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Blair Castle, Perthshire

The re-instatement of an early micro-hydroelectric plant

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Contents

1. Introduction

This refurbishment case study describes the re-instatement of an early 20th century hydro system at a large visitor attraction in the Highlands of Scotland. In older buildings much focus has been on perceptions of high energy use and sub-optimal internal conditions. While these are undoubtedly true in places, work by Historic Scotland, and its successor Historic Environment Scotland, has shown that the energy demand for space heating in historic and traditional domestic buildings can be reduced substantially. However, in larger buildings, especially non domestic ones that are open to the public as visitor attractions or retails establishments, fabric improvements can only go so far in demand reduction as the service load on energy is high.

That locally generated electricity was available, through small hydro-turbines from the late 19th century onwards, is often forgotten. With no central generating and distribution system at that time electricity only came from local sources, and local power generation has a long tradition in Scotland. Mill dams, lades and mill sites are found all over the countryside, including in what were then large cities. The development of hydro systems goes back a long time, and there existed many examples where the installations were integrated, both technically and architecturally, into new or existing houses or schemes. Because of this, the history and the development of hydro systems in Scotland is described, as well as specific details an original 1905 hydro installation.

The shift from using water power to turn wheels, to power machinery to turn turbines and dynamos at speed to produce domestic lighting and power, was a natural progression; and the many such systems were in country houses and rural estates. However, the advent of the national grid and the expectation of low cost electricity meant that the maintenance associated with such micro hydro turbine systems was too high and most were decommissioned. That the critical infrastructure survived at Blair Castle through an alternative use allowed the owners to feasibly reconsider the provision of hydro power again as energy prices have risen.

It has also to be admitted that there was technical and project experience at Blair that perhaps made this project more possible. This was through experience gained in several new hydro schemes in locations close by. Current incentives such as the ‘Feed in Tariff’ also made the project more viable from a financial perspective. When hydro schemes are pictured it is easy to focus on the engineering of the moving parts, the turbine, the dials and the dynamo. However, what this case study proves is that it is the channelling, gathering, holding and managing the liquid water from its source at sufficient height and moving it to the generating house is almost the hardest part, and can be the most costly. But it is hoped that this case study will give others the confidence to consider such works, and re-instate what proved to be a sustainable technology which is now enjoying a deserved re-birth.

From a wider perspective, the re-use of legacy mill and hydro systems should be encouraged, both from a historic cultural perspective, but also from economic and environmental ones. However, there will have to be balances in what is feasible, and how that can integrate with the requirements of a modern hydro plant.

2. The development of early micro hydroelectric systems and considerations for reinstatement

2.1 Domestic hydro systems

Much of the technology for electrical systems originated from the new steel warships developed in the late 19th century which required extensive services of all types. Subsequently in Edwardian homes electrical power became increasingly used for cooking and heating. Fire (then as now) was a constant threat in houses heated and lit by conventional means, and electricity was a way of reducing the risk. The first domestic electrical installation in Britain was at Cragside in Northumberland in 1868, where Lord Armstrong, the arms manufacturing magnate and builder of ships on the Tyne, installed an early lighting system in a part of the house (Figure 1), initially powered by a 6 horse power Siemens dynamo.

Figure 1: Cragside in Northumberland, the first house in Britain to have electricity. This was generated by a turbine system powered from a dam close to the house.

As is often the case today, developing technology and increasing demand obliged upgrades, and in 1886 a Gilkes turbine was installed; this again was upgraded in 1895. The water power came from a dam and turbine system in the river close to the house, with a vertical fall of about 100 metres. A reliable source of water and a reasonable height or fall of water was (as is now) a requirement for such domestic hydro projects. Such systems were quickly adopted in other houses, and Scotland, with suitable topography and rainfall was well positioned to adopt this new technology. While able to power large houses, the size of such systems (compared to subsequent hydroelectric power schemes) means that they are today described as 'micro-hydro'; the modern definition of micro-hydro is an installation of under 100 Kilowatts.

2.2 Early systems in Scotland

When Sir William Usher, the successful Edinburgh brewer, built a new mansion at Wells in the Scottish Borders in 1905 it was fitted with electricity throughout supplied from an integrated micro-hydro system. The infrastructure for this was extensive, involving a new concrete cauld or weir and a penstock approximately 200 yards long; parts of this system are still visible today (Figure 2). It is of note that these works were designed with a level of care as part of a designed landscape.

Figure 2: Remains of the steel penstock for the Wells House hydro system of 1905. The remains of the cauld can be seen in the background.

Storage of the electrical energy generated required a substantial quantity of batteries or accumulators. These were housed in a dedicated building 300 metres from the turbine. The investment and space required were substantial. As with the cauld, the battery house was designed with an element of Arts and Crafts style (Figure 3) to complement the new stable block built at the same time; technical infrastructure does not have to be bereft of aesthetic merit.

Figure 3: The former battery house at Wells.

This pattern of infrastructure was repeated elsewhere in Scotland, generally with similar components. Such systems became redundant with the advent of the National Grid, and much of the equipment was typically removed and the plant sold for scrap.

Occasionally original turbines are found still in situ; until recently the Gilkes turbine installed in 1909 in the policies of a country house near St Abbs in Berwickshire was still in situ in 2007 (Figure 4).

Figure 4: A 1909 Gilkes turbine surviving near a country house in Berwickshire.

2.3 General considerations for re-instatement

The potential re-use of a mill or other early hydro system should consider its possible designation. If the mill is Listed or in a Conservation Area consultation should take place with the Local Planning Authority, or Historic Environment Scotland in the case of a Scheduled Ancient Monument. The curtilage of a listed building may be taken to include the water system that serves it, and the extent of any scheduled area will likely be shown on a web-based map such as Pastmap. Even if the site is not designated in any way, it is possible that the Local Authority Archaeologist will recommend some actions, for example recording the site in some way.

Reinstatement of an existing micro-hydro system is commonly carried out with the intention of being sustainable and outweighing the cost and environmental disruption associated with the installation of new infrastructure; however a view should be taken on this by the relevant authorities. One factor may be the relative importance of existing mill wheels and turbines; and in some cases the preferred option may be to put them back into use. Where the existing plant is extensively damaged and of minor interest, recording and replacement by new equipment within the same masonry enclosure may be an appropriate outcome. In many cases, especially at a domestic level, a legacy turbine may not be easily restored or re-commissioned due to difficulties in obtaining spares and future maintenance requirements. It might be preferable that legacy equipment is simply left in place, with modern replacements sited close by.

3. Water power on the Blair Castle, Atholl Estates

3.1 Traditional uses of water power

As in most parts of Scotland, water power was utilised in different ways for many years. At Blair, the Estate sawmill, in common with many others in the early 19th century, was powered by water (Figure 5). The sawmill dates from 1840, and was in use until the advent of diesel powered portable power units (sometimes called oil engines).

Figure 5: The former Estate sawmill at Blair; this was water powered until 1905. The wheel pit is visible in the middle foreground.

The system for the sawmill followed a generally standard pattern of infrastructure, common to all water powered facilities of this scale - water routed to a holding pond, a lade taking the water to the mill, a launder taking the water to the wheel, and the wheel itself that powered the machinery.

3.2 The original hydro system at Blair Castle

In 1907, the owner of Blair Castle wished to install electrical power for the castle, adjacent buildings and the associated estate offices and workshops. Records relating to the works held at Blair Castle Archives give a useful insight to the project, including cost and design information. The engineer for the project was a William Massey, who appeared to design and manage the project. The nature of the work is much as one would expect today: electrical wiring and the required re-plastering in the castle itself, construction of the power house and the installation of three turbines and the dynamos that generated the power. Switchgear and cabling was also a cost.

It is important to note that at Blair there was not a single large body of moving water that could be tapped into. It had to be created by collection. The castle sits well above the river, and although there is a good sized burn that passes close to the castle it was not big enough to take off enough water continuously, nor would there be sufficient drop to give any effective power. In addition, the power requirements to provide electricity for the castle was considerably more than the modest needs of the sawmill, and therefore an entirely new system for collecting water was required, although the existing sawmill holding pond was included in the new system.

To increase the supply of water for the turbine, a new network of ditches were created further up the hill, linking into the existing sawmill supply (Figure 6).

Figure 6: Part of the 1908 ditch system on the moor above the castle; this was crucial in ensuring a continuous water supply for the new turbine.

These ditches gathered and routed water from the moorland into existing burns, and into the holding pond built for the sawmill water supply; and then to a new larger pond just below, now called 'Top Pond' (Figure 7). This pond was a way of storing water to allow the provision of a steady flow of water for the turbine. It also allowed an initial settle out of debris and grits from the water prior to entering the hydro system. This work was carried out in May and June in 1908.

Figure 7: The larger holding pond (called ‘Top Pond’) for the turbine water supply, excavated in 1908.

An even pressure in the pipe that supplied the turbine, called a penstock, was important to enable the turbine and the generator to run at optimal efficiency, and also to prevent pressure damage to the penstock (the re-learning of some of these water supply management issues was an important part of the successful running of the new system, which will be described later). This enclosed penstock is required to maximise the pressure of water going into the turbine. It was buried to minimise its impact on the parkland behind the castle. The penstock was made of 430mm diameter steel pipe of 5 metre lengths – with bitumen sealed flanges. At high points or flatter sections of pipe there was an air valve, accessible from above ground to allow the venting of air pockets. There were also 2 close-off valves to isolate sections of the penstock for any repairs. The penstock terminated at the turbine house, built about 100 metres from the castle next to the Estate yard. The water pressure in the penstock was 11.6 bar, which was the result of the 120 metres of head or height back up to the Top Pond.

The turbine house was a plain brick structure with a pitched roof. It housed the pressure control machinery that allowed control of the speed for the three pelton wheel type turbines, as well as the electrical switchgear that allowed output to be matched to demand. Without some form of energy storage, this matching had to be done manually; later on, banks of batteries were installed to buffer the power and the demand. At Cragside this person was named as “caretaker of the electric light”, although at Blair the electrical power operated more than lights alone.

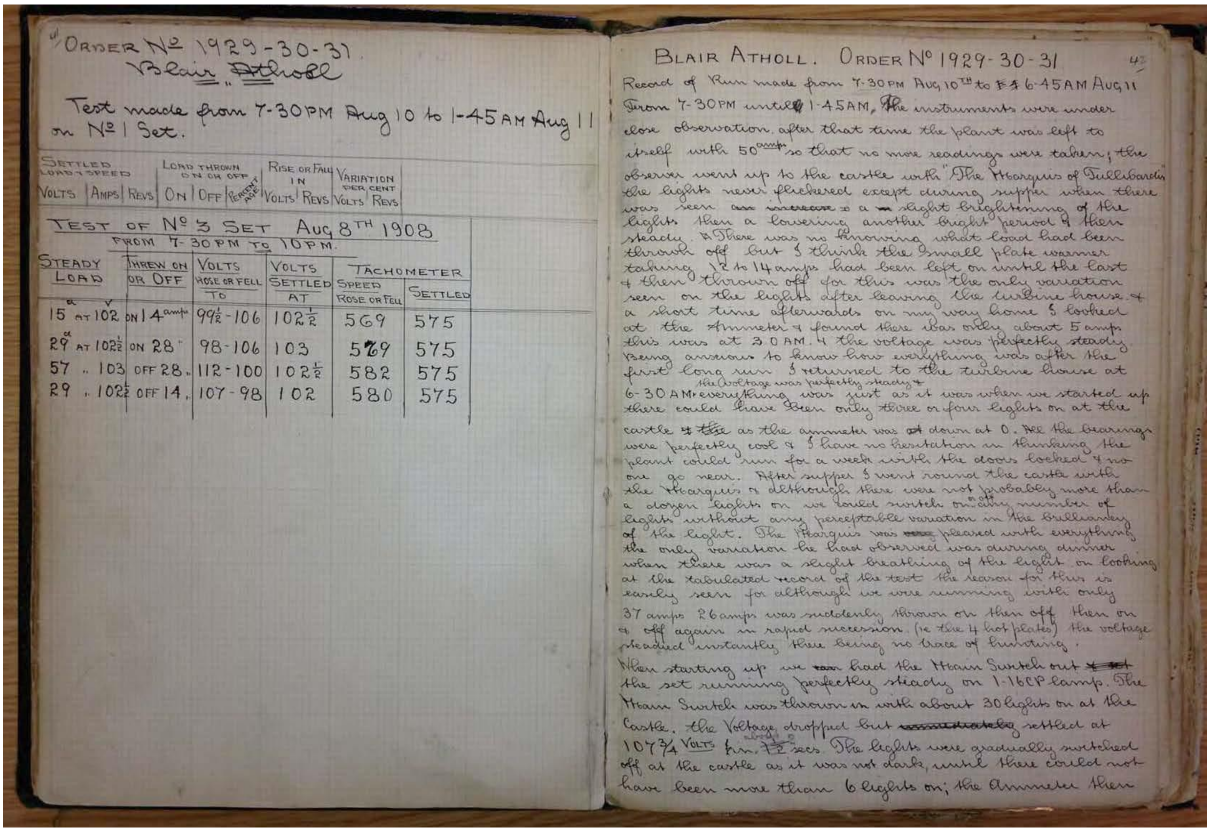
The first turbines were described as being a 60 brake horsepower consisting of three enclosed pelton wheels that converted jets of water into rotary motion, with a designed speed of 570 revolutions per minute. This rotary motion drove three dynamos, generating the electricity at 100 volts direct current, with a power rating of around 14 amps. This voltage and current are very high for domestic circumstances compared to today's standards, and require a high level of insulation. This was achieved through large ceramic insulators and brass connectors. High power and high voltages require such large distinctive switchgear (this imagery lives on in certain genres of film to this day). No images of the original turbines survive, although they are likely to have been similar to the Gilkes turbines shown in Figure 4; but the larger power requirements of Blair Castle requiring in 3 devices.

Cabling then took this electrical power from the turbine house to the battery house, where a bank of batteries allowed a modest degree of energy storage. From the battery house another cable run took the power to the castle, where there was a further switchboard and fuse panel. The costs of the work were recorded by the Estate and following reconciliation with inflation and other financial adjustments are broadly equal with the costs for the new work described later (Table 1).

Work Item	**Contractor**	**Cost (1908)**	**Cost (2016)**
Engineers fees	William Massey	£325	£27,335
Digging the ditch system on the hill	Estate Staff	£372	£31,288
Reservoir construction ('Top Pond')	Estate Staff	£249	£20,942
Construction of the power house	Estate Staff	£179	£15,055
Electrical plant & wiring in the Castle	Belshaw & Co	£1,652	£138,944
Plastering and remedial works	Estate Staff	£2,100	£176,623
Three dynamos	Electric Construction Co	£501	£42,137
Electrical cabling	Western Electric Co	£300	£25,232
Electrical switch board	Belshaw & Co	£70	£5,887
Penstock and turbine assembly	Gilkes	£3,154	£265,272
	TOTAL	**£8,902**	**£748,715**

Table 1: Installation costs for the 1908 Blair Castle hydro system, from Atholl Estate records.

The high cost of the plastering and other works hints at quite a lot of work and disruption aside from the work directly related to the hydro system. As is the case today, routing new wires and installing new domestic equipment in large houses is disruptive and costly work. The power output of the system as designed was 81 Kilowatts, and proved effective in delivering power to the castle. During the initial tests the Estate Factor reported that under William Massey's supervision a test run of the system on the 10th August 1908 ran '100 lights' in the Castle. Some of this test information has been preserved by Gilkes the manufacturers of the turbine (Figure 8).



Order No 1929-30-31
Blair Atholl

Test made from 7-30PM Aug 10 to 1-45AM Aug 11 on No 1 Set.

Settled Load & Speed			Load thrown on or off			Rise or Fall in		Variation per cent	
Volts	Amps	Revs	On	Off	Percentage	Volts	Revs	Volts	Revs

Test of No 3 Set Aug 8th 1908
from 7-30PM to 10PM.

Steady Load	Threw on or off	Volts rose or fell to	Volts settled at	Tachometer Speed rose or fell	Tachometer Settled
15 at 102	on 14 amps	99½-106	102½	569	575
29 at 102½	on 28 "	98-106	103	579	575
57 " 103	off 28 "	112-100	102½	582	575
29 " 102½	off 14 "	107-98	102	580	575

Blair Atholl. Order No 1929-30-31 43

Record of Run made from 7-30PM Aug 10th to 6-45AM Aug 11
From 7-30PM untill 1-45AM, the instruments were under
close observation after that time the plant was left to
itself with 50 amps so that no more readings were taken; the
observer went up to the castle with "The Marquis of Tullibardine"
the lights never flickered except during supper when there
was seen ~~an increase~~ & a slight brightening of the
lights then a lowering another bright period & then
steady. There was no knowing what load had been
thrown off but I think the small plate warmer
taking 12 to 14 amps had been left on until the last
& then thrown off for this was the only variation
seen on the lights after leaving the turbine house &
a short time afterwards on my way home I looked
at the Ammeter & found there was only about 5 amps
this was at 3.0 AM. & the voltage was perfectly steady
Being anxious to know how everything was after the
first long run I returned to the turbine house at
6-30 AM. the voltage was perfectly steady & everything was just as it was when we started up
there could have been only three or four lights on at the
castle ~~& the~~ as the ammeter was ~~at~~ down at 0. All the bearings
were perfectly cool & I have no hesitation in thinking the
plant could run for a week with the doors locked & no
one go near. After supper I went round the castle with
the Marquis & although there were not probably more than
a dozen lights on we could switch on any number of
lights without any perceptable variation in the brilliancy
of the light. The Marquis was ~~very~~ pleased with everything
the only variation he had observed was during dinner
when there was a slight breathing of the light on looking
at the tabulated record of the test the reason for this is
easily seen for although we were running with only
37 amps 26 amps was suddenly thrown on then off then on
& off again in rapid succession (ie the 4 hot plates) the voltage
steadied instantly there being no trace of hunting.
When starting up we ~~ran~~ had the Main Switch out ~~& set~~
the set running perfectly steady on 1-16CP lamp. The
Main Switch was thrown in with about 30 lights on at the
Castle. the Voltage dropped but ~~immediately~~ settled at
107¾ Volts in about 1½ secs. The lights were gradually switched
off at the castle as it was not dark, until there could not
have been more than 6 lights on; the Ammeter then

Figure 8: The manufacturers test run information from 1908 (photograph Gilkes Power Ltd).

3.3 Decommissioning

The advent of the National Grid and the distribution of centrally generated electricity meant that the cost of running the system could not compete with grid power, and with the emergence of nuclear power in the second half of the 20th century it was expected that the cost of electricity would reduce to minimal levels. Although this situation of cheap power never transpired, the Blair hydro system was decommissioned in 1958, and the turbines were sold for scrap. The turbine house was retained, and used for a variety of purposes, including a kennel. The penstock however was given a new use, and kept full of water as a secondary water supply for the Castle's fire protection sprinkler system. It was the preservation of the penstock through this new use that meant subsequent re-commissioning of the hydro system was possible.

4. Re-commissioning

4.1 The initial idea

The thought of re-instating a turbine system at Blair came from an unlikely source, that of a small but persistent, ponding of water in a car park. Investigations showed that this water was coming from a small leak in the joint of the original penstock, in later use as a storage vessel for the water for fire protection system in the castle. The joint had been displaced by the roots of a tree. While this leak was easily fixed it set in train an idea about re-instatement.

4.2 Energy costs

Rising prices and increased energy demand at Blair Castle obliged a re-assessment of energy provision to the estate. Experience by The Blair Charitable Trust with new hydro schemes on other parts of the Estate had resulted in a degree of confidence and experience in this area, and a very clear understanding of costs and benefits. The existence of Government subsidies for micro-hydro projects was also a consideration, and a good relationship had been built up with Gilkes, who were still manufacturing turbines and related equipment.

4.3 Recent experience with micro-renewables

The Estate had used biomass for some years and found that there were difficulties in managing the wood fuel, the efficiency of the plant, and the maintenance of the boiler system and its fuel feed devices. A fire in 2012 led to a review of this fuel source. Wind power was considered, but its visual impact on the landscape was felt to be inappropriate, especially in an area such as Blair Atholl. In addition, there were reservations over the embodied carbon and interventions on the land involved with the civil engineering work required for construction traffic, footings for the turbines themselves and the ongoing maintenance requirement.

4.4 Assessment of potential power

A major part of a proposal for hydro power generation must be an assessment of what power the installation can deliver. For turbines this is generally a factor of how much height there is (the head) and how much water is available. At Blair, with an existing water supply with a head of 120 metres, conditions were good for potential power. Against the figure for potential power has to be balanced the efficiency of the conversion into power, and the cost of installing the plant. Where there is a good height of water available, turbines are very efficient, but to achieve this efficiency there is a considerable degree of mechanical, electrical, and civil engineering.

4.5 Feasibility study

This basic finances and economic costing had to be progressed before any further work was done. A feasibility study was commissioned by The Blair Charitable Trust with a firm of consulting engineers to carry out accurate calculations as to output, investment required, and payback times. From this work it was envisaged that power could be supplied to the castle at a cost of 24p per kilowatt-hour (as opposed the then electricity price of 13p per kwh) giving an 8 year payback period. Integral to this was the rate for the Feed in Tariff (FIT) an incentive by the Government, designed to prompt innovation in equipment and installation in suitable locations such as Blair. The rate for the FIT varied with the size of the installation, so it was decided to choose an 84kw system so as to remain within the higher FIT band (although retaining the existing penstock determined the power output). There was an additional incentive to progress the project, as it was understood that the FIT subsidy was provided on a tapering annual scale, to reward early adopters. These positive results gave rise to the appointment of a project team in January 2012.

4.6 Assessment of the penstock

This was a critical aspect of the feasibility study. The re-use of the existing penstock, upon which the economic viability of the projects depended, was fundamental. To assess condition, the original penstock was excavated at four points, and a section was removed for inspection and assessment as to condition (Figure 9). A cut section through the steel works showed it to be in very good condition with minimal rust on either side (Figure 10). Its condition was therefore assessed as very satisfactory and fully able to handle the required water pressure from the hill supply. While a pressure test was possible and desirable, this was not progressed in case it caused damage to the pipe, and in any event, having held water at pressure for the fire system for many years, it had passed its own test.

Figure 9: A section of the 1908 steel penstock was removed to allow close inspection and assessment (image Atholl Estates).

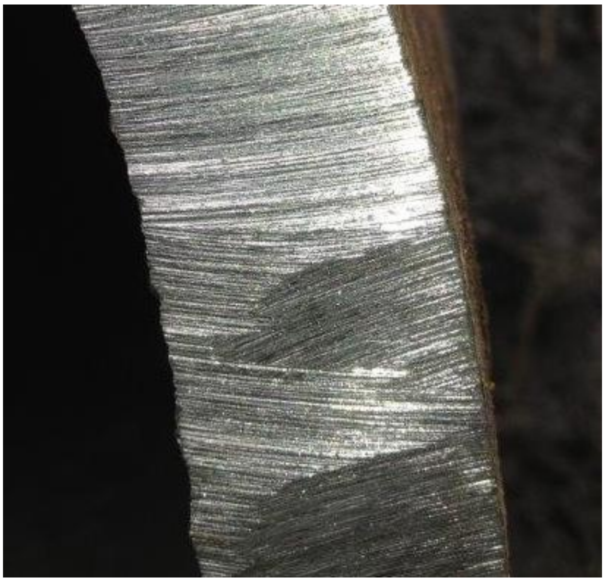


Figure 10: A close view of a cut through the 1908 steel of the penstock; the amount of corrosion was minimal (image Atholl Estates).

5. The design of the new system

5.1 Limitations of the legacy hill drainage system

Crucial to the old scheme, and the planned new one, was the proper functioning of the drainage ditch system on the moor above the castle. Since the de-commissioning of the plant in 1953, the ditch had filled up and water had scoured out new routes. The amount of water this legacy arrangement could provide was assessed as being 180 litres per second. The new system would require less, 92 litres per second, and therefore some additional mitigation works would be required to reduce capacity in flood conditions.

5.2 The limitations of the existing penstock

The costs of turbines were well understood through previous recent work with Gilkes, but the principal question was the cost of getting the water to the turbine. Here the condition of the existing penstock, now holding water for the castle fire system, was important. If it was found to be damaged, or could not route water at pressure to a new turbine then a new penstock would be required. The cost of a new penstock, over a mile long, would be very high, and would render the project unviable. Assessing the condition was difficult, for the penstock was buried. However, it was known that it could hold water at full load pressure as it had been in operation as the fire hydrant for 50 years without any visible leaks.

5.3 Options for the turbine house

The original turbine house was still standing, and re-using the existing building also meant that planning permission and Listed Building Consent was not required. Therefore it was decided to repair the turbine house for the new plant.

5.4 Turbine design and configuration

With the re-use of the penstock confirmed, the flow rate and pressure of water to the turbine could be calculated using the ‘head’ of 120 metres. Gilkes, the turbine manufacturers, were then able to configure a turbine unit to suit. The lead time for the supply of such a unit would be 10 months. In addition to this the control gear and distribution board of the correct specifications was required.

6. Planning consents and permissions

6.1 SEPA

To take water from a burn or river, consent is required. At Blair, this was not quite the situation as the water would be gathered off the hill in an existing ditch system, not newly ‘diverting water’ as such. However, the Scottish Environmental Protection Agency (SEPA) had to be approached, as the head waters of the river Tay (the river system that Blair is part of) were monitored for fish breeding purposes. While they were not opposed to the scheme, a number of details had to be attended to, the most significant of which was a silt trap on the hill drain.

6.2 Planning Consent

The proposed facility was in the Cairngorms National Park, and planning consent was required. This obliged a site visit by planners and SEPA in spring 2012. Once the relatively modest scale of the works had been seen and explained (essentially the collection ditch on the hill) and the need for a silt trap established, progress was satisfactory.

6.3 Listed Building Consent

The grounds of the castle are also on the Register of Parks and Designed Landscapes, and therefore dialogue with Historic Scotland was also required. As the project planned to utilise the existing buried water route, there were no issues with the designed landscape.

7. Site work and the construction phase

7.1 Works to the hill drainage

The existing ditch from 1908 needed clearing. While it was simple in concept to clear and open up the route, and to a degree it was in practice, the work still took some time. A mechanical excavator worked for 6 weeks to clear the route. The cleared ditch was termed 'the 4 mile ditch' (Figure 11) and reflects the scale of the project.

Figure 11: The recently cleared ditch on the hill above the castle, termed 'the 4 mile ditch' (image Atholl Estates).

In all the work on the hill, the governing principle was that of ensuring an even and steady water flow into the Top Pond. This required the construction of several overflow cills or spillways along the route to manage and handle additional water during times of heavy rain. The new spillways were constructed using wire gabions and concrete matting (Figure 12).

Figure 12: One of the new spillways needed to manage surges in water coming off the hill in periods of high rainfall or snow melt.

Whilst most of the works on the hill were essentially agricultural in nature, the requirement from SEPA for the construction of a silt trap required a designed structure, constructed from reinforced concrete (Figure 13). Transport of materials for this was resource intensive.

Figure 13: The new concrete silt trap on the hill moor behind the castle.

Figure 14: Surplus water management was important at all stages of the pond supply, and lower down the hillside new solutions were needed to route excess water clear of the pond.

Lower down the ditch route, where the construction of spillways and the routing away of water was not possible, some burns had to be channelled over the pond supply ditch in order to reduce flow into the pond. This required imaginative engineering (Figure 14).

7.2 The holding pond

As with the old system, a holding pond was required to keep the water in the penstock at a constant pressure. The pond from the 1905 scheme (Top Pond) had been kept for fishing use, and although partially silted up, was still adequate for the restored scheme. The penstock entry point was moved however, and a new cill and spillway was formed. While this was mainly to regulate the water flow, it was also designed to catch debris and prevent it progressing down into the turbine (Figure 15).

Figure 15: The new cill for the holding pond. Note the filter screen designed to keep debris out of the penstock.

The existing access chambers to the penstock, located at four positions in the parkland of the Castle, were dug out and new inspection chambers constructed using standard concrete manhole components (Figure 16). New isolation valves, to allow selective draining of the penstock, were fitted. New air valves were installed to ensure air pockets could be bled from the restored penstock.

Figure 16: The manhole cover over one of the new chambers for the isolating and air bleeding valves (image Atholl Estates).

7.3 Repairs to the turbine house

It was also decided by The Blair Charitable Trust that the existing turbine house would be used as a showcase for the project, so from the outset there was an intent for the building, and the plant inside, to be viewed both by casual visitors as well as by engineers and other professionals. This meant that the presentation and finish of the structure was going to be of a higher standard than other similar structures. The brick structure from 1905 was in reasonable condition; and the structural repairs were relatively simple, with its existing profile metal roof covering, new internal linings, a new concrete slab and a new entrance lobby being formed. This lobby contains the firefighting systems and equipment for the first response team for the castle. The internal walls of the lobby were lined in vertical timber lining of Scots Pine, a common 19th century finishing detail in the Highlands (Figure 17).

Figure 17: The new entrance lobby of the turbine house finished in local Scots Pine from the Blair Estate.

7.4 Noise management

Turbines create heat, so ventilation was a key requirement; however turbines operating at capacity are noisy and an important factor for The Blair Charitable Trust was noise management. The Gilkes 82kw turbine will produce about 85 decibels, and the visitor experience for those visiting the castle and the historic landscape had to be considered carefully, along with all residents and those working in the estate office close by. Therefore a high degree of acoustic engineering was required. The lobby to the turbine house acted as a noise buffer, and was entered through acoustically sealed doors. These were highly engineered and consequently costly. In addition the intake and extract air ventilation louvres were designed with acoustic baffles, one of which is shown in Figure 18. Such bespoke equipment was costly (costing about £14,000), but considered necessary in this situation. An ‘S’ trap sump contains all mechanical noise on the outfall. With these works completed, there was no discernible mechanical noise outside the turbine house.

Figure 18: One of the noise mitigation features in the turbine house – a sound proofed ventilation opening.

During the 1939-1945 conflict the castle grounds were used for military training, and many new temporary structures had been put up. Remains of paint, possibly representing a camouflage paint from this time were found on the turbine house, and the building was painted in a disruptive pattern in acknowledgement of this. The exact details of such schemes are a separate study in themselves, but at Blair a credible new version was painted (Figure 19).

Figure 19: The restored power house in the re-instated disruptive camouflage pattern.

7.5 Work inside the turbine house

The route for the penstock into the turbine house had to be adjusted to align with the new turbine position internally with new pipework (Figure 20).

Figure 20: The installation of the new pipework in the turbine house (image Atholl Estates).

The turbine itself was delivered to site in November 2013, and installation took 2 weeks, including the electrical connections. All electrical below slab ducting was covered with Douglas fir boards – in effect trench covers. This is an old fashioned, but durable system that Atholl Estates had adopted for all its five power stations. It allows easy access at modest cost and utilised local materials that could be easily be replaced in the event of wear or damage. The control panel is fully automated and allows remote monitoring and assessment by The Blair Charitable Trust and maintainer (Figure 21). To add visual interest, a display of animal skulls was mounted on the inside.

Figure 21: The new control panel and switchboard for the turbine and dynamo.

7.6 New electrical routes to the castle

A new 440 volt cable was buried in a new trench following the line of the 1950s fire hydrant. It terminated in a commercial grade main board located in the castle electrical switch gear room.

8. Commissioning the system

8.1 Commissioning

Construction work finished in February 2014 and the penstock was pressurised in March 2014. The turbine was first run on the 25 March and the electrical distribution board was powered up shortly afterwards.

8.2 Adjustment of the water supply

It was at this stage that the importance of the flow rates from the hill were fully appreciated, and the establishment of optimum flows in the burns and ditches on the hill. A second pass or review of water management features was carried out, including the addition of a simple flow gauge where the hill water enters the holding pond and adjustment of the spillway cill heights. The optimal flow rate from the ditch off the hill into the top pond was worked out as being 92 litres per second. The turbine house was finished in May 2014, and formally opened by Fergus Ewing MSP in January 2015 (Figure 22).

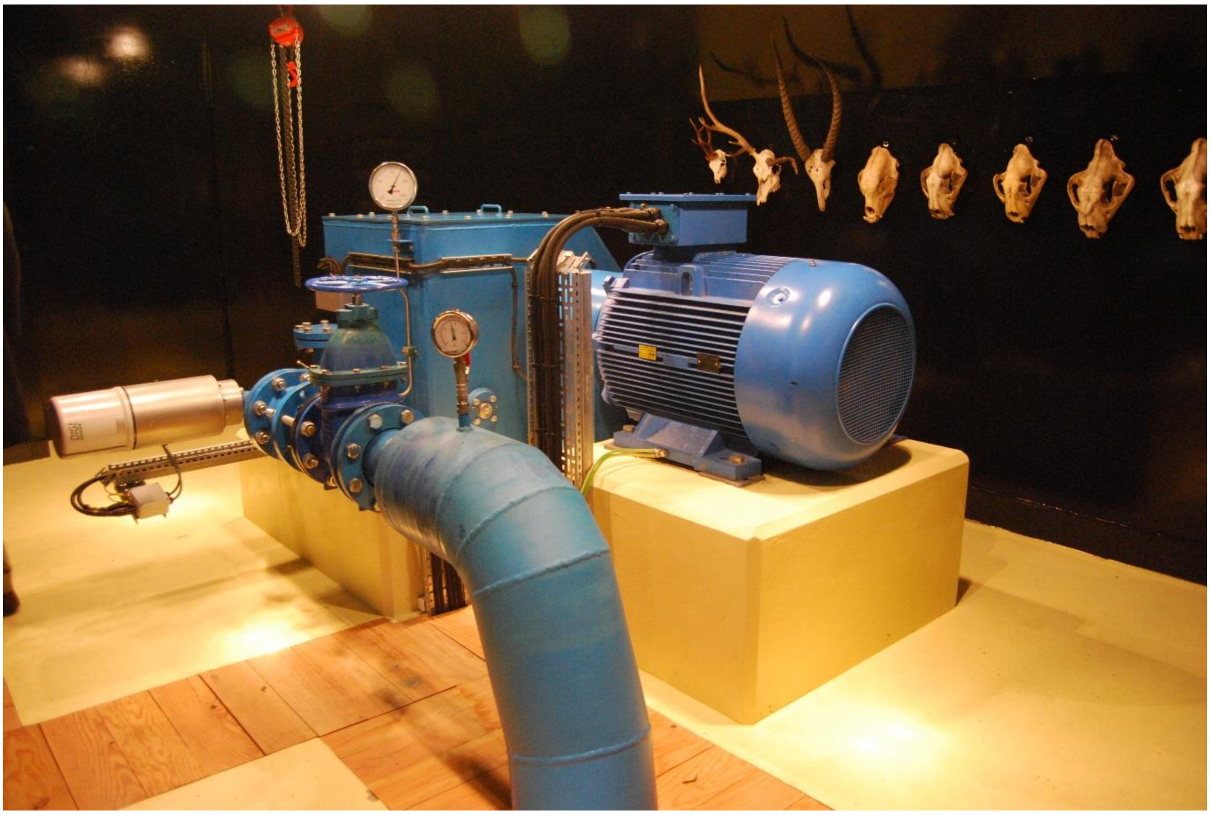


Figure 22: The completed interior of the turbine house (image Atholl Estates).

8.3 Interpretation

The Estate was keen to ensure that the hydro system and the source of renewable energy that it gave was demonstrated to the visitors to the castle and to the wider public. As such the interior of the turbine house was finished to a higher standard that might otherwise have been the case, and an interpretation panel and viewing window was provided (Figure 23).

Figure 23: The interpretation board and the viewing window into the power house.

9. Evaluation

9.1 Energy generated

The system runs very well. Power was first generated in September 2014. The pattern of electrical energy demand at the castle is different to many businesses in that peak requirement is in mid to late summer, and is lowest in the winter when the castle visitor operations were quieter. Therefore the hydro system is able to export the most electricity when the grid needs it. This maximised the revenue from the Feed in Tariff. Graphs showing the Energy generated in Financial Year 2015/16 is shown in Table 2.

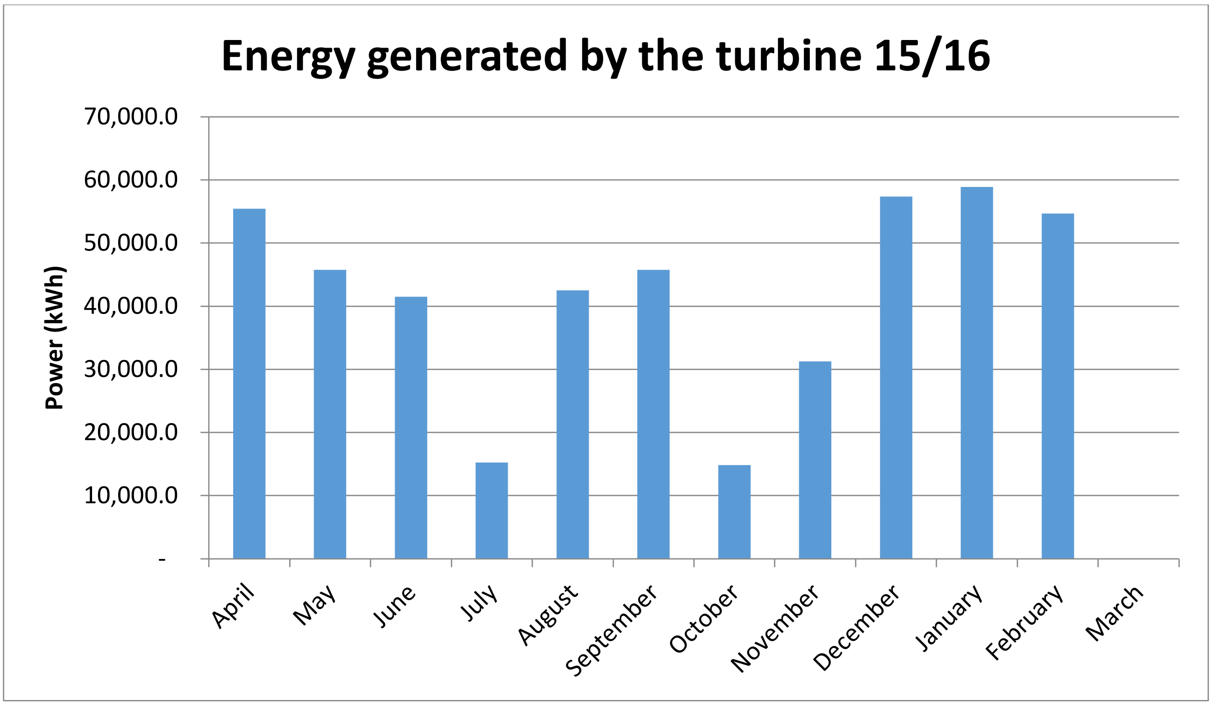


Table 2: Energy generated by the restored turbine system in 2015/16.

9.2 Energy exported to the Grid

Power not required for the operation of the castle and the estate is exported to the grid. Energy exported to the Grid in FY 15/16 is shown in Table 3.

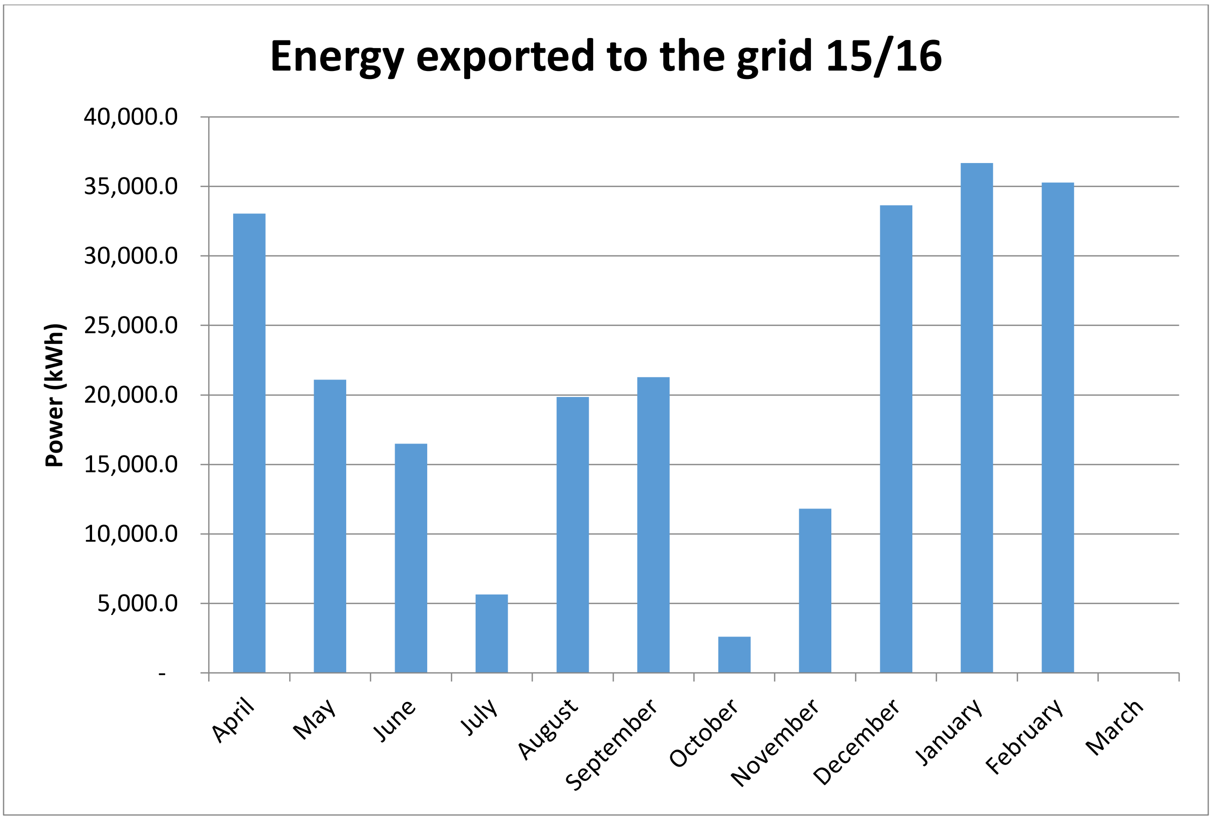


Table 3: Energy exported to the Grid in FY 15/16.

9.3 Running and maintenance requirements

A six monthly service of the turbine, the generator and its associated electrical systems is carried out by the turbine manufacturer. Gilkes is also able to monitor the performance of the system remotely in real time, so areas of excessive wear and other aspects needing attention are known prior to the visit.

9.4 Costs of the work

As with the operational functions of the system, the project costs are best viewed as a series of distinct elements (Table 4).

Work element	Cost
Feasibility study	£20,000
Consultant Engineer	£25,000
Works to the hill drain	£26,000
Ground works on the hill (Silt trap)	£40,000
Works to the main intake (Top pond)	£55,000
Works to the existing penstock	£6,000
Fabric works to the turbine house	£34,000
Turbine cost and installation	£143,000
Power management system and turbine house wiring	£39,000
Cabling to Castle and connections	£22,000
General contracting and facilitating	£200,000
Total	**£610,000**

Table 4: Costs for the work to the re-instated hydro system at Blair Castle.

10. Conclusion

This project has shown that the re-use of legacy hydro facilities is possible in an historic context, with repair and upgrade of some elements being needed. At Blair the fortunate circumstance of already having an important element of the hydro infrastructure meant that the re-use of the system was economically possible. The experience and confidence of the professional team on this project undoubtedly played a part in its success. The pragmatic and flexible approach taken by The Blair Charitable Trust ensured that costs were managed carefully, and risks were understood and accounted for. The Castle now has a sustainable energy supply and a new source of revenue. After 2 years of operation estate staff have a good understanding of the running and maintenance of the system, and a sound appreciation of the varying power demands of the castle.

Further reading

Refurbishment Case Studies

This series details practical applications concerning the conservation, repair and upgrade of traditional structures. The Refurbishment Case Studies seek to show good practice in building conservation; some describe projects supported by Historic Environment Scotland, and some are entirely privately resourced projects. The results of some of this work are part of the evidence base that informs our technical guidance. At the time of publication there are 20 case studies covering measures such as repairs to masonry, upgrades to windows, walls and roof spaces in a range of traditional building types such as tenements, cottages and public buildings.
All the Refurbishment Case Studies are free to download and available from the HES website ***https://www.historicenvironment.scot/refurbishment-case-studies/***

Technical Papers

Our Technical Papers series disseminate the results of research carried out or commissioned by Historic Environment Scotland, mostly related to improving energy efficiency in traditional buildings. At the time of publication the series has 23 titles covering topics such as thermal performance of traditional windows, U-values and traditional buildings, keeping warm in a cool house, and slim-profile double-glazing.
All the Technical Papers are free to download and available from the HES website ***https://www.historicenvironment.scot/technical-papers***/

INFORM Guides

Our INFORM Guides series provides an overview of a range of topics relating to traditional skills and materials, building defects and the conservation and repair of traditional buildings. At the time of publication the series has over 50 titles covering topics such as: ventilation in traditional houses, maintaining sash and case windows, domestic chimneys and flues, damp causes and solutions improving energy efficiency in traditional buildings, and biological growth on masonry.
All the INFORM Guides are free to download and available from the HES website ***https://www.historicenvironment.scot/inform-guides/***

Short Guides

Our Short Guides are aimed at practitioners and professionals, but may also be of interest to contractors, home owners and students. The series provides advice on a range of topics relation to traditional buildings and skills.
All the Short Guides are free to download and available from the HES website ***https://www.historicenvironment.scot/short-guides/***