Energy from Hydro Storage Reservoirs and from Wind

We discuss some of the questions raised by on our forum in relation to Spirit of Ireland's Hydro Storage Reservoirs and the related input from Wind Farms. We have tried to keep the Physics to a minimum for ease of understanding.

How can we calculate energy storage in the Hydro Storage Reservoirs?

The maps of suitable Irish valleys were digitized and 3D models of individual sites were built. The volume of water that could be stored was calculated for a range of dam heights and required rock fill. We also have accurate information on the height of the valleys above sea level – which represents the lower lake in our pumping storage plan.

Although there are many factors relating to losses etc. to be factored in, the basic Physics potential energy formula for our reservoir situation is

$E=mgh$

m is the mass of the seawater in the dammed valley, g is the acceleration due to gravity (a constant) and h is the vertical head height from the sea to the dammed reservoir. In the SI (metric) system the mass m of the water in Kilograms is calculated in turn from the formula

$m=pV$

V is the volume of the water in cubic metres an p is the density of the sea water [1]. The energy E resulting from the volume of water falling will be expressed in units called Joules. The energy released per second is the power and is measured in Joules per second – more commonly called Watts. In power engineering we use large numbers of Watts (W) in calculations so the terms Kilowatt KW (1,000W), MegaWatt MW (1,000KW) and even GigaWatt GW (1,000MW) will be seen regularly.

An added twist is that it is more convenient in power engineering to measure energy based on power Wattage used over a period of 1 hour. Hence rather that stating energy in Joules we highlight energy in units called the Kilowatt Hour (KWh). This is the amount of energy involved in 1KW of power running continuously for 1 hour. In the scales of national power generation of course we talk in terms of Mega Watt hours (MWh) and even Giga Watt hours (GWh).

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[1] The density of sea water is 2.5% greater than fresh water so this is to our advantage in adding to the energy stored in a given volume of reservoir water.

How much electricity does Ireland consume?

Ireland needs about 70 GWh of electrical energy per day. The amount changes throughout the year. It is smaller in the summer. Annual consumption is around 26,000 GWh. This year the electricity consumption is less than in the previous year due to the effects of the recession. Power demand varies throughout the day and is obviously lower at night time.

Even non-technical readers will find it very interesting to study information on Eirgrid's[2] excellent website at www.eirgrid.ie This site includes an almost live graph showing the power demanded during the day updated every 15 minutes. It is like looking into the engine of our nation as we work and rest. It will be helpful to readers to look at this graph in the context of night and day time demands. There is also an interesting time of day graph showing outputs from existing wind turbine plants.

How much Electrical Energy is available from water stored in the reservoirs?

A very typical natural valley water reservoir would have a dammed lake area when full of 4 square Km – e.g. average 2Km x 2Km. Based on studied shapes, depths and height from the sea etc., two such reservoirs would deliver some 200 GWh of electrical energy. A third reservoir would increase this to 300 GWh. This is truly massive energy store and in fact there are many valleys studied which would give considerably larger storage. In contrast the very fine ESB Turlough Hill pumped hydro storage plant in Co. Wicklow built many years ago can store only about 1.5 GWh of energy.

As we said earlier Ireland needs about 70 GWh of energy per day. So looking in a simplistic way with no inputs whatsoever from wind farms or other sources we can see that the average reservoirs mentioned above in isolation could offer Ireland's total electricity needs for about 3 days with 2 reservoirs and about 4 days with a 3 reservoir plan.

Many people at first glance at the parameters above will understandably argue that these reservoirs will not provide sufficient electrical energy for Ireland during very protracted periods of negligible wind conditions throughout the country. A simplistic view does not do justice to the unique and highly useful ways in which large Hydro Storage Reservoirs can exploit time of day factors as well as the wide variances of high and low wind energy to our economic and operational advantage. We can see how this works as we offer answers to further questions which follow below.

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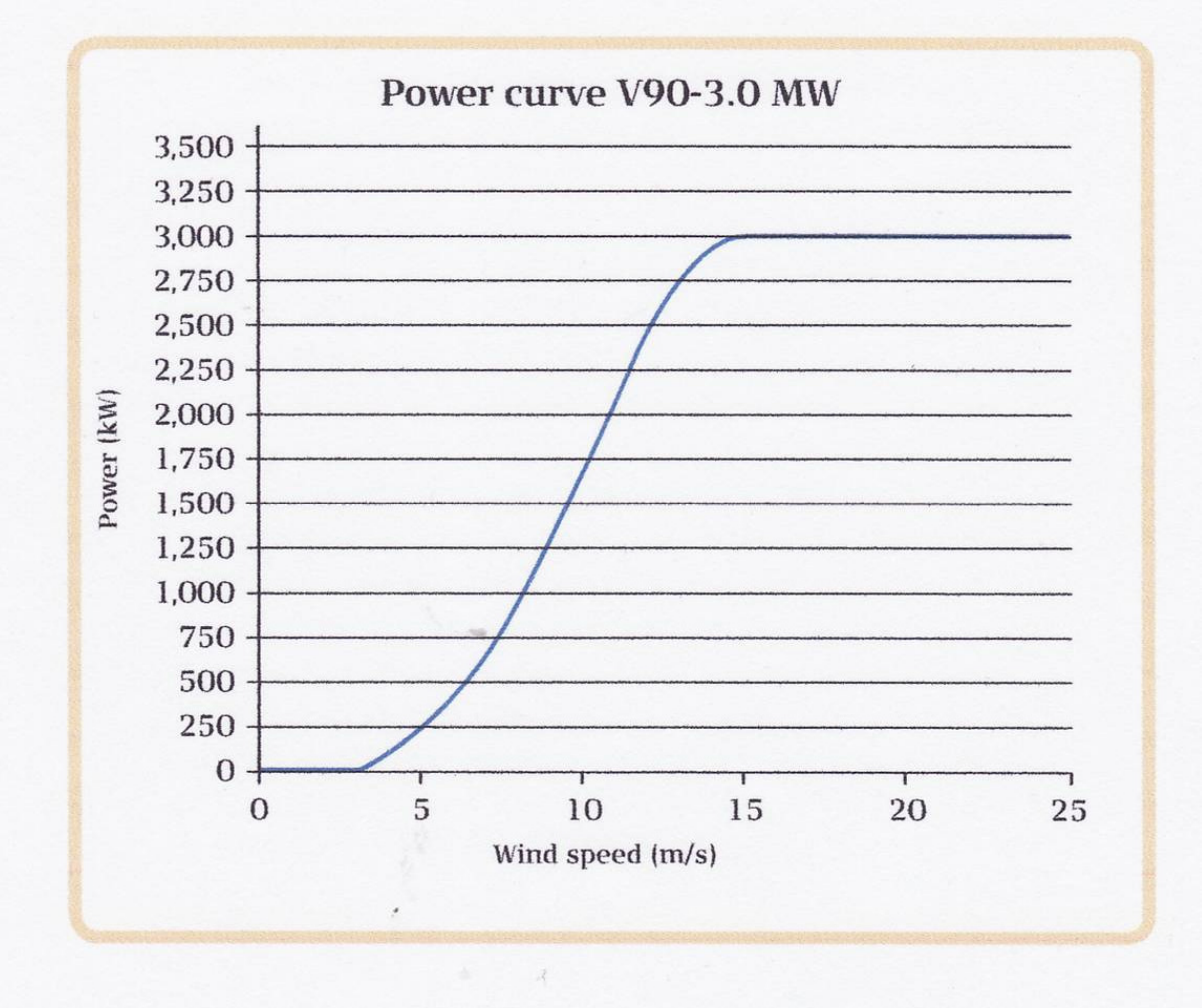
[2] Eirgrid PLC is the independent electricity Transmission System Operator (TSO) in Ireland and the Market Operator in the wholesale electricity trading system. EirGrid's role is to deliver services to generators, suppliers and customers across the high voltage electricity system, and to put in place the grid infrastructure needed to support Ireland's economy.

How have Irish wind speeds and wind turbine modeling been studied?

Irish wind speeds as supplied by Met Eireann and Eirgrid have been extensively analyzed in computerised models. The raw data included several years of hour by hour wind speed information from many regional collection points. It is also very important to point out that our analysis allowed for wind at a height of 100 metres from the ground – which is the elevation proposed for the new wind turbines. Wind speeds at this height are actually on average at least 35 - 40% higher than speeds measured at a 10 metre height. So our daily impressions and experiences of wind speeds as people who spend our lives at ground level even near the west coast are considerably lower than those the turbines will be enjoying in their lofty locations. Furthermore, this speed increase at 100m is very useful to us. Power produced by wind actually increases dramatically as wind speed rises – in fact it is directly proportional to the cube of the wind speed. This is most important and the basic Physics behind it are explained better in Appendix A.

In plain English what this means is that we can produce much more electrical power from the turbine array at 100 metres elevation than we can near the ground. So with turbines at 100 metres we can also see from the same reasoning that even a slight increase in wind speed at this height will have a further large effect on the power output.

The dramatic wind speed to power effect is visible in the chart below – which is the performance characteristics of the Vestas V90 wind turbine. This is a machine in common usage and is recognized as a practical model in many ways for Irish conditions. The V90 machine can produce a maximum power output of 3MW from a wind speed of 15m/s (incidentally for people used to imperial measurements 15m/s is about 33mph).



Vestas V90 Power Curve

Our studies found an average wind speed of about 8m/s (18mph) at 100 metres height throughout a large band of the northern, western and southern parts of Ireland. This gives a figure of 1MW output from each wind turbine. On this basis 2,500 such turbines geographically spread would very comfortably provide an average power output of at least 2,500MW. When combined with existing wind turbine plants we will have more than enough power to keep Ireland running over average usage periods. Ongoing studies of wind patterns over several years are already showing that periods of sustained low wind speeds on a national level below the cut out point for turbines at 100metre collection height are quite rare.

The reason why we are explaining the Physics in detail relating to wind velocity, is that the effects of higher than average wind speeds are quite dramatic and very useful to us.

Can Ireland export excess electrical energy produced during periods when wind is higher than normal?

Yes! This is a very interesting feature of both the wind turbine characteristics and the Hydro Storage solution. There are regular periods of high wind in Ireland when the combined wind turbine power outputs will produce more electricity than needed to fulfill even Ireland's daytime demands. Electrical Interconnectors already exist but more and higher capacity types are planned to the UK and Europe. Daytime green stable electrical energy as offered by our reservoirs will enjoy a premium price for export from Ireland. In the first phase of the Spirit of Ireland project the amounts exported would be modest.

What about excess wind energy at night time?

On average the wind blows at night as much as it does in daytime but of course the country consumes much less electricity at night. One benefit of this is that our reservoirs keep being topped up and full and ready for daytime demands. But there are going to be very frequent night time situations in the model when the reservoirs are already full and the wind is still blowing! What do we do with this extra energy? It is a good question. Exporting energy at night time is theoretically possible but it may not be in demand internationally at this time – or at best only achieve a very low price. Excess energy may be used for industrial applications, hydrogen production, horticulture or other uses where burning fossil fuels could not be justified.

What happens if there are long periods of negligible wind?

In the earlier questions we explained how Ireland can export considerable amounts of electricity using international interconnectors. This type of electricity trading model is already well used and practiced in Ireland and throughout the World. Good international trading can work in two ways. In the very rare occasions when our reservoirs are under pressure from sustained very low wind, we can then buy in electricity. Of course through proper application we can buy in the electricity nationally or internationally cheaply at night time rates to top up our reservoirs!

Spirit of Ireland's design plan will show that on balance Ireland will be exporting far more electricity than it will be importing. This is mainly due to the dramatic effect of higher wind speeds on power output as explained earlier.

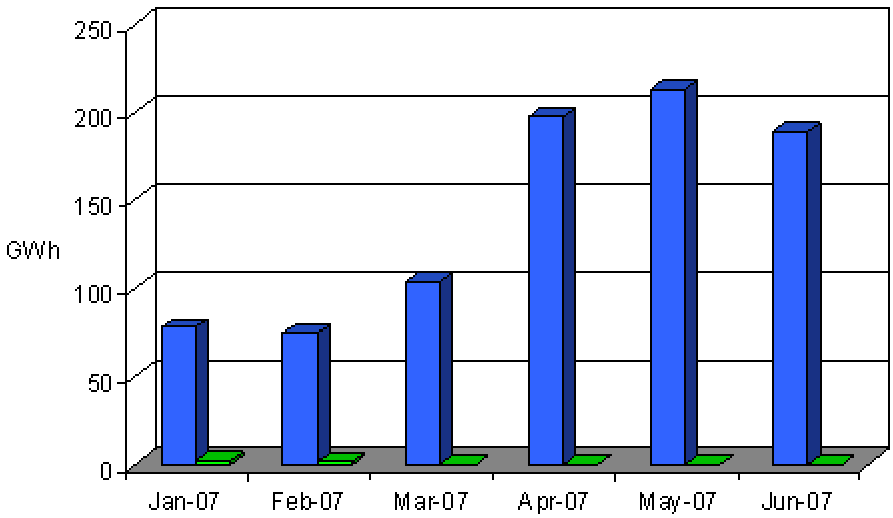
Let us not forget that Ireland has existing conventional power stations. Energy- efficient combined cycle gas turbine plants have been commissioned in recent years. These will remain in service for some time and can work with reservoirs to alleviate protracted low wind conditions. Suitable energy portfolios using efficient existing plant, increased wind power and storage reservoirs are being modeled under all meteorological conditions to arrive at optimum solutions.

What is happening today with Interconnectors – is Ireland importing or exporting power?

In the context of trading on the existing Irish North-South electricity interconnector it is very worthwhile to have a look at the extensive graphical data on this Eirgrid web page…

www.eirgrid.com/EirgridPortal/DesktopDefault.aspx?tabid=MAINTERCONNECTOR%20TRADING

Look at the export/import bar charts in particular (one example is in the diagram below). The very small green export bars look tiny! So even today Ireland needs to import certain levels of electricity to meet peak demands and has negligible exports. Even worse is that a lot of energy is being imported in daytime hours which is the most expensive period in which to buy electricity.



	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07
Actual Imports	77.5	74.4	103.7	197.4	212.9	189.1
Actual Exports	2.5	1.5	0.2	0.0	0.0	0.1

Interconnector Trading Volumes in GWh (January - June 2007) Source Eirgrid PLC.

In following the reasoning in earlier parts of this article we can use our proposed large natural reservoirs to turn this situation the opposite way and export much more electricity than we import. The actual net amount exported will not be very large in GWh terms in the first phase of the Spirit of Ireland programme. However with Ireland at net energy independence, we can produce on demand using our valued Hydro Storage Reservoir model combined with more green indigenous energy sources and become a significant exporter of electrical energy.

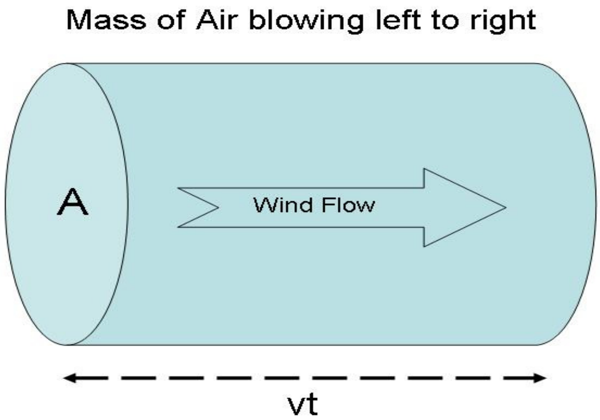
A final Reflection.

Short of cataclysmic climatic events – we can guarantee that the raw resources of high wind will remain available and free to Ireland for thousands and thousands of years. When combined with the natural valleys at our disposal for large scale Hydro Storage, the energy future for our nation will indeed be bright and green. Can we achieve this? YES WE CAN.

Appendix A.

The Basic Physics relating to Wind Power

Imagine a cylindrical mass of wind blowing along from left to right. The area A is facing the wind and the speed of the wind is v.



The volume of the wind is the area A times the distance travelled in time t.

V=Avt

The mass of the wind is the density p times the volume V

m=pV

Therefore…

m=pAvt

Now there is a famous formula in Physics for the kinetic energy of a moving mass m of velocity (or speed) v……

$$E = \frac{1}{2} m v^2$$

Mass m=pAvt

So.. $$E = \frac{1}{2} pAvt\, v^2$$

Power P is energy with t=1sec

Hence.. $$P = \frac{1}{2} pA v^3$$