Power from the Glens
Neart nan Gleann

Scottish Hydro Electric

This booklet is dedicated to the memory of the 'Hydro Boys' whose legacy is the largest source of renewable energy in the country.

Contents

Scottish and Southern Energy is one of the largest energy companies in the United Kingdom. It is involved in the generation, transmission, distribution and supply of electricity; energy trading; the storage, distribution and supply of gas; electrical, environmental and utility contracting; domestic appliance retailing; and telecoms.

It is the leading generator of electricity from renewable resources in the UK, owning and operating around 40% of the country's total capacity.

Foreword

Scottish and Southern Energy owns and operates around 40% of the United Kingdom's renewable energy capacity. Most of this is hydro electricity, produced in the north of Scotland by a highly effective region-wide generating system which this publication describes in detail.

Despite its century of controversial history, hydro power has provided the technical means to give the Highlands vital access to modernity by harnessing 'power from the glens'. Half a million people visit the Pitlochry Dam and Fish Ladder each year: a resounding endorsement of hydro power's economic and environmental achievements. But as this booklet explains, hydro also has a crucially important future at the forefront of the battle to counter climate change.

Emma Wood 2005

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Introduction

Scottish Hydro Electric, then known as the North of Scotland Hydro Electric Board and now part of the Scottish and Southern Energy Group, was established by an Act of Parliament in 1943. It was to be responsible for generating, transmitting, distributing and supplying electricity throughout the north of Scotland, including the Highlands and Islands. This covers about 25% of the total land area of Britain but just 3% of the population. The region contains Britain's highest mountains and largest inland lochs which, combined with high rainfall, make hydro electricity viable.

Hydro electricity is produced using the power of running water to turn the turbines of generating sets in power stations. The technology dates back to the late 19th Century when the first privately owned hydro electric power stations were built to power the aluminium smelting industry and to provide local electricity supplies. But it took the vision of one man, Tom Johnston, the Secretary of State for Scotland in Churchill's wartime coalition government, to bring power from the glens for the benefit of all. At the time, it was estimated that just one farm in six, and one croft in a hundred, had electricity. Today, virtually every home in Scotland has mains electricity.

Today, hydro electricity, together with wind farms and emerging technologies such as wave and tidal power, is helping the country meet its commitment to provide increasing amounts of energy from renewable sources. A major refurbishment programme of Scottish Hydro Electric's hydro stations has ensured these wonderful assets can produce clean electricity for the nation for decades to come.

Hydro electric schemes and catchment areas

How it all began

Surveying during construction at Pitlochry

The first successful public supply of hydro electricity provided power to the Benedictine Abbey in Fort Augustus, at the west end of Loch Ness, and to 800 inhabitants of the village. The year was 1890. It was to be another 40 years before the first large-scale scheme came into operation, in 1930. This development, at Rannoch and Tummel Bridge in Perthshire, was built by the Grampian Electricity Supply Company.

Testament to the speed of change possible in the shadow of the Second World War, during the period between 1941 and 1947, the newly-formed Council of State for Scotland had considered the potential for hydro electric development in the north of the country. An enquiry was established into what development was possible and what type of body should undertake it.

The committee's report was published in 1942 and the Hydro Electric Development (Scotland) Act was passed in 1943. The Act recommended the creation of a board to manage hydro generation in the north, to be known as the North of Scotland Hydro Electric Board.

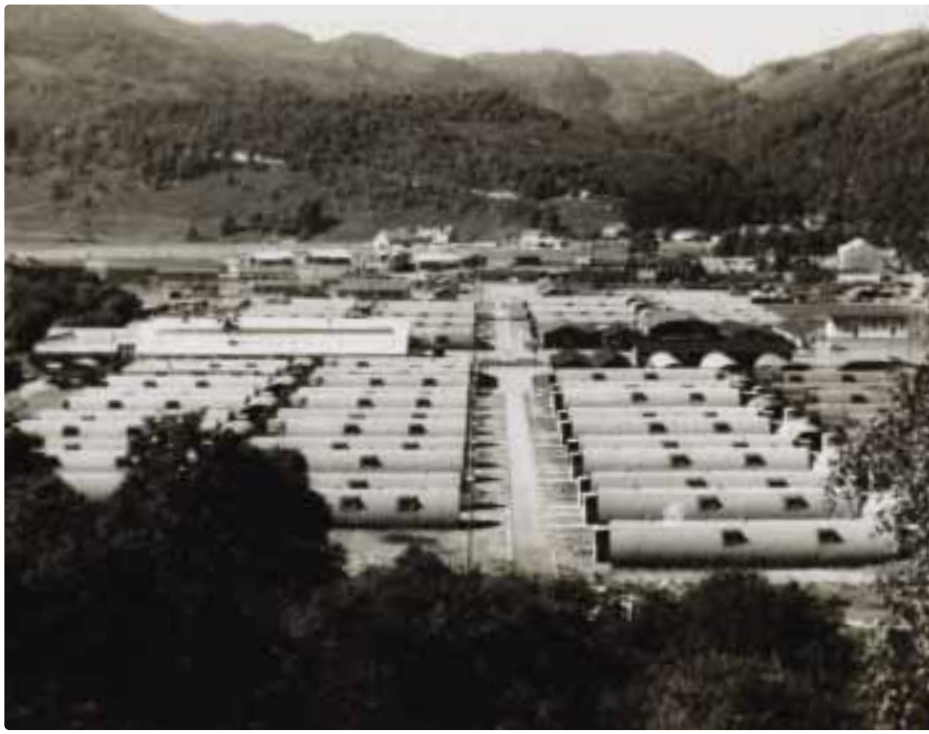
The first attempts to get approval for two schemes, Tummel/Garry and Loch Duntelchaig, were strongly opposed and resulted in the resignation, in 1946, of the Board's first chairman, Lord Airlie. So it was under the stewardship of the second chairman, Tom Johnston, that most of the construction of the Board's first scheme, at Sloy, near Loch Lomond, was done, with the station being commissioned in 1950.

In 1948, the Electricity Supply Industry in Britain was nationalised. The assets of the Grampian Electricity Supply Company and other public producers in northern Scotland were taken over by the North of Scotland Hydro Electric Board. Its challenge was to combine these existing assets with new schemes which would be built over the next 20 or so years, to harness the water power of the Highlands. These would provide electricity to the northern part of Scotland on a scale which would otherwise have been impossible.

By 1965, 54 main power stations and 78 dams had been built, providing a total generating capacity of over 1,000 megawatts. (A megawatt (MW) = 1,000,000 watts). Over 300 kilometres of rock tunnel had been excavated and a similar length of aqueducts and pipelines constructed. Over 32,000 kilometres of electricity network was built to distribute the electricity throughout the north of Scotland, with a further 110 kilometres of submarine cable taking power to the major Scottish islands.

All this work was achieved by a workforce that averaged 4,500, and which, at its peak, numbered about 12,000. In many cases, the workforce was made up of a mixture of British workmen and German and Italian former prisoners of war. This provided a significant financial boost for the area but was not always welcomed by local landowners, many of whom had a vested interest in keeping the Highlands exactly as they had been for years before.

Temporary camps like these housed up to 3,000 workers



Then, as now, new development was greeted with concern for the environment and amenity. Many feared that the construction of power stations and dams would damage tourism which was already a major employer in Scotland. There was also concern that if electricity was to become readily available, industry would be attracted to the area, causing further damage to tourism and the established way of life.

Lord Airlie, the first Chairman of the North of Scotland Hydro Electric Board, knew better when he said: "Do not let anybody think that the Highlands are going to become repopulated and revived by an influx of generating stations. This is wholly false. Industry on a heavy scale will never come to the Highlands, because it is common sense that it is easier to bring current to industry than industry to the current." This is still true today, as many of the renewable energy schemes developed in Scotland export their output to meet demands in other parts of Britain.

After the Second World War, men from all over Scotland came to work on the schemes, attracted by high wages. The highest wages were earned by the men who dug the tunnels. Germans, Poles and Czechs were acknowledged to be skilled tunnellers. They became known as the Tunnel Tigers because of their cavalier approach to safety in their quest to earn the huge bonuses that were available. The lower regard for health and safety issues than there is today inevitably led to high accident rates and deaths amongst the workers. No definitive accident statistics exist, but in one camp alone, which housed some 1,000 workers at its peak, there were 22 deaths in just one year.

For the vast majority of workers the rewards were great. In the late 1940s, a Tunnel Tiger could expect to earn up to £35 a week, compared to £3 or £4 for a Highland estate worker. Mostly they lived in temporary work camps built nearby the construction site. Not surprisingly, the sites looked like military camps, sometimes housing up to 3,000 men.

They could be tough places to live, with food and accommodation of variable quality. Off duty, there was little for the workers to do but drink.

As a result, alcohol-fuelled fights were commonplace, with local police being called upon to restore the peace all too regularly.

By the 1960s, the face of the Highlands had changed forever. New dams headed new, or larger, lochs. Rivers had been diverted through aqueducts and underground tunnels, and power stations settled on loch-sides. Electricity lines on steel pylons and wooden poles distributed electricity to remote settlements and individual crofts, bringing the power from the glens into people's homes. Life would never be the same again.

Today, what was once feared as a threat to tourism, now actually attracts visitors. The dam and fish ladder at Pitlochry, a town which once closed its doors to North of Scotland Hydro Electric Board officials, is now a major tourist attraction, visited each year by over 500,000 people from all over the world.

Clunie Arch - a memorial to some of the men who lost their lives building the hydro schemes

Working with the power of nature

There is no doubt that the continued production of hydro electricity is an essential part of the UK's efforts to counter the effects of global warming. Every unit of electricity produced from renewable energy is one less that needs to be produced from carbon-based fuels. Scottish Hydro Electric is the UK's largest producer of electricity from renewable sources, traditionally from hydro electricity, but also from wind energy and biomass - waste vegetable matter. In addition, the company is working with partner organisations, including Talisman Energy, on the possible development of the world's first deep-water off-shore wind farm, in the Moray Firth. Scottish Hydro Electric is also working in partnership with The Weir Group to invest in the development of a tidal generating device and with Renewable Devices Swift Turbines Limited to promote small-scale wind energy schemes.

Whatever the technology, there is, and always has been, an expectation that the wider environmental benefit of renewable energy must be balanced against care of the immediate environment directly affected by such development.

The salmon story

Many major river systems in the Highlands have long been renowned as breeding grounds for salmon and trout. As far back as the 1943 Act of Parliament that established the North of Scotland Hydro Electric Board, there was a requirement on the company to avoid, as far as possible, injury to fisheries and the stock of fish.

When the power stations and dams were constructed during the second half of the last century, great care was taken to minimise their environmental impact. As the stations have been refurbished, wherever possible, care has been taken to ensure modern technology is employed to further reduce the environmental impact of the stations. For example, measures are taken to reduce the risk of oil leaking into the water and in a few particular cases the profile of the turbine blades is more 'fish friendly', allowing safer passage for small fish through the machines.

Fundamental to helping preserve fish stocks is the need to maintain a flow of water in the rivers and streams that fish have access to. In these rivers, carefully regulated water flow, known as compensation water, is released downstream from the dam to protect the natural water environment. This helps the eggs hatch and the young fish to feed and grow. It also assists the adult salmon and sea trout ascend the river to their spawning grounds.

In some cases, such as at Pitlochry Dam and Power Station in Perthshire, the hydro electric infrastructure would have created an impassable barrier to salmon unless some means of allowing them to by-pass the obstruction was provided. The solution was to build fish passes.

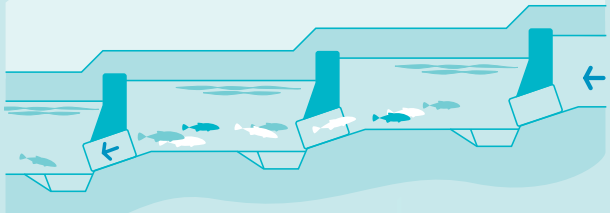
There are two types of fish pass, the fish ladder and the fish lift, known as the Borland lift.

At Pitlochry, the North of Scotland Hydro Electric Board installed a fish ladder. This comprises a series of pools which are connected by underwater pipes. The ladder is 310 metres long and has 34 pools, including three larger pools which allow the fish to rest as they travel upstream. The rise between each pool is 50 centimetres. Bar screens prevent large adult salmon from entering the power station intakes and tailraces (where the water is discharged back into the river after it has been used to generate electricity). The fish are attracted to the fish ladder by the flow from a small discharge of compensation water near the ladder's entrance.

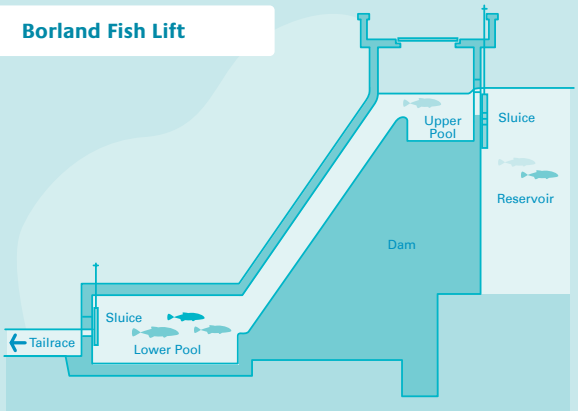
From here they can swim through the pools from the river to Loch Faskally behind the dam. There are three exit points from the ladder so the fish can enter the loch regardless of the water level.

Aigas Dam on the River Beauly has an example of a Borland lift. This type of fish pass works on the same principle as a canal lock. Downstream of the dam, the fish are attracted by the flow of water into a pool at tailrace level. A sluice gate is closed at set intervals and the water gradually fills the pool and a shaft which connects it to an upper pool. As the water level rises, the fish are lifted to the upper pool which is at the same level as the reservoir above.

Fish Ladder



Borland Fish Lift



Visiting our sites

In the early days, as the hydro electric infrastructure was being developed, Scottish Hydro Electric established fish hatcheries at Contin, Invergarry, Pitlochry and Inverawe. District Salmon Fisheries Boards co-operated in the stripping of fish to obtain eggs and in the distribution of salmon fry to existing salmon rivers and to new tributaries never before stocked with salmon. In addition, to offset the loss of some spawning grounds, work was undertaken to improve waterfalls which were previously impassable to salmon on rivers such as the Lochay and the Bran, enabling fish to reach new stretches of river with gravels suitable for spawning.

Today, Scottish Hydro Electric continues to employ a leading fisheries biologist, who works closely with the District Salmon Fisheries Boards and other environmental agencies to minimise the impact of the company's hydro operations on the local environment and to help preserve the biodiversity of the area.

Scottish Hydro Electric welcomes walkers and visitors to many of its sites which are, after all, set in some of Scotland's most beautiful countryside. Its visitor centre at Pitlochry Power Station is open to the public between Easter and the end of October every year. Also at Pitlochry, there is a viewing chamber which enables visitors to see salmon as they migrate up and down the fish pass. The site is one of the top ten tourist attractions in Scotland.

On the pages that follow in this booklet we have selected one site from each of our major hydro schemes which is easily accessible and which you may want to visit.

Although the power stations are not open to the public, they are set in stunning surroundings and are well worth a visit to see how we work with the power of nature to produce clean, renewable energy.

The company's hydro operations can make rapid changes to the speed and depth of water flowing downstream from dams and weirs, without any prior warning. Visitors are reminded to be careful when taking part in recreational water activities such as fishing, canoeing and gorge walking where such changes could be extremely dangerous.

In addition to the more obvious dangers of deep or fast-flowing water, there is an invisible danger associated with hydro electric installations – high voltage electricity. The electrical equipment in our power stations and substations can operate at voltages up to 275,000 volts. Whilst visitors are welcome to our sites and to walk across our dams where they are safely accessible to the public, we ask everyone to respect locked gates and compounds, and to pay attention to warning signs and notices. By following these simple rules, everyone can continue to enjoy the benefits of our open access policy.

Our advice to everyone is - please visit, but stay safe!

Shin

Shin is the most northerly hydro electric scheme on the mainland of Scotland and lies mostly in open moorland. Loch Shin, by far the largest loch in this part of Scotland, is the main reservoir for the scheme which also makes use of the headwaters of the Rivers Cassley and Brora in a catchment area which extends to almost 650 square kilometres. The total installed capacity is small compared with other schemes but it is a very significant output in this northern part of Scotland.

Water is collected from the headwaters of the River Cassley by two aqueducts and diverted into a headpond at Duchally, where it is used to drive two small turbines in a tiny power station built into the Duchally weir. This is a remote and inaccessible area and so the output of the turbines is remotely controlled by the level of the water in the aqueducts with provision for automatic shutdown during periods of very low water.

From the Duchally headpond, compensation water is allowed to flow down the River Cassley, the remainder is diverted by a 4 kilometres long tunnel to Cassley Power Station on the western shore of Loch Shin.

The water level in Loch Shin was raised about 11 metres by the construction of Lairg Dam and Power Station. This concrete and embankment dam, which is 427 metres long and 12 metres high, was built where the natural loch narrowed.

From Loch Shin, water is released through Lairg Power Station into a smaller reservoir immediately below the dam, known as Little Loch Shin, the level of which is regulated by the Shin diversion weir. Compensation water is released through the weir to maintain a minimum flow in the River Shin below the weir.

Most of the water from Little Loch Shin is diverted through an 8 kilometres tunnel to Shin Power Station at Inveran. The tunnel feeding the power station also collects water from the River Grudie, a tributary of the River Shin.

After passing through the turbines the water is discharged back into the River Shin by means of an open channel tailrace. A fish screen across the tailrace outlet prevents salmon from entering and helps to guide them upstream. Borland fish lifts at Lairg Dam and the Shin and Duchally diversion weirs also assist the passage of salmon.

One to visit

Lairg Dam and Power Station (Ordnance Survey Landranger Sheet 16) lie just to the north of town of the same name and are visible from the A836. Approximately 1 mile away on the A839 is the Forest Enterprise Interpretative Centre and forest walks.

	Gross head* (metres)	Installed capacity (megawatts)	Average annual output (million units)
Cassley	**113**	**10**	**26**
Lairg	**10**	**3.5**	**12**
Shin	**81**	**18.6**	**125**

* The 'head' is the difference in height between the water supply feeding the power station and the turbines.

Conon

The Conon Valley, one of the major west-east valley systems extending across Scotland, lies within the north west Highlands and receives heavy rainfall throughout the year. Recognising the potential for the development of hydro electricity, the Ross-shire Electricity Supply Company built a power station to make use of the Falls of Conon in the 1920s.

Today the water resources of the Conon Valley are utilised as part of a development including six major dams and seven power stations. Some of the water passing through this scheme is used up to three times to generate electricity.

The first stage of the development was the Fannich section. A series of tunnels and aqueducts were built to increase the water flow into Loch Fannich. A spectacular event during construction was the blowing out of a large plug of rock from the side of Loch Fannich, about 25 metres below the surface to complete a 6.5 kilometres long tunnel to supply Grudie Bridge Power Station. This became popularly known as "Operation Bathplug".

Dams were built at Loch Droma and in Strath Vaich, in the far north, to create high level reservoirs. Water from Loch Vaich and Loch Droma is fed into Loch Glascarnoch, a large new loch formed in Glascarnoch Glen by the building of Glascarnoch Dam. From Glascarnoch an 8 kilometres tunnel carries water to Mossford Power Station where it discharges into Loch Luichart, a short distance below.

Loch Luichart also receives water from Grudie Bridge Power Station and from the River Bran, which drains the area around Achnasheen.

Before reaching Loch Luichart, the River Bran passes through Loch a Chuilinn, the water of which is regulated by a small barrage which also acts as a diversion weir to supply water to Achanalt Power Station immediately below the barrage. Beside the power station at Achanalt Falls is an unusual fish pass which is a combination of natural and artificial pools.

Some 8 kilometres to the south the waters of the River Meig are held back by Meig Dam and the waters of this reservoir are diverted into Loch Luichart. From here, a tunnel carries water to Luichart Power Station. Further downstream is Torr Achilty Dam and Power Station. Loch Achonachie formed by the building of the dam absorbs sudden increases in the flow of the Conon.

From the surface of Loch Droma, 270 metres above sea level in the upper part of the scheme, to the tailrace of Torr Achilty Power Station, there is a fall of 255 metres.

The Orrin section of the scheme harnesses the waters of the River Orrin above Loch Achonachie. Two dams separated by a small hill hold back the river to form Loch Orrin. From there water is diverted by tunnel and pipeline to Orrin Power Station on the southern shore of Loch Achonachie in Strathconon. This water can then be used again in the turbines of Torr Achilty Power Station.

During the development of the Conon scheme a main line railway station and over 3 kilometres of railway track were replaced and about 48 kilometres of public and private roads were either constructed or reconstructed.

One to visit

Loch Glascarnoch and Dam, (Ordnance Survey Landranger Sheet 20) to the north of the A835 Garve to Ullapool Road, is set in stunning scenery a few miles from the Aultguish Inn. 10 miles west of Glascarnoch on the A835 are the Falls of Measach set in the Corrieshalloch Gorge. The new Cuileig Power which is close by can be spotted by the observant from the view point on the A832, 1 mile west of Braemore Junction.

	Gross head (metres)	Installed capacity (megawatts)	Average annual output (million units)
Achanalt	**20**	**3**	**7**
Grudie Bridge	**168**	**18.7**	**87**
Mossford	**161**	**18.6**	**121**
Luichart	**56**	**34**	**135**
Orrin	**222**	**18**	**80**
Torr Achilty	**16**	**15**	**42**

Affric/Beauly

The eastern slopes of the western Highlands are drained by the main tributaries of the River Beauly immediately to the south of Strathconon. As early as 1918 this area was identified as one of the nine great sources of water power running to waste in the Highlands, but it was not until 1947 that a plan to develop these resources was approved.

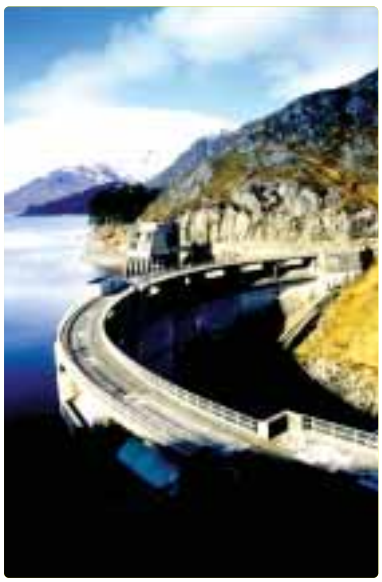
The Affric-Cannich section in the south was the first part of the area to be developed and was planned with great care to preserve the scenic beauty of Glen Affric in particular and also to reduce the severe flooding to which Glen Affric and Strathglass were prone.

The principal works comprised: a large dam, 727 metres long and 48 metres high, at Loch Mullardoch on the River Cannich; a tunnel to divert water from this loch via an underground power station into Loch Beinn a Mheadhoin (Loch Benevean) on the River Affric; a smaller dam at Loch Benevean; and another tunnel to the main generating station at Fasnakyle.

Benevean Dam, in Glen Affric, is a small structure almost hidden in a gorge about 3 kilometres below the natural outlet of the loch. When the dam was built, the road by the riverside was submerged. This was replaced by a new road which winds around the hillside in leisurely curves, offering superb views over the loch and surrounding area.

In order to conserve the outstanding scenic beauty of the area , the level of Loch Benevean is not allowed to vary greatly and the level of Loch Affric remains largely unaffected by the hydro electric developments.

In the northern part of the scheme - Strathfarrar and Kilmorack - the main dam is at Loch Monar, an unusual double curvature concrete arch dam which is one of the few examples of this type in Britain.



Monar Dam

A 9 kilometre tunnel carries water to Deanie Power Station located underground near the western end of Loch Beannacharan. Loch Beannacharan was increased in size when the Beannacharan Dam was built across the River Farrar a short distance below the natural outlet of the loch.

Below the Falls of Farrar is Culligran Power Station, which is underground and receives water from Loch Beannacharan, by tunnel.

Below Culligran the Rivers Farrar and Glass join to form the River Beauly. The Cannich and the Affric are the main tributaries of the Glass and much of its water has already been used to generate hydro electricity further upstream in the power stations at Mullardoch and Fasnakyle.

Downstream on the River Beauly there are two gorges, at Aigas and Kilmorack, each containing a dam into which a power station has been built.

The waters of the Affric/Beauly scheme are recognised as important for salmon and compensation water is released down all the main salmon rivers, the flow of which is kept above agreed levels. Borland fish lifts have been installed at Kilmorack, Aigas and Beannacharan.

One to visit

Benevean Dam (Ordnance Survey Landranger Sheet 25) is tucked unobtrusively in a gorge within Glen Affric which is a Forest Enterprise Natural Native Reserve containing Caledonia pines and other native species. There are forest walks at Dog Falls $1^1/_2$ miles east of the dam and at Loch Affric 7 miles west of the dam.

	Gross head (metres)	Installed capacity (megawatts)	Average annual output (million units)
Mullardoch	**27**	**2.4**	**8**
Fasnakyle	**159**	**69**	**254**
Deanie	**113**	**38**	**92**
Culligran	**60**	**19**	**59**
Aigas	**18**	**20**	**60**
Kilmorack	**17**	**20**	**58**

Great Glen

The Great Glen scheme lies along the shores of Loch Ness, and the area to the west of Fort Augustus, incorporating Glenmoriston up to Loch Cluanie, and from Loch Garry, west to Loch Quoich. This is an area of exceptionally heavy rainfall, on average four times greater than that on the east coast of Scotland.

Loch Quoich, the main storage reservoir on the Garry development is held back at its eastern end by the largest rockfill dam in Scotland - 320 metres long, with a height of 38 metres and a base width of 90 metres. At the western end of the loch two dams prevent water spilling over the watershed and down towards the west coast.

Water is carried by tunnel from Loch Quoich to Quoich Power Station on the banks of the River Garry. Further downstream, water collects in Loch Garry which is held back by a dam set into the narrow gorge at its outlet. From here, the water is carried by tunnel to Invergarry Power Station near the mouth of the River Garry on Loch Oich.

To the north, lies the River Moriston and its associated catchment area. There are two main upper reservoirs both held back by dams, one at Loch Loyne and one at Loch Cluanie. Blast furnace slag was used for the first time in Britain in the construction of Cluanie and Loyne Dams as a substitute for 70% of the cement which would otherwise have been needed. Water is diverted from Loch Loyne into Loch Cluanie via a tunnel.

The water is carried by tunnel and pressure shaft to Ceannacroc Power Station which was one of the first underground power stations to be built in Britain. The bare rock has been left exposed on the side walls of the chamber which forms the machine hall.

Water from the upper reaches of the River Doe is delivered via a branch tunnel either directly to Ceannacroc Power Station or to Loch Cluanie for storage. Water is discharged from the power station back into the River Moriston.

Loch Dundreggan, which is held back by a small dam lies 15 kilometres downstream. This dam has a small generator which uses compensation water, and a Borland Lift to assist the passage of salmon.

The largest power station on this part of the scheme is Glenmoriston which lies 90 metres underground directly beneath Dundreggan Dam. Water drops down a vertical shaft into the turbines and discharges into Loch Ness.

North of Glenmoriston Power Station a system of aqueducts collects water from a number of streams which would otherwise flow into the River Moriston, downstream from Dundreggan. This is delivered to Livishie Power Station, another underground facility, which discharges into Loch Dundreggan and subsequently feeds Glenmoriston Power Station.

One to visit

Quoich Power Station and nearby dam (Ordnance Survey Landranger Sheet 33) are worth a visit. The dam is the largest rockfill dam in Britain. At the west end of Loch Quoich lies Knoidart one of the last "wildernesses" in Britain. Approximately 9 miles east of the power station on the A827 Kyle of Lochalsh road lies the viewpoint from which the famous "Map of Scotland" view of Loch Garry can be seen.

	Gross head (metres)	Installed capacity (megawatts)	Average annual output (million units)
Ceannacroc	**90**	**20**	**87**
Livishie	**259**	**15**	**29**
Glenmoriston	**93**	**37**	**153**
Quoich	**101**	**18**	**87**
Invergarry	**53**	**20**	**78**

Foyers

The Foyers catchment area was first developed for hydro electric power in 1896, by the British Aluminium Company. The plant, the first large scale commercial hydro electric development in Britain, was in continuous operation until the aluminium smelter it served closed in 1971.

In 1974, the Foyers combined pumped storage and conventional hydro scheme began operating on the shores of Loch Ness. Pumped storage schemes use machine sets that are designed for dual purpose operation.

Water from the River E and the River Fechlin is diverted via an aqueduct into Loch Mhor. When Foyers is generating, water is allowed to flow through tunnels from Loch Mhor through the turbines producing electricity during times of peak demand. At times of low demand, surplus electricity is drawn from the system and fed to the machine sets. These now operate in reverse, and the generators - acting as motors - drive the turbines which now act as pumps. In this way water is pumped back up from Loch Ness into Loch Mhor ready for the next generating requirement.

The tunnel system that connects to the power station reduces in size from 7.3 metres in diameter to 3 metres wide at the point where they reach the turbine inlet valves. This narrowing of the pipes has the effect of increasing the pressure of the water flowing through them.

In order to satisfy the technical requirement which dictated that the pump/turbine runners had to be positioned a minimum of 35 metres below the water level of Loch Ness, the two machine sets are located at the bottom of shafts over 50 metres deep.

Foyers can begin generating electricity from a standing start in under two minutes, but if conditions demand, the machines sets can be spun in air to act as "spinning reserve". In this way electricity can be supplied within 30 seconds.

When generating at full load the two turbines pass water into Loch Ness at the rate of 200 cubic metres per second. When pumping at full power they can lift 167 cubic metres of water per second from Loch Ness up through the tunnel system.

In 1973 when the water level in Loch Mhor was temporarily lowered to allow the construction of the upper control works, a 'crannog', or artificial island, often built and inhabited by prehistoric people was discovered. The details of this were recorded by the consulting engineers before it submerged again when the water returned to its previous level.

One to visit

Foyers Power Station (Ordnance Survey Landranger Sheet 26) is on the east shore of Loch Ness. It is best viewed from the opposite shore where there are plenty of opportunities to walk or cycle along the beautiful Great Glen Way. To the west of the power station is the original 1896 aluminium smelter building that houses Foyers Falls Power Station which uses the original pipeline for the smelter.

	Gross head (metres)	Installed capacity (megawatts)	Average annual output (million units)
Foyers	**179**	**200**	**213**
Pumped Storage			
Foyers Falls	**108**	**5**	**13**

Tummel Valley

The Tummel Valley catchment area extends over 1,800 square kilometres of the Grampian Mountains and includes some of the most rugged and remote parts of the Scottish Highlands, much of which can remain snow covered for several months of the year. The snowfields act as 'nature's batteries', storing water until the snow melts.

The potential of this area for the development of hydro electricity was recognised at an early stage, when the Grampian Electricity Supply Company built power stations at Rannoch and Tummel in the 1930s. Today, there are nine power stations within the Tummel scheme.

In the north, the tiny Cuaich Power Station collects water from the areas around Loch an-t-Seilich, Loch Cuaich and the headwaters of the Spey. It discharges water into Loch Ericht via an aqueduct. Loch Ericht Power Station is on the eastern shore of the loch, fed by tunnel from Loch Garry above.

Rannoch Power Station, on the northern shore of Loch Rannoch, has been generating hydro electricity for over 70 years, fed by water brought by pipeline and tunnel from Loch Ericht.

Water flowing from Rannoch Moor is collected behind Gaur Dam and fed by pipeline to a power station on the River Gaur before flowing into Loch Rannoch. From here, the water flows down to Loch Tummel via a small reservoir at Dunalastair, from where it is carried by aqueduct to the next power station at Tummel Bridge.

Errochty Power Station is the largest on the Tummel scheme. It is supplied via a 10 kilometres tunnel from Loch Errochty. The buttress dam on Loch Errochty is 364 metres long and 49 metres high. Compensation water, used to maintain a minimum flow in the River Errochty at all times, is also used to generate electricity at the Trinafour Power Station.

Water from Loch Tummel is diverted via tunnel and pipeline to Clunie Power Station before flowing on to Loch Faskally. Loch Faskally is entirely man-made, being formed when Pitlochry Dam and Power Station were built.

Pitlochry is the last power station in the Tummel scheme and by the time the water reaches this point it may already have generated electricity up to five times during its course down the Tummel Valley.

Nowadays, Pitlochry Dam with its associated fish ladder, and the scenic beauty of Loch Faskally, are recognised as a major tourist attraction. It is estimated that up to 500,000 tourists cross the dam each year. Many visit the Scottish Hydro Electric Visitor Centre, or the fish ladder viewing chamber to catch a sight of salmon as they pass upstream.

One to visit

Pitlochry Dam and Fish Ladder (Ordnance Survey Landranger Sheets 43/52). There is ample parking nearby. The Scottish Hydro Electric Visitor Centre and fish pass observation chamber are open between April and October, Monday to Friday, and at weekends during July, August and Bank Holidays, 10.00am to 5.30pm. There are plenty of well-marked walks around Loch Faskally with the town of Pitlochry just ten minutes' walk away.

Tummel Valley scheme

	Gross head (metres)	Installed capacity (megawatts)	Average annual output (million units)
Gaur	**30**	**7.5**	**21**
Cuaich	**27**	**2.5**	**7**
Loch Ericht	**55**	**2.2**	**12**
Rannoch	**156**	**44**	**187**
Tummel	**53**	**34**	**142**
Errochty	**186**	**75**	**103**
Trinafour	**91**	**0.5**	**4**
Clunie	**53**	**61**	**186**
Pitlochry	**15**	**15**	**60**

Breadalbane

The Breadalbane scheme lies in the mountainous region around Loch Lyon, Loch Earn and Loch Tay in Perthshire and contains several deep glaciated valleys with high peaks well above 900 metres high. The steep slopes and heavy rain and snowfall of this region combine to create favourable conditions for the production of hydro electric power.

There are three main sections on the Breadalbane scheme with a total of seven main stations.

The Lawers section collects water through a system of tunnels and aqueducts and diverts it into Lochan-na-Lairige, the main storage area which lies in the pass between Loch Tay and Glen Lyon. The water is held back by Lawers Dam, a massive buttress-type dam 344 metres long and 42 metres high.

Finlarig Power Station on the shores of Loch Tay uses this water by means of a pipeline and operates under a gross head of 415 metres, the highest currently available on any of Scottish Hydro Electric's schemes.

The Killin section has three dams and three power stations, with the main storage in Loch Lyon. The water level of this loch was raised about 21 metres when Lubreoch Dam was built. This huge buttress-type structure is 530 metres long and 39 metres high. A system of aqueducts collects water from the catchment above Glen Dochart and the River Lochay and conveys it by tunnel to Loch Lyon.

Cashlie, which receives water from Loch an Daimh in the north, discharges water into the Stronuich headpond which was created by the construction of a gravity-type dam.

Lochay Power Station is fed from Stronuich through a pipeline and tunnel system over 9 kilometres long and is the largest station in the Breadalbane scheme. The Falls of Lochay above the power station were previously a barrier to salmon but the small power station built at the falls was equipped with a Borland Lift in order that salmon can now bypass this obstacle. Two pool type ladders were also built upstream to open up the spawning gravels of the whole river.

To the south east lies the St Fillans section of the scheme with two main dams and three power stations. Loch Breaclaich collects water from a series of small streams which would otherwise flow north into Loch Tay. This water is carried from Loch Breaclaich through a system of tunnels and aqueducts to Lednock Power Station on the shores of Loch Lednock.

St Fillans Power Station at the foot of Loch Earn is fed water from Loch Lednock via a tunnel and discharges into Loch Earn. The machine hall of this station is a cavern hewn out of solid rock.

From Loch Earn, water is diverted into a tunnel to feed Dalchonzie Power Station.

One to visit

Lubreoch Dam (Ordnance Survey Landranger Sheet 51) spans the picturesque Loch Lyon at the head of Glen Lyon, popular with walkers and motorists. Walkers should take care during the deer-stalking season (October to February). The local estate provides a contact phone number to check if there is likely to be shooting.

	Gross head (metres)	Installed capacity (megawatts)	Average annual output (million units)
Lubreoch	**30**	**4**	**16**
Cashlie	**142**	**11**	**26**
Lochay	**180**	**45**	**175**
Finlarig	**415**	**16.5**	**71**
Lednock	**91**	**3**	**4**
St Fillans	**253**	**16.8**	**75**
Dalchonzie	**29**	**4**	**15**

Sloy/Awe

To the west of Loch Lomond is the rugged and mountainous landscape of Argyll. This area provides ideal conditions for hydro electric power development.

The waters of Loch Sloy are held back by Sloy Dam which is 357 metres long and 56 metres high. Water is diverted into Loch Sloy from areas well to the north and south via a system of tunnels and aqueducts.

A tunnel 3 kilometres long carries water from Loch Sloy through Ben Vorlich, which towers almost 940 metres above Loch Lomond, to the valve house immediately above Sloy Power Station. From here the water plunges down the side of the mountain through four large pipelines into the power station.

Sloy Power Station, the largest conventional hydro electric power station in the UK, can be operating at full load within five minutes of a standing start and it is this almost instant availability that makes it ideal for use during times of peak demand.

In the mountains to the north west of Sloy is Loch Shira. This reservoir is 338 metres above sea level and was created by building a dam across Glen Shira.

Water released from Loch Shira passes through Sron Mor Power Station sited on the shore of Lochan Sron Mor, a small headpond just in front of the main dam. Water is carried from this headpond by tunnels and pipelines to Clachan Power Station over 7 kilometres away at the head of Loch Fyne.

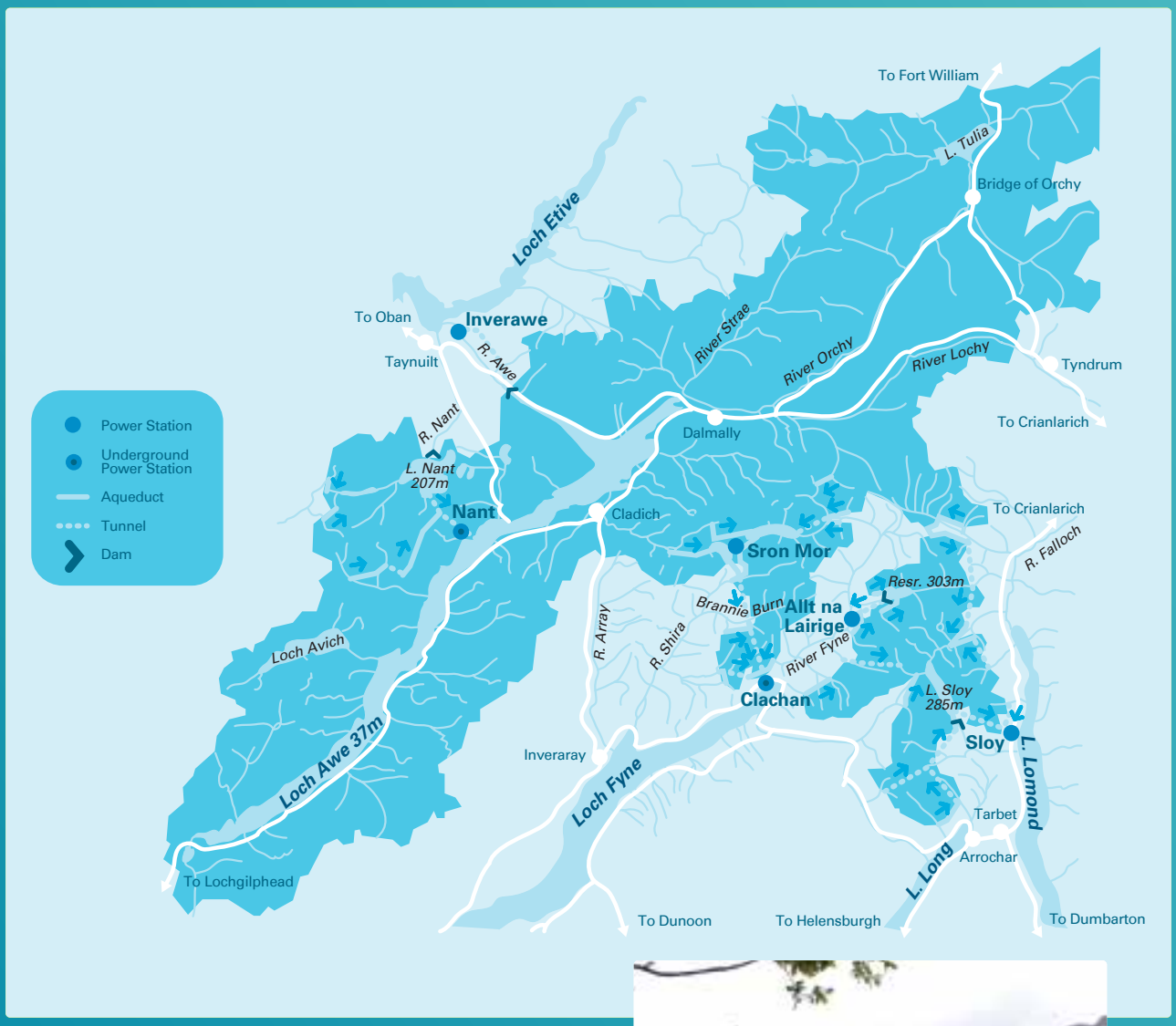
The Allt-na-Lairige scheme uses the water resources of upper Glen Fyne in an area lying between Sloy and Shira. The dam built across one of the tributaries of the River Fyne to form the main storage reservoir was the first pre-stressed dam to be built in Western Europe. The dam is 425 metres long and 24 metres high, and is anchored to its rock foundation by high tensile steel rods. Water is carried from here by tunnel to Allt-na-Lairige Power Station on the River Fyne.

In the far north west of this scheme lies the Awe development containing two main power stations and four smaller ones. The largest, Inverawe, is fed by a 5 kilometre tunnel from an 18 metres tall barrage built across Loch Awe, a short distance below its natural outlet. Incorporated into the barrage are two radial flood gates, a freshet gate, a Borland Lift and two completely submerged bulb turbine generators, which are used to discharge compensation water down the River Awe, which is an important salmon river.

Nant Power Station is built underground, and fed by Loch Nant, which had its surface area tripled by the building of Nant Dam, and a system of aqueducts which collect water from nearby streams. As this water discharges into Loch Awe it effectively serves Inverawe Power Station in addition to Nant.

One to visit

Sloy Power Station (Ordnance Survey Landranger Sheet 56) is best viewed from the West Highland Way long distance path which runs along the opposite shore of Loch Lomond. There is a public car park at the Inversnaid Hotel which is accessible from the B829 from Aberfoyle. There is direct access from this car park to the West Highland Way.



	Gross head (metres)	Installed capacity (megawatts)	Average annual output (million units)
Sloy	**277**	**152.5**	**130**
Sron Mor	**46**	**5**	**7**
Clachan	**294**	**40**	**82**
Allt-na-Lairige	**249**	**6**	**19**
Nant	**172**	**15**	**36**
Inverawe	**36**	**25**	**106**
Kilmelfort	**111**	**2**	**12**
Loch Gair	**109**	**6**	**19**
Striven	**123**	**8**	**22**
Lussa	**116**	**2.4**	**9**

Renewable energy for the 21st Century

In this publication, we've looked back at the men and organisations involved in bringing power from the glens and at the story of the Hydro Boys and Tunnel Tigers who, in the last century, made the vision a reality. We've also looked at the balance between the need for clean, renewable energy, essential to help reduce Climate Change, and the preservation of the local biodiversity and environment.

Scotland's hydro electric schemes are a wonderful resource that continues to provide clean energy to customers throughout the United Kingdom.

But the story doesn't stop there.

As the demand for renewable energy has increased, mainly in response to the United Kingdom government and European Union initiatives to promote reductions in carbon dioxide emissions, so interest has grown in developing new renewable energy sources, with long-established and new companies entering the sector.

Scottish and Southern Energy is committed to the long-term development and sustainability of renewable energy in the United Kingdom. In addition to on-going maintenance, the company is comitted to investment in its hydro power stations to ensure their long-term future.

In addition to its interests in a number of on-shore wind farms, Scottish and Southern Energy is working with partner organisations looking at a wider range of initiatives including off-shore and deep water wind farms, solar, wave and tidal energy devices.

Clean renewable energy can even be found in the most unlikely places. Scottish and Southern Energy owns two, 2,000 megawatts coal-fired power stations in the north of England. These have been modified to burn biomass – waste vegetable matter – so reducing the amount of coal burned. Biomass is considered 'carbon-neutral' and therefore more environmentally friendly because the carbon dioxide produced when it is burned has been offset by the amount of the same gas absorbed by the plants whilst growing.

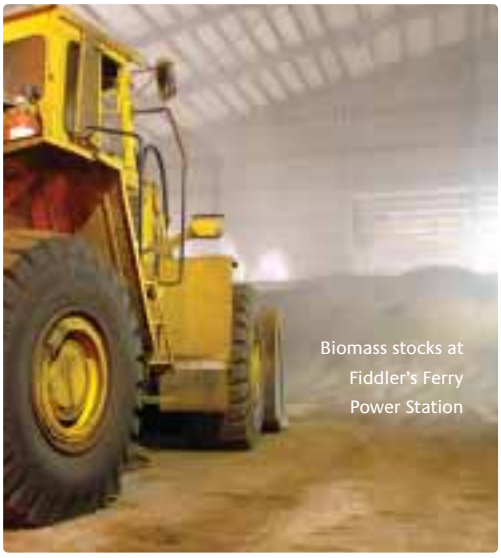
And the hydro story goes on.

In 2001 Scottish and Southern Energy began generating electricity at Cuileig, south of Ullapool. This is its first new hydro electric power station to be built since the major hydro programmes of the 1960s and 1970s. It is a small, 3 megawatts station which has been developed as a model of good practice in modern hydro electric development. Positioned as it is, in the beautiful Corrieshalloch Gorge, the power station is hardly visible in the landscape.

Cuileig Power Station viewed from above

In 2005 the company's second new hydro development, a 3.5 megawatts station at Kingairloch on the Morvern Peninsular, south west of Fort William, also began generating.

Tangy wind farm



Biomass stocks at Fiddler's Ferry Power Station

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