

University of Wales Trinity Saint David

HNC / HND in Electrical and Electronic Engineering

Renewable Energy Sources

Electrical Power

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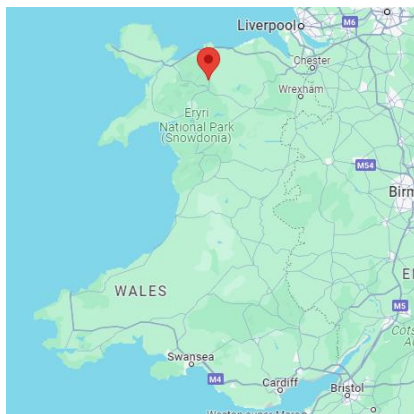
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Introduction

The reliance of the European Union and, indirectly, the United Kingdom on Russian natural gas supplies has increased over the last decade. Since the start of the war in Ukraine, Russia has suspended the supplies of the natural gas that continental Europe and the UK used for years to run factories, generate electricity and heat homes. Accordingly, the price of natural gas is nearly 5 times what it was two years ago, putting governments worldwide under enormous pressure. Rising energy prices are accelerating the cost-of-living crisis; increasing food and energy poverty; and increasing social unrest. The current global energy crisis and the impacts of environmental/ climate change accelerate the transition towards cleaner renewable and cheaper energy sources than fossil fuels.

In the UK there are many small rural villages that suffer from insufficient electrical power supply due to technical and environmental problems in connecting these villages with the high voltage grid and the current worldwide energy price crisis. One of these villages is Llanrwst, south of the town of Colwyn Bay, in North Wales. The aim of this report is to deal with renewable energy problems by introducing low-cost solutions that are simple to manufacture, assemble and maintain. This can be done with either wind or solar power.

This report will demonstrate the calculations for the use of both wind and solar energy sources, and which will be used will be determined by the costs and efficiency of the power farms.



(Google, 2024)

Power Consumption Calculations

The assignment brief gives the power consumption of every building and facility in the village of Llanrwst. The table below demonstrates the average daily power consumption of each building, the amount of buildings there are, and the total daily power consumption.

Building	Average Power Consumption per Day (kWh)	Amount of Buildings	Total Average Power Consumption per Day (kWh)
Cottage	10	120	1,200
School	100	2	200
Hospital	250	1	250
Sports Centre	40	1	40
Police Station	120	1	120
Worship Building	6	2	12
Street/Traffic Lights	2	80	160
			= 1982

Below are the calculations for the costs of electricity supply by the National Grid for a period of 10 years:

Total Average Power Consumption per Year =

$$1982 \times 365 = 723,430 \text{ kWh}$$

Total Average Power Consumption over 10 years =

$$723,430 \times 10 = 7,234,300 \text{ kWh}$$

The average electricity bill in North Wales in 2021 was 18.40p/kWh (Jones, 2021), therefore the calculations for the cost of the power consumption of the village over 10 years are as follows:

$$7,234,300 \times 18.40 = 133,111,120 \text{ p}$$

$$\frac{133,111,120}{100} = \text{£}1,331,111.20$$

Over 10 years, the village of Llanrwst has an average total energy cost of £1,331,111.20. This is under the assumption that there is a fixed electricity tariff at the end of 2021 (before the Ukraine war).

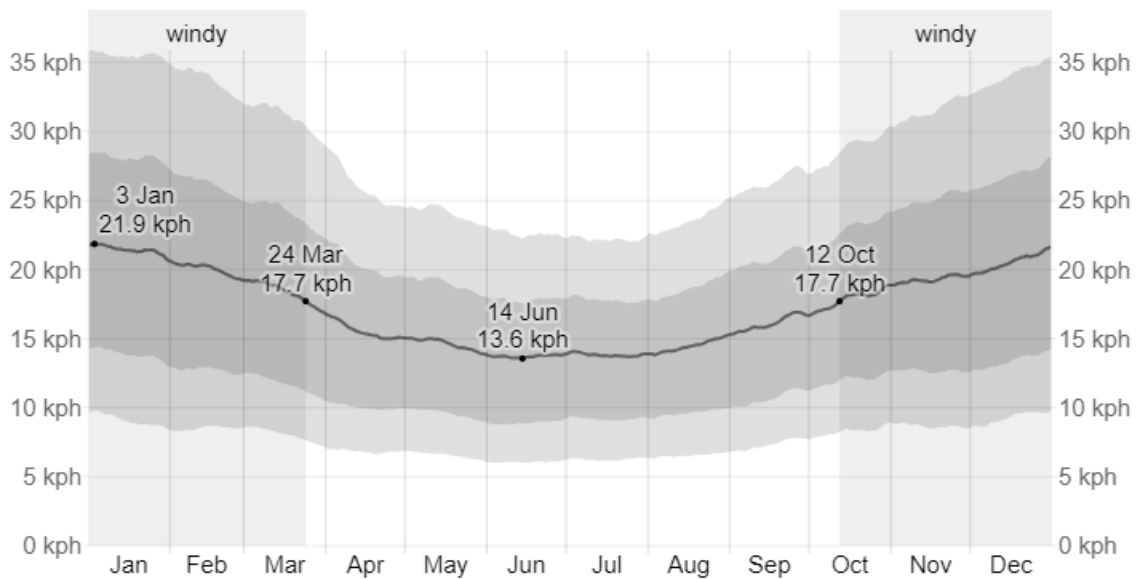
Wind Power Calculations

In order to power the village of Llanrwst using wind power, a design of the system is required. This design should include:

- Wind machines property and number.
- Wind viability survey.
- Turbine.
- Converter.
- Low Voltage Switchgear (220V).
- Battery property and number.
- Protection devices and settings.

The wind power system can only be designed after knowing the wind speed of the village and the location which is best suited to be able to get the most amount of power to be produced by the system.

Below is a diagram detailing the average wind speed in Llanrwst per month:



(Weather Spark, 2023)

Below is a table demonstrating each of the wind speeds for each month taken from the graph shown above. The wind speeds shown are measured in kilometres per hour.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Wind Speed (kph)	21.5	20.0	18.3	15.5	14.6	13.7	13.8	14.5	16.2	17.9	19.3	20.6

The wind speeds above are measured in kilometres per hour, therefore it is required to convert them to metres per second in order to find a suitable turbine to use. The formula for converting kilometres per hour to metres per second is as follows:

$$\text{metres per second} = \text{kilometres per hour} \times \frac{5}{18}$$

The table below shows the wind speeds converted to m/s.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Wind Speed (m/s)	6	5.6	5.1	4.3	4.1	3.8	3.8	4	4.5	5	5.4	5.7

These figures will be useful when trying to find a suitable wind turbine / turbines that can produce enough power at the wind speed that the village is able to receive.

In order to compare this data with the requirements for the wind turbine, the average annual wind speed needs to be calculated. Below is the calculation for the annual average wind speed of the village of Llanrwst:

$$\frac{6 + 5.6 + 5.1 + 4.3 + 4.1 + 3.8 + 3.8 + 4 + 4.5 + 5 + 5.4 + 5.7}{12} = 4.775 \text{ metres per second}$$

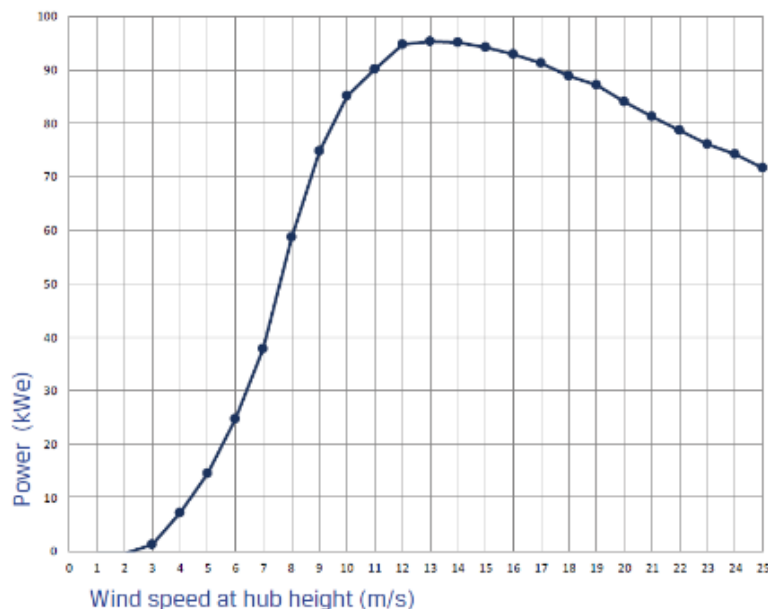
Wind Turbine Model

Searching for a suitable wind turbine model proved to be a difficult task, as wind turbine models were not simple to come across, and most wind turbines had power outputs far too large or were far too costly. After a large amount of research, a suitable wind turbine was found, the NPS 100C-24 100kW wind turbine from Northern Power (Earthmill, 2023). Below is an image of the wind turbine model which will be used:

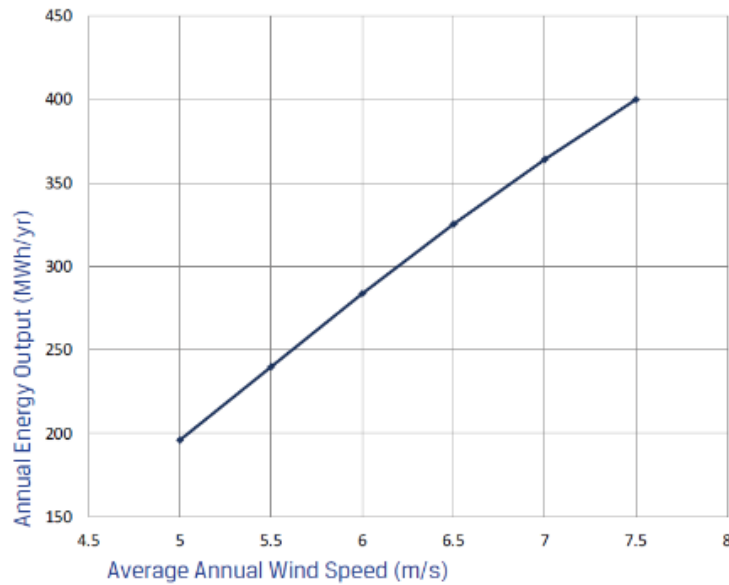


The reason why this particular wind turbine was chosen is because the cut in speed of the wind turbine is 3m/s, which means that the turbine is able to produce power for the village if it were to be placed within the area of Llanrwst. The same could not be said about other models, which had higher wind cut in speeds than the average wind speeds of the village, meaning they were not suitable for the area.

Here is a graph detailing the power curve of the wind turbine that has been chosen:



And below is a graph showing the annual energy production of the wind turbine:



Wind Turbine Calculations

In order to calculate the number of wind turbines required to power the village, the annual average wind speed has been rounded up to 5 m/s, which according to the graph above translates to 200MWh per year. The annual energy consumption of the village as calculated previously is 723,430 kWh, or 723.43 MWh, meaning that one wind turbine alone would not be enough to satisfy the energy consumption of the whole village, therefore it is required the minimum number of wind turbines required, as is shown below:

$$\frac{723.43}{200} = 3.617 = 4 \text{ wind turbines}$$

The average cost of a typical 100kW wind Turbine is £441,000 (Renewables First, 2023). As 4 of these particular wind turbines is required to power the village, the total cost of the wind turbines would be as follows:

$$441,000 \times 4 = \text{£}1,764,000$$

Below is a diagram showing the wind speed map of the area surrounding Llanrwst at 45m which shows potential areas that can be used to place the wind turbines.



(RenSmart, 2023)

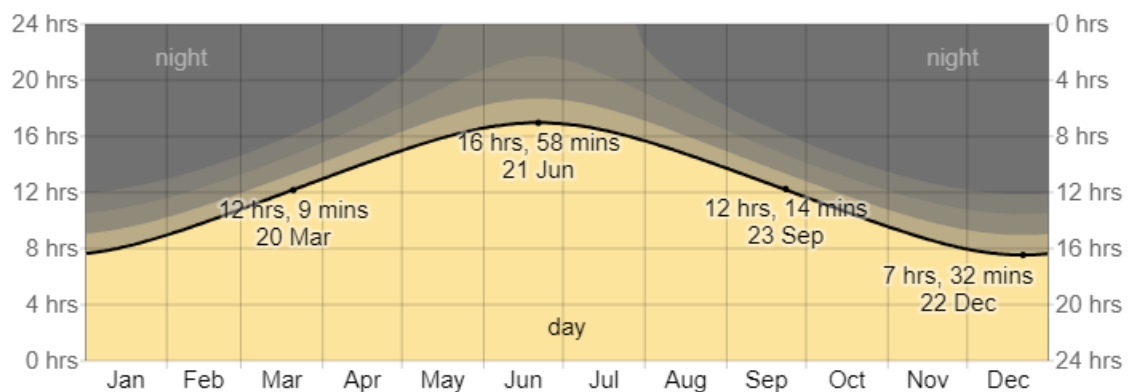
Solar Power Calculations

In order to power the village of Llanrwst using solar power, a design of the system is required. This design should include:

- Photovoltaic cell and working principle.
- Sunshine viability survey.
- Types of PV system.
- Sizing of the PV generator.
- Inverter.
- Solar charge controller.
- Solar power Battery property and number.
- Reliability (redundancy in equipment – soft failure).

The solar power system can only be designed after knowing the sunlight of the village and the location which is best suited to be able to get the most amount of power to be produced by the system.

Below is a diagram detailing the average hours of daylight and twilight in Llanrwst per month:



(Weather Spark, 2023)

Below is a table demonstrating the average daylight hours for each month taken from the graph shown above.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Daylight (Hours)	8.2	9.9	11.9	14.1	15.9	16.9	16.3	14.7	12.6	10.5	8.6	7.6

This information is valuable as it can be used to calculate the number of solar panels and hence the area required to be used for the solar farm with which to power the village of Llanrwst.

In order to compare this data with the requirements for the solar panel, the average annual daylight hours need to be calculated. Below is the calculation for the annual average daylight hours of the village of Llanrwst:

$$\frac{8.2 + 9.9 + 11.9 + 14.1 + 15.9 + 16.9 + 16.3 + 14.7 + 12.6 + 10.5 + 8.6 + 7.6}{12} = 12.26 \text{ hours}$$

Annual Average = 12.26 hours/day

Solar Panel Option

Searching for a specified solar panel was simpler than the wind turbines as they are easier to come across and there are many more options. A suitable solar panel was chosen being the Bluetti PV350 350W Portable Folding Solar Panel (Energian, 2023). Below is an image of the solar panel that would be used for the solar farm:



The reason this solar panel was chosen is that the average solar panel produces 350W of power, so the solar panel that would be chosen would be the of a similar power output, which this solar panel is.

Solar Panel Calculations

With the annual average hours of daylight having been calculated along with the power output of the solar panel that was chosen, it is possible to calculate the average energy consumption per day, which would be:

$$12.26h \times 350W = 4,291 Wh$$

Then convert the value to kWh as shown below:

$$\frac{4,291}{1000} = 4.291 kWh$$

Now it is possible to calculate the number of solar panels required to cover the energy demand of the village for a day.

$$\frac{1982}{4.291} = 461.9$$

Therefore, 462 solar panels would be required.

The cost of this particular solar panel is £799. The cost of all of the solar panels that are required is as follows:

$$799 \times 462 = £369,138$$

The area of the solar panel is as follows:

$$2400 mm \times 905 mm = 2,172,000 mm^2 = 21,720 cm^2 = 2.172 m^2$$

$$2.172 \text{ m}^2 \times 462 = 1,003.464 \text{ m}^2$$

Wind Power over Solar Power

In the case of the village of Llanrwst, when researching which wind turbine models to use (Wind Turbine Models, 2023), the task of finding a model proved difficult, either because the power output for the wind turbine was too large for the village and therefore would produce a significant amount of wasted power and would be inefficient in terms of costs, or the input needed for the wind speeds of the area to be higher than they were. Because of this, research into solar power began instead, as it was much simpler to find different types of solar panels as they were easier to come by.

In conclusion, between either wind or solar power, it was decided that wind power would be the better option.

The battery that was chosen is the 12.8V 100Ah LiFePO4 Battery DL-LFP-RP12100 (DeLongtop, 2024). This battery is a Lithium Ion battery. The battery uses an outer shell made of ABS+PC material, which can withstand high-intensity impacts and effectively protect the internal battery. Additionally, it is waterproof with an IP55 protection rating.

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The reason that a lithium ion battery was chosen is that they are longer lasting, more lightweight than lead acid batteries while providing more energy, and quick and efficient with a lot of versatility (Relion, 2024).

A 12V lithium battery costs around £279.99.

Off-Grid Wind System Costs

In total the cost of the off-grid wind system are as follows:

$$£1,764,000 + £279.99 = £1,764,279.99$$

Environmental Impact

When designing a wind power system with large wind turbines, it is important to note the environmental impact and possible negative effects that can occur. Of course, using renewable energy as a power source rather than the alternatives can do a significant amount of good for the environment, such as producing less pollution, or being a renewable energy source, but there can also be disadvantages to constructing a wind power system.

One such disadvantage is noise pollution. Wind turbines can be very noisy as the turbine blades slice through the air, and the machinery that generates the power inside of the turbines can also be loud, and if wildlife is nearby, they can also be affected by the noise.

Another disadvantage is that the wind turbines can be dangerous to wildlife in more fatal ways than just being noisy. Birds and bats often collide with wind turbines, and the bats' sonar navigation can be interfered with by wind turbines (Constellation, 2024).

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