Energy for generations

40 YEARS Turlough Hill

Welcome to Turlough Hill

ESB was established in 1927 as a corporate body in the Republic of Ireland under the Electricity (Supply) Act 1927. As a strong, diversified, vertically integrated utility, ESB operates right across the electricity market: from generation, through transmission and distribution to supply.

In terms of generation, ESB currently operates 7 thermal stations, 12 windfarms and 10 hydro stations in the Republic of Ireland, one of which is Turlough Hill.

Turlough Hill, Ireland's only pumped storage power station, is located approximately 60km south of Dublin City in the Wicklow Mountains. Construction commenced in 1968, and the station became fully operational in 1974.

The station generates up to 292MW during peak demand periods by releasing water from its upper reservoir and allowing it to flow through its four turbines into a lower reservoir. During periods of lower demand the water is pumped back to the upper reservoir ready to be used again. In 2004, Turlough Hill became the Hydro Control Centre (HCC) for the entire ESB hydro fleet which contains 19 generators in total.

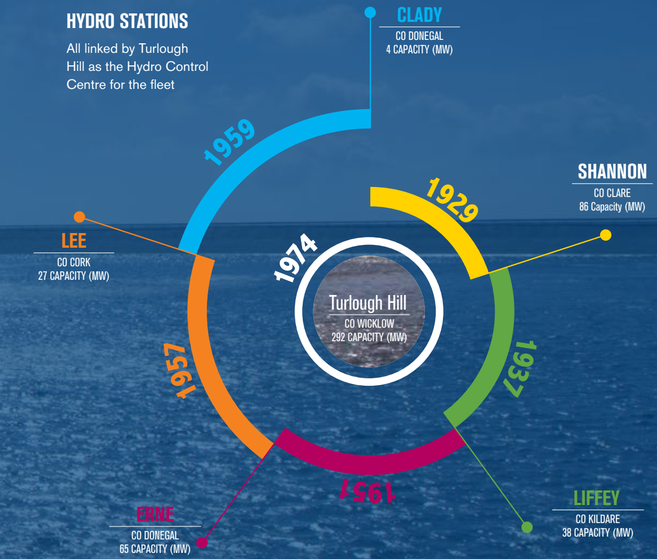
Contents

Design Zahra Media Group
Colour photography (except Glendalough) Neil Warner

The upper reservoir at Turlough Hill

HYDRO STATIONS

All linked by Turlough Hill as the Hydro Control Centre for the fleet



Turlough Hill

01

The new hydro control centre(HCC) at Turlough Hill'

Electricity for an expanding economy

The original control room at Turlough Hill which served the station until 2004 when the HCC was commissioned

By the late 1960s, ESB had supplied electricity to customers in Ireland for more than 40 years. It had become apparent that electricity demand would continue to grow rapidly across the country and ESB needed to respond quickly and in an environmentally friendly way to help manage this booming demand for power.

Designing and developing a pumped-storage hydroelectric station was a unique and innovative civil engineering solution for Ireland at the time. It would expand the electricity supply for the growing population through an environmentally-friendly system and also provide flexibility when it came to handling the challenging peaks and troughs in demand.

A rapidly responsive pumped-storage hydroelectric station was the solution and would be a huge advantage to customers across Ireland at peak electricity demand times.

See diagram page 10

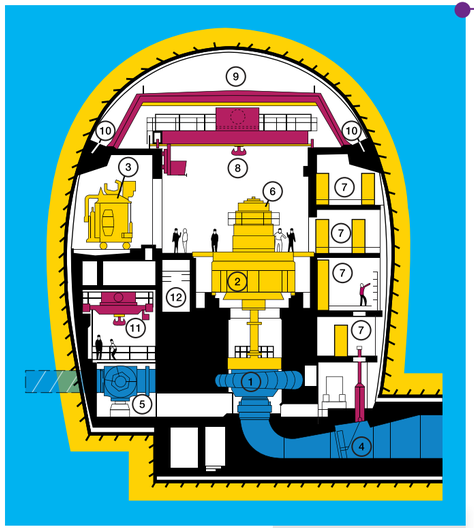
» How Turlough Hill helps smooth out the typical electricity demand over 24 hours.

Getting started

ESB's engineers began looking for the right location in County Wicklow. The 'Garden of Ireland' features many mountains and lakes and is in close proximity to Ireland's main centre of demand – Dublin. Turlough Hill was chosen because of Lough Nahanagan, a natural corrie lake, which could become the lower reservoir for the station. There was also a suitable site on the mountain where ESB could build an artificial upper reservoir.

Once approval was granted by the Irish Government, construction on Turlough Hill began in1968 and ended six years later.

Staff from many departments within ESB were involved in the construction phase, as well as external contractors who helped to bring the project to life. At the time of completion, Turlough Hill was the largest civil engineering project ever undertaken in Ireland.



Cross-section view of cavern

1. Pump Turbine
2. Motor/Generator
3. Main Unit Tranformer
4. Flap Gate
5. Turbine Inlet Valve
6. Pony Motor/Generator
7. 10 kV Switchgear, Control Panels and Relays.
8. 2 x 70 ton Bridge Cranes
9. False Roof with Soundproofing
10. Haunch Beams
11. 50 ton Bridge Crane
12. Cable Gallery for 220 kV Cables

CAVERN DIMENSIONS

The cavern housing the power station is the same space as a medium-sized cathedral.

The dimensions are: length 82m, breadth 23m, height 28m.

The cavern is 15m below the water level of the lower reservoir.

Digging in

The project really caught the public's imagination at the time – it was the country's first and only pumped storage station. There had not been anything of this scale built in Ireland since the Shannon Scheme was built in the 1920s. The construction team worked for more than six years:

- carving a massive underground chamber in the granite mountain to house the main station, so that it would be hidden from view (length 82m, breadth 23m, height 28m – the same space as a medium-sized cathedral);
- excavating 2.5 million tonnes of rock to build the upper lake, then lining it with asphaltic concrete;
- drilling tunnels through the rock to connect the station and upper/lower lakes.

> **ESB was always very conscious that we were working in an area of outstanding natural beauty.**

Taking care

ESB was working in an area of outstanding natural beauty and wanted to ensure minimal impact wherever possible.

The main station was buried out of sight, inside the mountain, but ESB also:

- hired landscape architect Sylvia Crowe to camouflage the upper reservoir with vegetation and design the works at the lower resevoir to fit into the background of rock;
- successfully used a pioneering technique to restore grass growth on the verges of the newly-constructed two-mile long road to the mountain top, using a mix of water, fertiliser, wood pulp, peat moss and grass seed;
- used the 1.305 million cubic metres of granite excavated from the upper reservoir to build its embankment (maximum height: 34m, length: 1,445m);
- ensured that the administration offices and transformer compound could not be seen from the Wicklow Gap Road.

The 220 kV Compound at Turlough Hill

All systems go!

In December 1973, ESB Turlough Hill's first generating unit started operating, followed by the three other units in the summer of 1974. And this incredible feat of civil engineering has been supplying Ireland with electricity ever since.

In 2004, ESB Turlough Hill became the Hydro Control Centre (HCC) for the company. This means that ESB can operate any of its 10 hydro stations direct from one single control room on site – increasing its responsiveness to customer needs even further.

Turlough Hill

02

How pumped storage works

A conventional hydro power station sits on a river, moving water from one reservoir above a dam through a station and then out to rejoin the main river. Pumped storage differs slightly because it uses two reservoirs:

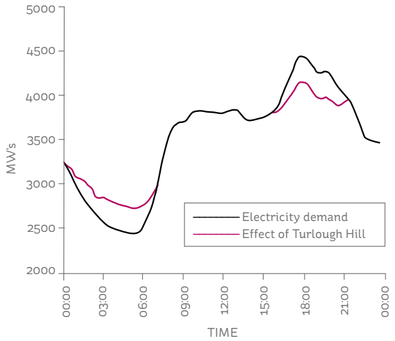
The upper reservoir: At Turlough Hill, this is the artificial lake. Water flows down a pressure tunnel, then through the station and the generation turbines to produce electricity, similarly to a conventional hydro power station.

The lower reservoir: At Turlough Hill, this is Lough Nahanagan. The water from the upper reservoir ends up here after moving through the station generators. That water is then pumped back up to the upper reservoir using a reversible turbine, ready to be resused when needed.

Work begins on the upper reservoir

> **Any pumped storage system can help smooth out the 'demand curve' by generating electricity at peak times to help meet demand and using the 'off-peak' electricity in the quieter hours to pump the water back to the top reservoir again, ready for the next peak demand window.**

Electricity demand curve



The effect of the Turlough Hill scheme on a typical load profile

The key to making pumped storage work effectively lies in when it is run. As pumped storage is so responsive, it can be an ideal way to help smooth out the peaks and troughs of electricity demand.

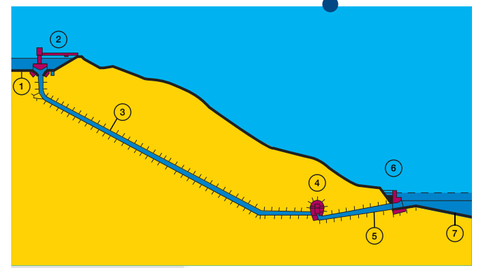
Demand is higher at certain points during the day ('peak time') as people need more electricity and much lower at night ('off peak time').

Running a pumped storage hydro electric station at peak times helps to smooth out the demand peak. It's 6pm and everyone's at home, cooking dinner or catching up on the news? Turlough Hill is probably running to

help meet those electricity needs, releasing water from the upper reservoir through the turbines and down into Lough Nahanagan.

Water is then pumped back up to the upper reservoir during the night, using cheaper electricity generated by other stations, so that the whole system is ready to go again when demand increases the next day. Overall, it helps to smooth out the 'demand' curve ›› **see the diagram opposite** and helps makes generation operations much more efficient.

Pressure shaft and tail race tunnel
The reversible pump turbines, operating under a mean geodetic head of 285.75 m are fed through a single pressure shaft and single tail race tunnel both excavated in granite, the 4.8 m diameter pressure shaft being steel lined and the 7.2 m diameter tail race tunnel being concrete lined.



1. Upper reservoir
2. Intake tower and bridge
3. Pressure shaft (steel lined)
4. Cavern
5. Tailrace tunnel (concrete lined)
6. Tailrace structure
7. Lough Nahanagan (natural lake)

Cross-section of Turlough Hill from upper reservoir to Lough Nahanagan

Turlough Hill

03

Generation and more: today and into the future

Today

ESB continues to evolve its business in supplying electrity across Ireland. The Generation part of ESB that was responsible for Turlough Hill still exists but its remit and activity have expanded.

It not only operates ESB's generation assets, it also develops and trades them with the implementation of this business model:

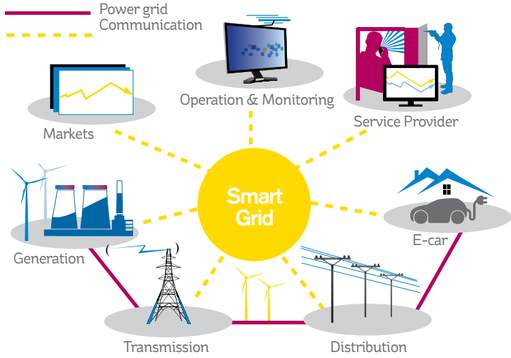
- Asset Development identifies and develops new generation assets;
- Generation produces electricity from those assets; and
- Trading takes that electricity and the associated commodities and trades them on the market.

Our asset portfolio includes approximately 4,300MW of generation in the Single Electricity Market (SEM) of the island of Ireland.

Smart future

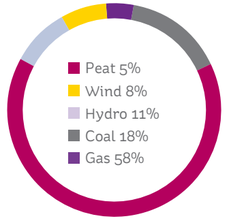
ESB understands that the delivery of an electricity network is not about the technologies and smart generation alone. The collective smartness of its users is key and ESB will continue to play a core role in maximising the full benefit of smart technologies for a sustainable future.

The tunnel leading down to the cavern which houses the power station, following its completion

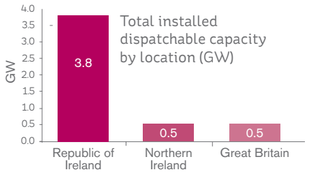


Generation traces its core purpose right back to the building of Ardnacrusha and the creation of ESB in 1927: providing a reliable supply of electricity for customers, for the economy and for the future in a safe, cost-effective and sustainable way.

Generation fuel mix in 2014



Generation capacity



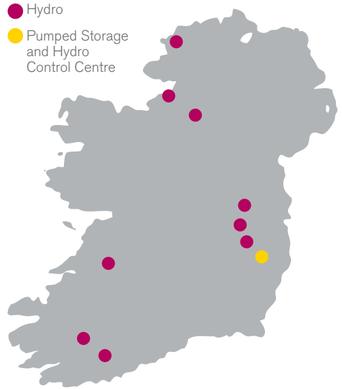
The future

ESB strategy has set its Generation business on a path of growth and change, setting out its ambition to be a company of scale in the Irish and UK markets. To help achieve that ambition, the Generation business has set the following strategic objectives:

- Build a sustainable position of scale in the Ireland and UK markets. Grow ESB's Irish and UK generation portfolio to 7GW and approximately 7% market share by 2025;
- Deliver a balanced low carbon generation portfolio that reflects the balance in the Irish and UK markets;
- Integrate generation and supply operations in the Irish and UK markets to optimise earnings and mitigate risks across the value chain;
- Optimise the return from the ESB's Ireland and UK assets by delivering excellent asset performance and managing costs to maximise trading and commercial opportunities.

Did you know… Turlough Hill is Ireland's only pumped-storage hydro station.

Hydro station network



Some examples of current activities in ESB that support those objectives include:

- A highly-efficient, low carbon-generating 880 MW Carrington power plant near Manchester;
- Developing a project pipeline of power plants in the UK;
- Investing in renewable technologies to reduce the carbon intensity of the generation portfolio;
- Developing alternative and newer technologies, including biomass, offshore wind, solar and wave energy.

Turlough Hill

04

Technical data and key facts

Excavating the cavern, which would house the massive power station

The main plant is housed in an underground power station 82 metres long, 23 metres wide, with a height of 30 metres. The operating floor level is 15 metres below low water level in the lower reservoir.

The main machines when rotated in different sense act as turbines or pumps and correspondingly give or take energy from the network. The power is nominally about 73 MW in each mode per machine with regulation down to lower loads in the turbine mode. The machines can also operate as synchronous condensers in either direction.

Rotational speed of the machines is 500 r.p.m with a max temp. runaway speed of 780r.p.m. based on an inertia per machine and water hammer pressure rise under fault conditions of approximately 40% above normal.

The machine governors are electro/hydraulic with load control and joint control of all machines.

Data for mechanical and electrical equipment

4 sets of vertical design, consisting of Pump Turbines, and synchronous motor generators with pony motors.

Mean geodetic head		285.75m.
Mean flow (turbining)	each	28.3 m3/sec.
Turbine output	each	73.0 MW.
Mean flow (pumping)	each	22.1 m3/sec.
Pumping load	each	68.2 MW.

Data for water conduits pressure shaft

Length	584m.
Internal diameter	4.8m.
Velocity at nominal turbine output	6.25m/sec.
Velocity at nominal pump output	4.92m/sec.

Upstream manifold

Internal diameters	2.4/3.4/4.15m.

Tailrace tunnel

Length	106m.
Internal diameter	7.2m.
Velocity at nominal turbine output	2.86m/sec.
Velocity at nominal pump output	4.92 m/sec.

Downstream manifold

Internal diameters	3.50/5.00/6.20m.

> Lough Nahanagan is a natural lake and holds twice the usable cubic metres.

Because of the reversibility of the electrical machines, phase change over links are provided on the busbars. Access and availability problems necessitated the use of single phase transformers in the cavern, three per pair of main sets with 22 kV cables to the outdoor switchyard.

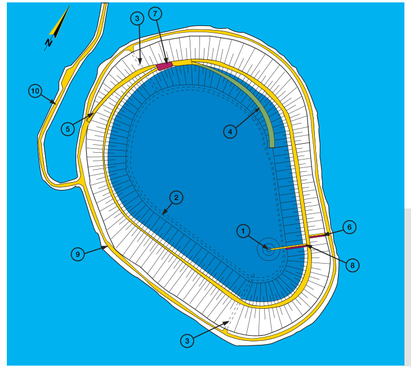
Start up in the pump direction is by a shaft mounted Pony Motor of 5.5 MW. The water having been previously exhausted from the pumps by compressed air.

Excitation of the main rotors is thyristor controlled. Starting in each mode and change of mode of operation is auto-matic following a push button command. Standby auxiliary power is provided by both a house machine, (1000 kVA), and an outdoor diesel set.

Mechanical auxiliaries include two 70 ton cranes to handle transformers weighing 70 tons each and generator rotors weighing 130 tons each and a 50 ton crane for the spherical isolating valves. The entire plant is air conditioned.

The artificial upper reservoir has a capacity of 2.3 million cubic metres of water and a maximum operating depth of 19.4 metres. It was formed partially by excavation and partly by the use of the excavated material in the construction of a ring shaped rock fill embankment.

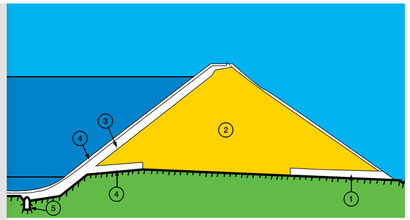
An asphaltic concrete lining covers the floor, inner slopes, and crest. A ring shaped under floor drainage gallery is provided at the foot of the inner slope of the embankment to collect and monitor any seepage through the asphaltic concrete lining.



See also diagrams page 6 and 11

» cross-section view of cavern (page 6) and Cross-section of Turlough Hill from upper reservoir to Lough Nahanagan (page 11)

1. Intake Structure
2. Ring Drainage Gallery
3. Access Gallery
4. Inner Access Ramp
5. Outer Access Ramp
6. Access Steps
7. Visitors' Platform
8. Access Bridge
9. Ring Road
10. Access Road from Wicklow Gap



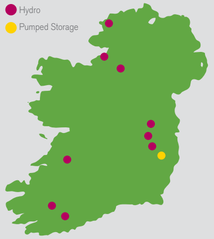
1. Drainage layer of crushed sound rock, graded from 150mm to 10% passing 2mm.
2. Rock filling.
3. Drainage layer of crushed sound rock graded from 200mm to 10mm, with blinding of crushed rock from 55 mm to 35 mm.
4. Asphaltic Lining- Spray coat of Cut Boat Bitumen. Asphaltic Concrete binding and equalizing course 5 cm in thickness. Dense asphaltic concrete course 6cm in thickness. Mastic sealing coat.
5. Ring Drainage Gallery

Cross-section of Turlough Hill from upper reservoir to Lough Nahanagan

Key facts

2004

Turlough Hill became the Hydro Control Centre (HCC) for ESB's 10 hydro stations



500 RPM ROTATIONAL SPEED OF THE MACHINES

Ireland's only pumped-storage hydro station

The underlying rock is granite

The first unit went live in 1973. The other three operating since 1974

60km south of Dublin, Wicklow Mountains

Turlough Hill took **6 years** to build. At its peak there was approx. **500 people** working on the construction.

Upper reservoir

- Holds 2.3 million cubic metres of water
- Excavated 2.5 million tons of rock
- 40acres/16.2ha/ 160,000 square metres of waterproof lining
- Built an embankment nearly 1 mile long/ nearly 30m high

Lower reservoir

- Lough Nahanagan is a natural lake and holds twice the usable cubic metres
- Around 48.8m deep
- Corrie lake left by a glacier at end of last ice age

The Glendasan and Glendalough valleys historically had thriving mining communities.

PRESSURE SHAFT CONNECTING THE TWO LAKES IS **584m** IN LENGTH

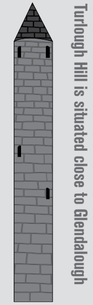
Did you know… Before the station was built, the hill didn't have a name on the Ordnance Survey map. The engineer who carried out the original survey and recommended the site, J O'Riordan, decided to name the hill after his son, Turlough.

681M HIGH

136th highest summit in Ireland

'TURLOUGH' IS THE GAELIC NAME FOR A DRY LAKE – ONE WHICH LOSES ITS WATER THROUGH A SWALLOW HOLE IN DRY WEATHER.

Catchment area of **1.81** km²



Turlough Hill is situated close to Glendalough

292MW

OVERALL CAPACITY

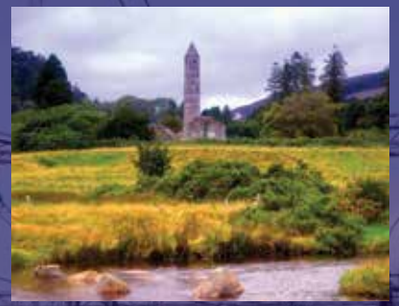
4 turbines with a capacity of approx. 73MW each

2.5 MILLION TONS OF ROCK

Did you know… The station can go from standstill to full generation in 70 seconds – stations using other kinds of fuel (for example, gas) can take up to 12 hours.

Turlough Hill

The position of Turlough Hill in the Wicklow Gap



Turlough Hill is situated on the Wicklow Gap close to the scenic Glendalough

Further reading

For further information please visit www.esb.ie

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