want to take on the dump load it could be retained at the hub for the same space heating function.

As part of the land purchase deal the option is left open to Pont-y-Gafel farm to lay a connection to the distribution point and use the dump load power themselves so long as their load has the integrity required. Under these circumstances, priority will be given to the Pont-y-Gafel farm to use surplus/ dump load electricity.

In the event of a dump load failure, the ELC will mechanically restrict flow to the turbine via signal cabling to the actuated spear valve on the turbine.

Battery Backup

Each spur of the supply will be fitted with a 2.2kW sinewave trace inverter/charger and 10kWh battery bank. This device can charge its battery bank when there is surplus power and use it to supplement the power provided by the generator when demand exceeds supply. This backup will be able to increase the supply available on a phase by 2.2kW with a storage capacity of 10kWh

Power Supplied

Based on the expected power available without hands off flow, the average power available per phase will be as below: This power will be shared between the 3 or 4 plots on the phase.

Total generation expected per year	138 MWh
Annual availability per phase	46 MWh
Annual availability per plot*	**11.5 MWh**
Average expected consumption	**1.8 MWh**
Maximum expected consumption	4.5 MWh

Instantaneous power available per phase (kW)	No. days per year	Minimum power available per plot* (kW)
9	100	2.25
8	118	2
7	136	1.75
6	157	1.5
5	184	1.25
4	214	1
3	254	0.75
2	302	0.5
1	356	0.25
0.75	365	0.19

* based on 4 plots sharing a phase and all running at maximum consumption/no surplus sharing

The per plot figures in the table above do not account for any sharing of surplus between the houses on the phase or any contribution from the battery/inverter backup. For example on the very lowest power availability days of the year, the battery backup could charge fully during the night and quiet portion of the day and then raise the available supply to 2.95kW for 4 hours, enough for each dwelling to run a washing machine cycle if well coordinated.

Plot Connection

Each plot will be wired with two separate circuits, the first will be on a 1A MCB, capable of delivering approx. 240W. This circuit will be used to power essential items including lighting, fridges and freezers. This will be available for 365 days of the year.

The second circuit would run through a 13A MCB capable of delivering approx. 3120W. This circuit would power all other appliances. This circuit will be shut down remotely by the ELC when the power produced by the generator falls below 3kW, ensuring that the primary circuits are maintained at all times.

Each plot's distribution board will be fitted with LCD showing the total amount of power on the plot's phase which is available and currently being directed to the dump load. This will mean that users can check that there is sufficient power available on the phase before connecting appliances to avoid tripping the supply to the phase.

Plot 9's livelihood plan involves the use of a workshop with a consumption of up to 6kW, for 48 days in the year. In this case and the case of any future high consumption users, they will be fitted with a second 13A MCB in parallel to the first. This will be activated only when the generator is producing at least 9kW per phase, for the equivalent of 123 days/year. On these days the workshop will be able to draw 6kW whilst leaving at least 3kW for the remaining dwellings on the phase. The inverter/battery backup would augment this remaining power by another 2.5kW and could sustain full loading on this total 11.5kW supply for up to 4 hours a day. Note that this would be very heavy consumption and that the 6kW need of the workshop would only usually be drawn on the simultaneous start up of two large machines, the likes of which are rarely run continuously for any great length of time.

Low Flow Power Management

At times of low flow, the smaller turbine will be switched in. This will produce single phase, which will be fed synchronously through all three lives of the three phase cable to the hub distribution point. This will require the resetting of the inverters but will then allow the 'borrowing' of spare capacity between phases.

Costs

Management Needs / Maintenance

The whole system will require a weekly check. This will include checking the leat, cleaning screens as required, checking turbine operation and switching turbines when required. This will be part of the site manager's job.

System Costs

Costs	
Aquashear Screen	£1,500
Generator recondition	£500
Electronic Load Controller	£4,000
Automated turbine control	£1,800
Battery and inverter system	£6,500
Installation costs	£4,000
Dump loads	£1,500
Additional low flow turbine	£5,500
Main Cables for community supply	£4,500
3ph +1 ph switchgear	£2,000
Connection to dwellings	£1,000
Only relays required	£200
Total	**£33,000**

Conclusion

The existing leat, pipeline and turbine are in serviceable condition. The turbine ran well for a long time with the intake screen being the only significant issue.

Refurbishment of the hydro-electric Scheme, including smaller system for low flow conditions will cost £33,000

The power will be distributed via a simple yet relatively equitable and efficient system. The system will include capacity to deal with large peak loads and will have a protected low consumption circuit to ensure supply for lighting, freezers and small consumption 'essential' items.

There will be adequate power for both domestic and business needs**. The expected annual generation will be 138MWh. This is over seven times the predicted annual demand of 18.8MWh**. In addition, considerations of variations in flow suggest that there will be no particular need for additional sources of power.

Excess power will be dumped in the form of optional indoor/outdoor space heating at individual plots and the community hub building. Subject to appropriate facilities, Pont-y-Gafel farm will be allowed to take this power when desired.