

Electrical Power

HNC / HND in Electrical and Electronic Engineering

By
Scott Tavner



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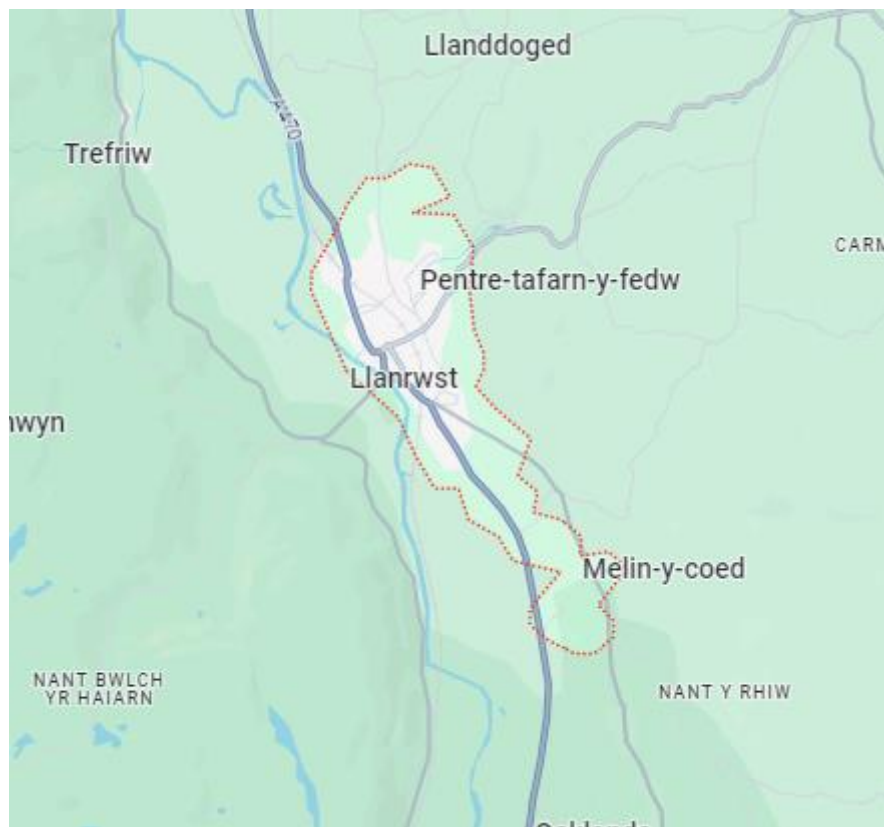
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Introduction

The United Kingdom has relied on natural gasses supplied from Russia for years however due to the Ukraine war, these supplies have been suspended. This has led to rising energy prices in turn accelerating the cost-of-living crisis; increasing food and energy poverty; and increasing social unrest.

With the rising prices of natural gas energy as well as worries about its effect on the environment more and more people are looking to renewable energy sources. There are a number of small villages in north Wales with a low power demand (8-10kW per household) and high potential for wind or solar power source.

A rural village in the south of the town of Colwyn Bay (Llanrwst valley) in north Wales suffers from a shortage of electrical power supply. The local village council decided to look at harvesting the potential energy resources in the area to generate reliable and adequate electrical power that can supply the village with electricity 24 hours a day for a whole year. For this brief we will be looking into a sustainable energy source for the village and look at the total cost and payback period for the project.



(Google Maps, 2023)

Energy Consumption and Power Demands

Per day

Building	Energy consumption (per day)	<u>Amount</u> of buildings	Energy consumption	Power demand
Cottage	10kWh	120	1.2MWh	50kW
School	100kWh	2	200kWh	8.3kW
Hospital	250kWh	1	250kWh	10.4kW
Sport centre	40kWh	1	40kWh	1.7kW
Police station	120kWh	1	120kWh	5kW
Worship building	5.7kWh	2	11.4kWh	0.5kW
Street/traffic lights	2kWh	80	160kWh	6.7kW
			1.98MWh	82.6kW

Per week

Building	Power consumption (per day)	<u>Amount</u> of buildings	Energy consumption	Power demand
Cottage	10kWh	120	8.4MWh	350kW
School	100kWh	2	1.4MWh	58.1kW
Hospital	250kWh	1	1.75MWh	72.8kW
Sport centre	40kWh	1	280kWh	11.9kW
Police station	120kWh	1	840kWh	35kW
Worship building	5.7kWh	2	79.8kWh	3.5kW
Street/traffic lights	2kWh	80	1.12MWh	46.9kW
			13.87MWh	578.2kW

Per month

Building	Energy consumption (per day)	<u>Amount</u> of buildings	Energy consumption	Power demand
Cottage	10kWh	120	33.6MWh	1.4MW
School	100kWh	2	5.6MWh	232.4kW
Hospital	250kWh	1	7MWh	291.2kW
Sport centre	40kWh	1	1.12MWh	47.6kW
Police station	120kWh	1	3.36MWh	140kW
Worship building	5.7kWh	2	319.2kWh	14kW
Street/traffic lights	2kWh	80	4.48MWh	187.6kW
			55.48MWh	2.3MW

Per year

Building	Energy consumption (per day)	<u>Amount</u> of buildings	Energy consumption	Power demand
Cottage	10kWh	120	438MWh	18.3MW
School	100kWh	2	73MWh	3MW
Hospital	250kWh	1	91.3MWh	3.8MW
Sport centre	40kWh	1	14.6MWh	621kW
Police station	120kWh	1	43.8MWh	1.8MW
Worship building	5.7kWh	2	4.2MWh	183kW
Street/traffic lights	2kWh	80	58.4MWh	2.45MW
			761.1MWh	30.2MW

Per 10 years

Building	Energy consumption (per day)	<u>Amount</u> of buildings	Energy consumption	Power demand
Cottage	10kWh	120	4380MWh	183MW
School	100kWh	2	730MWh	30MW
Hospital	250kWh	1	913MWh	38MW
Sport centre	40kWh	1	146MWh	6.21MW
Police station	120kWh	1	438MWh	18MW
Worship building	5.7kWh	2	42MWh	1.83MW
Street/traffic lights	2kWh	80	584MWh	24.5MW
			7611MWh	302MW

Energy consumption cost

Region	Gas unit rate per kWh (October to December 2023)	Gas daily standing charge (October to December 2023)	Electricity unit rate per kWh (October to December 2023)	Electricity daily standing charge (October to December 2023)
Eastern	6.78p	29.62p	27.93p	44.02p
East Midlands	6.77p	29.62p	26.76p	50.71p
London	6.90p	29.62p	28.43p	38.52p
Midlands	6.82p	29.62p	26.85p	54.38p
Northern	6.82p	29.62p	26.58p	57.46p
Northern Scotland	6.85p	29.62p	27.26p	59.40p
North West	6.90p	29.62p	27.21p	51.81p
North Wales & Mersey	6.93p	29.62p	28.26p	62.23p
Southern	6.99p	29.62p	27.51p	49.99p
South East	6.92p	29.62p	28.10p	47.58p
Southern Scotland	6.85p	29.62p	26.88p	62.10p
South Wales	7.05p	29.62p	27.45p	54.23p
Southern Western	7.10p	29.62p	27.18p	58.70p
Yorkshire	6.83p	29.62p	26.52p	56.02p

(Gallizzi, 2023)

Total price of energy for Llanrwst

From the taken average for north Wales being 28.6p / kWh we can calculate that:

the cost of energy for a day:

$$28.6p \times 1,980kWh = 56,628p \text{ or } £ 566.28$$

The cost of energy per year:

$$£566.28 \times 365 = £206,692.20$$

The cost per 10 years:

$$£206,692.20 \times 10 = £2,066,922$$

Solar Option

How do solar panels work?

A solar panel utilises solar cells or photovoltaic cells in order to harness solar energy from the sun and convert it into electricity. These photovoltaic cells use semi conductive materials such as silicon to absorb a portion of the sun's rays and the absorbed energy will knock electrons loose allowing them to flow freely. The cells will then use electric fields to force the electrons in a certain direction creating current which can then be drawn off using metal plates attached to the top and bottom of the cell. (Krisciunas, 2023)

Calculations

Average direct sunlight per day for Llanrwst (1991 – 2021)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg sunlight (hrs)	3.3	3.8	4.7	6.3	7.3	7.3	7.0	6.2	5.1	4.4	3.5	3.3

(climate-data, n.d.)

The average solar panel has a power output rating of 250 to 400 watts (W). (David, 2023)

The months with the lowest averages are January and December with 3.3hrs of direct sunlight.

$$3.3hrs \times 400 = 1,320Wh \text{ or } 1.32kWh \text{ per day minimum}$$

However, this is not the final Wattage as solar panels come with several energy losses.

Solar panel systems efficiency losses:

Problem effecting the system	Maximum potential energy loss
Shading	7%
Dust and dirt	2%
Reflection	2.5%
Spectral	1.5%
Irradiation	1.5%
Thermal	0.5% for every 1°C over 25°C
Array mismatch	+/-5%
DC cables	1%
inverter	5%
AC cables	1%
Total loss bellow 25°C = 26.5%	

Deduct potential power loss $1,320W - 26.5\% = 970.2W$ or $0.972kW$

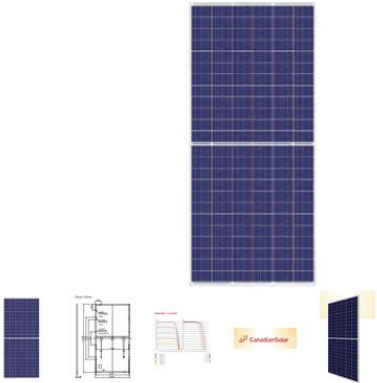
So the amount of solar panels need for a day would be:

$$\frac{1,980kWh}{0.972kWh} = 2038 \text{ solar panels}$$

Using the price for this 400w solar panel we can calculate the total cost.

Home : Shop (Buy Renewable Energy Products) : Canadian Solar CS3W-400P-MC 400W Solar Panel

Home : Shop (Buy Renewable Energy Products) : Solar Panels PV : Canadian Solar CS3W-400P-MC 400W Solar Panel



CANADIAN SOLAR

Canadian Solar CS3W-400P-MC 400W Solar Panel

£122.60

SKU:
CS3W-400P-MC

Weight:
25.00 KGS

Width:
104.80 CM

Height:
210.80 CM

Depth:
4.00 CM

Shipping:
Calculated at checkout

Minimum Purchase:
1 unit(s)

(renugen, 2023)

Total cost:

$$2038 \text{ panels} \times £122.60 = £249,858.80$$

An issue facing solar option is the space requirement for the panels.

Each solar panel area:

$$104.8 \times 210.8 \text{ cm} = 22092 \text{ cm}^2 \text{ or } 2.21 \text{ m}^2$$

Assuming each solar panel will be 2m apart:

$$304.8 \times 410.8 \text{ cm} = 125,212 \text{ cm}^2 \text{ or } 12.52 \text{ m}^2$$

$$\text{Total area needed} = 12.52 \text{ m}^2 \times 2038 = 25,516 \text{ m}^2 \text{ minimum}$$

Wind option

How do wind turbines work?

A wind turbine utilises the kinetic energy of wind to make mechanical energy followed by electrical energy. This usually incorporates 3 or more angled blades placed on a central hub that are moved in a certain direction by the wind. The central hub is rotated by the blades which in turn rotates a shaft that connects to a gearbox which turns a generator creating electrical energy to be collected.

The Blades:

The blade of a wind turbine has a number of airfoil cross-sections in different shapes and sizes along the blade. These airfoils will produce lift on one side of the blade when wind travels over it causing the blades to spin around a central hub. The angle of the blade directly corresponds to the speed of the wind. There is a gradual twist in the blade as you reach the tip which is to account for the velocity of the blade increasing as you reach the tip.

The Gearbox:

The central hub is connected to a gearbox instead of directly to the generator as the hub will spin at a very low rpm due to the size of the blades and mechanical strain. The gearbox utilises a planetary gear set arrangement in order to produce a high rpm shaft that connects to the generator. A break sits between the gearbox and generator and is there in order to slow the turbine down during demanding wind speeds.

The Generator:

A generator is spun allowing for electricity to be run down through wires to the step up transformer at the base of the wind turbine. However if the wind turbine is speed varying the ac signal will have a lot of fluctuations and so it needs to be converted to DC and then back to a more reliable AC signal.

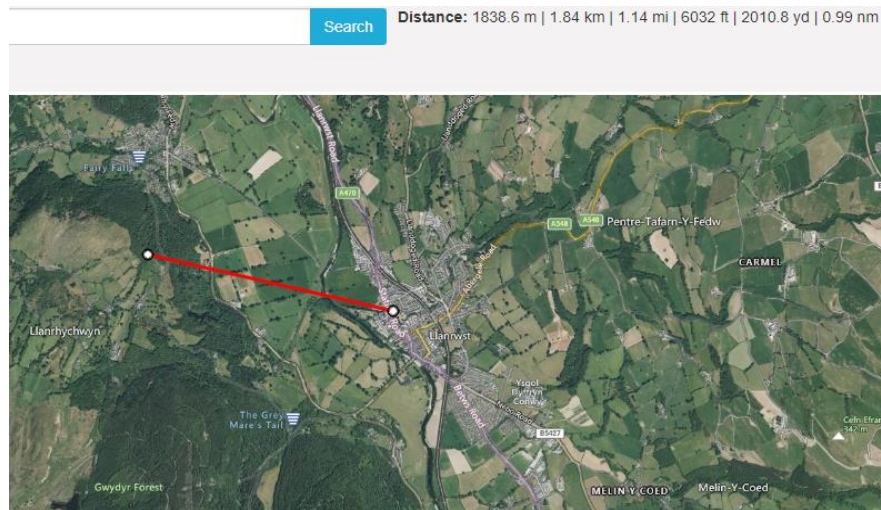
Velocity Sensor:

In order to account for changes in wind speed and direction the wind turbine is fitted with a velocity sensor that measures the wind speed and direction. The sensor will then tell the wind turbine's electronic control unit (ECU) to make adjustments to the wind turbine's yaw allowing for the wind turbine to always be facing the wind. It will also tell the brake to engage based on the wind speed to avoid damage to the turbine.

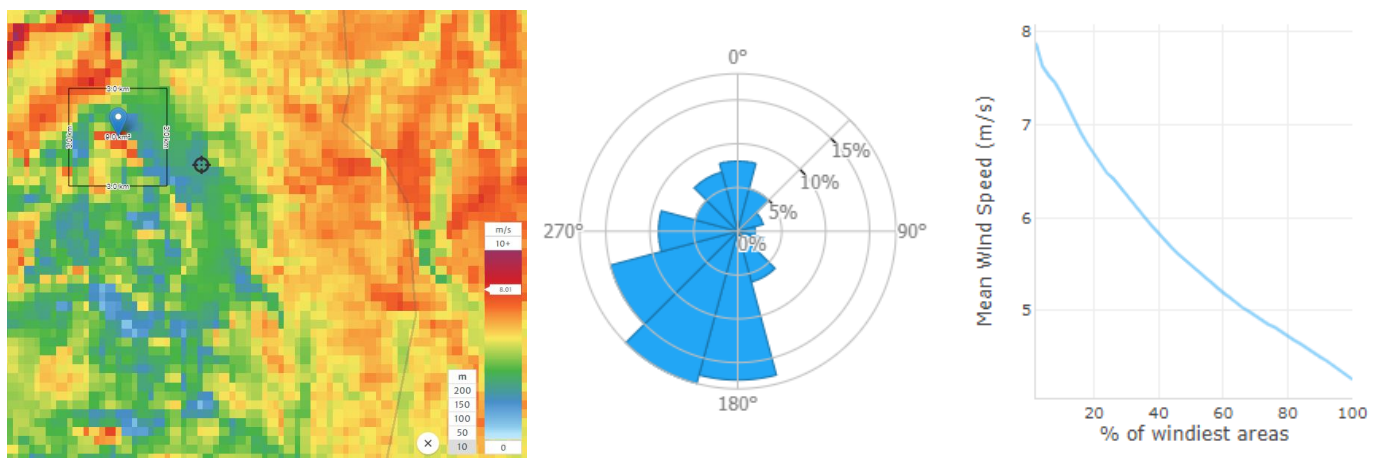
(Grogg, 2005)

Wind Turbine Location

In order for the wind turbine to be most efficient it should be built at a higher altitude 1.8 kilometres West of Llanrwst as Llanrwst its self is sheltered from the wind due to the surrounding mountains. At this location the wind speed is an average of 8m/s.



(calcmaps, 2023)



(globalwindatlas, 2023)

Due to the location being a distance a way form the village we need to look into how the energy will be transferred to the village

price of overhead lines:

132kV overhead line £150k per km (Brechfa Forest Connection, 2014)

$$1.84km \times £150,000.00 = £276,000.00$$

Wind turbine options

Endurance E-3120

Power Production

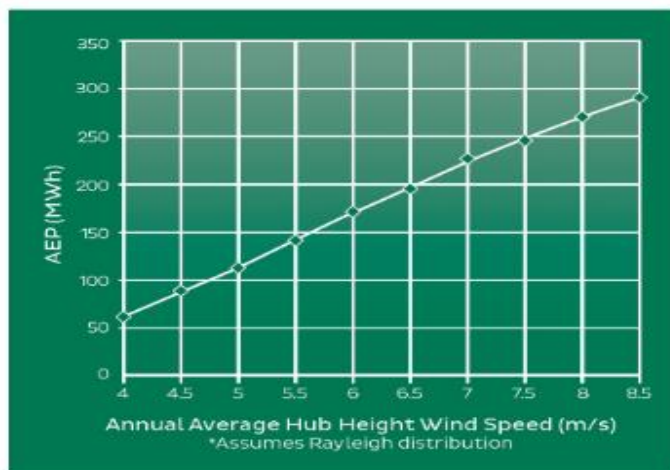
The E-3120 Endurance turbine is classified as a 50kW wind turbine. Often manufacturers rate wind turbines at their peak performance, however Endurance rate their turbines by their average performance. Through monitoring the turbines currently installed across the UK, we have found that the E-3120 is so efficient that it frequently outperforms other turbine models rated at 80kW.

The AEP table allows you to see what the annual energy production is likely to be based on the wind speed of your site. If you aren't sure what your wind speed is you can find out by requesting a [complimentary site assessment](#) through Earthmill.

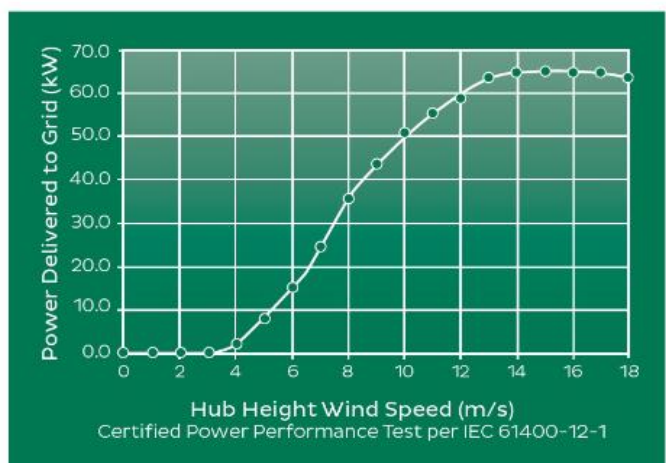
Annual Energy Production Chart

Annual Average Hub Height Wind Speed (m/s)	Annual Energy Production (kWh)
4.0	61 600
4.5	87 800
5.0	113 900
5.5	141 700
6.0	169 400
6.5	195 900
7.0	222 400
7.5	246 100
8.0	269 900
8.5	290 100

Annual Energy Production (AEP)



Power Curve



Specification

E Series Specs E3120-4 50kW

Turbine

Configuration Three blade, horizontal axis, downwind
Rated Power 50kW at 10 m/s
Application Direct Grid Tie
Rotor Speed 43 RPM
IEC 61400-1 Turbine Class: IIIA except annual average wind speed can be up to 8.5 m/s
Maximum Average Wind Speed 8.5m/s
Survival Wind Speed 52 m/s or 116mph
Cutout Wind Speed 25m/s
Overall Weight 3990kg / 8800lbs

Rotor

Rotor Diameter 19.2m
Swept Area 290m²
Blade Length 9m
Blade Material Fiberglass Composite
Power Regulation Stall control

Generator

Generator Type Asynchronous, Induction
Configuration 3-phase, 400 VAC, 50 Hz

Brake & Safety Systems

Main Brake System Rapid Fail-Safe dual mechanical brakes
Secondary System Spring-loaded pitch mechanism for over-speed regulation
Automatic Shutdown triggered by High wind speed, grid failure, over-speed, all other fault conditions

Controls

Control System User Interface Programmable Logic Controller (PLC) and ERIC™ Endurance Remote Interface Centre

Towers

Available Hub Heights 24.6m and 36.4m
Tower Type Free Standing Monopole, Safe climbing system

Warranty

Standard – 5 year parts and labour
CE Compliant Yes

(earthmill, 2023)

Time period	Energy production at 8m/s
Per Day	739 kWh
Per Year	269,900 kWh
Per 10 Years	2,699,000 kWh

Calculations:

Total wind turbines needed

$$\frac{761,100\text{kWh}}{269,900 \text{ kWh}} = 2.8 \text{ so } 3 \text{ turbines}$$

Total cost:

Price of turbine = £250,000

The price for all turbines needed would be:

$$£250,000.00 \times 3 = £750,000.00$$

(hitwind, 2014)

Aeolos Wind Turbine 100kW

100kW wind turbine



Aeolos Wind Turbine 100kW Specification

Rated Power	100 kW
Maximum Output Power	120 kW
Generator	Direct-Drive Permanent Magnet Generator
Blade Quantity	3 Glass Fiber Blades
Rotor Blade Diameter	24.5 m (80.4 ft)
Start-up Wind Speed	2.5 m/s (5.6 mph)
Rated Wind Speed	10 m/s (22.3 mph)
Survival Wind Speed	59.5 m/s (133.1 mph)
Controller	PLC With Touch Screen
Safety System	Pitch Control, Electrical Brake & Hydraulic Brake
Turbine Weight	8350 kg (18408.6 lbs)
Noise	60 db(A) @ 7m/s
Temperature Range	-20°C to +50°C
Design Lifetime	20 Years
Warranty	Standard 5 Years

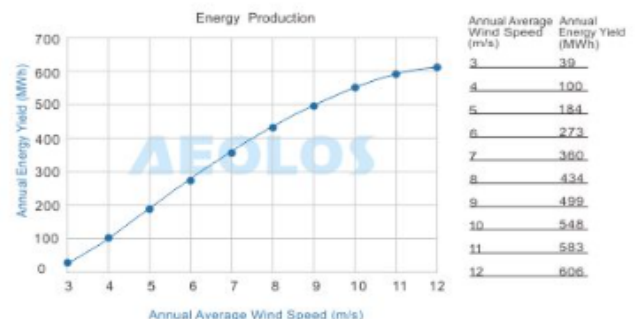
100kW Wind Turbine Application

Aeolos-H 100kW wind turbine used three phase direct-drive generator, no gearbox or booster device. It is more reliable and efficient than the induction generator with gearbox or booster. The 100kW wind turbine is controlled by PLC controller with touch screen. There are triple safety protections for Aeolos-H 100kW wind turbine including pitch control, PWM dump loading system and hydraulic brake system. Remote monitoring is the optional configuration for the 100kw wind turbine. You can access the wind turbine control panel in anywhere through the internet.

Aeolos-H 100kW wind turbines provide grid on and off grid wind power solutions to the customer. Aeolos-H 100kW wind turbines were widely applied in small wind farm, college, hospital and other commercial projects. Our 100kW wind generator has the excellent performance on ROI which is about 3-5 years in different areas. It is a good investment project in the rich wind source countries, like Italy, Greece, Spain, UK, France, Australia, German, USA and Romania.

More Horizontal Axis Wind Turbines

• Aeolos-H 1000W	• Aeolos-H 10kW	• Aeolos-H 50kW
• Aeolos-H 3000W	• Aeolos-H 20kW	• Aeolos-H 60kW
• Aeolos-H 5000W	• Aeolos-H 30kW	• Aeolos-H 100kW



Why Choose Aeolos Wind Turbine?

- Reliable Design
- Triple Safety Protection For All Faults
- More Efficiency
- Competitive Price
- One Package Solution
- 5 Year Standard Warranty

100kW Price & brochure , please contact us sales@windturbinestar.com

(windturbinestar, n.d.)

Time period	Energy production at 8m/s
Per Day	1,189 kWh
Per Year	434,000 kWh
Per 10 Years	4,340,000 kWh

Calculations:

Total wind turbines needed

$$\frac{761,100\text{kWh}}{434,000 \text{ kWh}} = 1.7 \text{ so } 2 \text{ turbines}$$

Total cost:

Using the typical cost of a 100kw which is £345,000

The price for all turbines needed would be:

$$£345,000.00 \times 2 = £690,000.00$$

(checkatrade, 2023)

Bonus B44/600

Power

Rated power:	600.0 kW
Flexible power ratings:	-
Cut-in wind speed:	3.0 m/s
Rated wind speed:	15.0 m/s
Cut-out wind speed:	25.0 m/s
Survival wind speed:	55.0 m/s
Wind zone (DIBt):	-
Wind class (IEC):	-

Rotor

Diameter:	44.0 m
Swept area:	1,521.0 m²
Number of blades:	3
Rotor speed, max:	27.0 U/min
Tipspeed:	62 m/s
Type:	LM 19.1
Material:	GFRP
Manufacturer:	LM Glasfieber
Power density 1:	394.5 W/m²
Power density 2:	2.5 m²/kW

Generator

Type:	Asynchronus
Number:	1
Speed, max:	1,500.0 U/min
Voltage:	690.0 V
Grid connection:	Thyristor
Grid frequency:	50 Hz
Manufacturer:	ABB

Tower

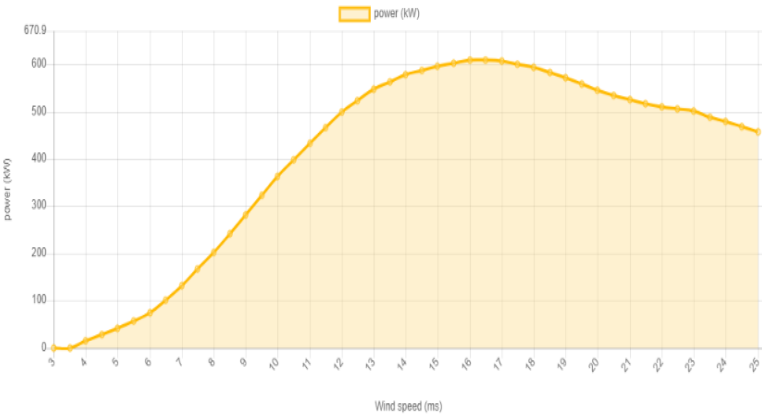
Hub height:	42/50/55/58 m
Type:	Steel tube
Shape:	conical
Corrosion protection:	painted
Manufacturer:	Bonus A/S
Ratio:	-

Weight

Single blade:	-
Hub:	-
Rotor:	14.0 t
Nacelle:	22.5 t
Tower, max:	57.0 t
Total weight:	93.5 t

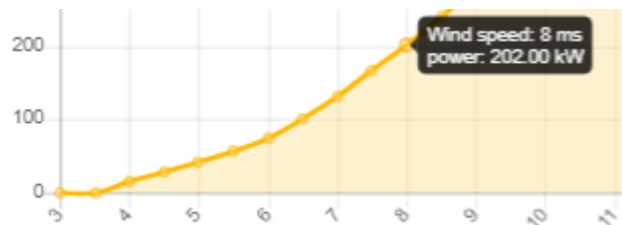
Manufacturer: Flender

Power curve



(wind-turbine-models, 2023)

Energy production at 8m/s



Time period	Energy production at 8m/s
Per Day	4,848kWh
Per Year	1,769,520 kWh
Per 10 Years	17,695,200 kWh

Calculations:

Total wind turbines needed

$$\frac{761,100\text{kWh}}{1,769,520 \text{ kWh}} = 0.4 \text{ so } 1 \text{ turbine}$$

Total cost:

“The costs for a utility scale wind turbine range from about \$1.3 million to \$2.2 million per MW of nameplate capacity installed” (windustry, n.d.)

Using the average price from this quote we can find the total cost per MW

$$\frac{1.3 + 2.2}{2} = £1.75\text{mil per MW}$$

600kW turbine is 0.6MW

$$£1.75\text{mil} \times 0.6\text{MW} = £1,050,000$$

Chosen turbine

Turbine	Endurance E-3120	Aeolos Wind Turbine 100kW	Bonus B44/600
Pros	• Relatively low cost • More than 1 windmill if problem occurs. • Very efficient • Low weight (3990kg)	• Lowest total cost • Built in PWM charge controller. • Direct drive so no need for gearbox (less maintenance) • More than 1 windmill if problem occurs.	• High production • Only 1 turbine required. • Lots of overproduction to be resold to the grid.
Cons	• 3 technicians required. • Requires charge controller. • Space for 3 turbines needed	• Space for 2 turbines needed. • 2 technicians required	• High cost • No spare turbine in case of failure • Assumed high weight. • Requires charge controller

After looking at the options I believe that the Aeolos Wind Turbine will be the best option as it has the lowest total cost, some energy overproduction that can be sold back to the grid. It also has 2 turbines in case of failure and a charge controller built in.



Energy storage

Now that energy is being produced by the turbine a place to store it is required. This is because of the unpredictable nature of wind meaning that the turbine may have days where it will not produce as much wind due to the conditions of wind speed. In contrast there could be days where more wind energy is being produced than required for the town. There are a number of options for storing energy all with positives and negatives. So, we will need a storage system with minimum 2 days of backup energy.

The options are as follows:

Battery Storage

Store the energy in several batteries. This is often used in solar farms as well and are suitable for trickle charging and have a high output efficiency. This option is cheap as well as having a low maintenance cost.

Compressed Air Storage

This solution requires the wind turbine to compress air to be stored in a large tank. When the wind turbine is non operational the compressed air can be expanded in order to power a compressed air motor or mixed with fuel to create an air fuel mixture which is combusted in an internal combustion turbine to produce mechanical energy. Issues with this solution is it quite complicated as you have to introduce a way to compress the air and also introduce an internal combustion turbine or compressed air motor which will bring costs up. There also arises the problem of finding space for the storage tank.

Hydrogen Fuel Cells

Another option is hydrogen fuel cells where a hydrogen generator will electrolyse water using power from the wind turbine. The hydrogen produced can then be harnessed for energy by use of a fuel cell power system when needed. This solution poses the problem of having to be located near a water supply as well as again bringing costs up with the inclusion of a hydrogen generator, water pump etc.

(Arnold, 2014)

Looking at these options, battery storage is the most appropriate option for the circumstance due to its simple nature and relatively low cost.

What is needed for battery storage?

First the type of battery must be chosen, there are 3 different battery systems that can be used. With each being subdivided into different types of battery.

The first system is a DC battery system. This will store energy DC (Direct Current) and will require an inverter in order to convert it from DC to AC for the town as well as requiring another inverter (AC to DC) as the wind turbines chosen will produce AC.

The second option is AC battery system. Which will store AC (Alternating Current) and will probably be the best option as no inverters will be required allowing for less energy loss, lower cost and less complexity.

The final system is a hybrid battery system. Which has the best of both world however for this situation we have no desire to withdraw or store DC so there is no need to chose this over an AC system.

(calderelectricalservices, n.d.)

Because the AC signal coming from the wind turbine will need to be changed to DC then back to AC (for a smooth signal) I have chosen for the battery system to be DC and intercept the signal before it is changed back to AC. It will then then be stepped up and sent through an inverter for the desired 230V AC of mains.

Charge Controller

Another thing that needs to be considered is having a charge controller which is needed for the batteries not be over charged and get damaged. It does this by measuring the voltage of the batteries and when they are full send the excess energy to a load dump. In this case the chosen wind turbine is already fitted with a PWM dump load system so there is no need for an additional controller.

(midsummerenergy, n.d.)

Battery Type

Furthermore the battery type needs to be chosen as there are several options.

These options include:

Lead-Acid – these batteries has a lower energy density however are cheaper and have good reliability

Lithium-Ion – this type of battery have very good energy density however this comes at a higher cost and due to thermal runaway these batteries have a chance of catching fire if not connected properly.

Nickel-Cadmium – these batteries are often used in industrial settings as they are very durable and stand up to cold temperatures very well. they also have low maintenance requirements. However cadmium is a highly toxic element that, if not disposed of properly, can have a significant negative impact on our environment.

Flow – flow batteries utilise electrolysed liquid to form a chemical reaction that produces electricity. Due to this they have low energy density and large storage space required for the liquid which makes them more costly.

(Crail, 2023)

For the storage system Nickel-Cadmium batteries will be used as they are very durable in cold weather, which is often prevalent in North Wales and have a low maintenance requirement yet high lifespan.

Chosen battery

<

Chosen Inverter

Victron 48V 5000VA Inverter:

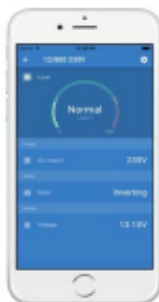
Inverters Smart

1600 VA – 5000 VA

www.victronenergy.com



**Inverter Smart
12/3000**



Bluetooth built-in: fully configurable with a tablet or smartphone

- Low battery voltage alarm
- Low battery voltage cut-off and restart levels
- Dynamic cut-off: load dependent cut-off level
- Output voltage: 210 – 245 V
- Frequency: 50 Hz or 60 Hz
- ECO mode on/off and ECO mode sense level
- Alarm relay

Monitoring:

- In- and output voltage, load and alarms

VE.Direct communication port

The VE.Direct port can be connected to a computer (VE.Direct to USB interface cable needed) to configure and monitor the same parameters.

Proven reliability

The full bridge plus toroidal transformer topology has proven its reliability over many years.

The inverters are short circuit proof and protected against overheating, whether due to overload or high ambient temperature.

High start-up power

Needed to start loads such as power converters for LED lamps, halogen lamps or electric tools.

ECO mode

When in ECO mode, the inverter will switch to standby when the load decreases below a preset value. Once in standby the inverter will switch on for a short period every 2,5 seconds (adjustable). If the load exceeds the preset level, the inverter will remain on.

Remote on/off

A remote on/off switch or relay contact can be connected to a two pole connector.

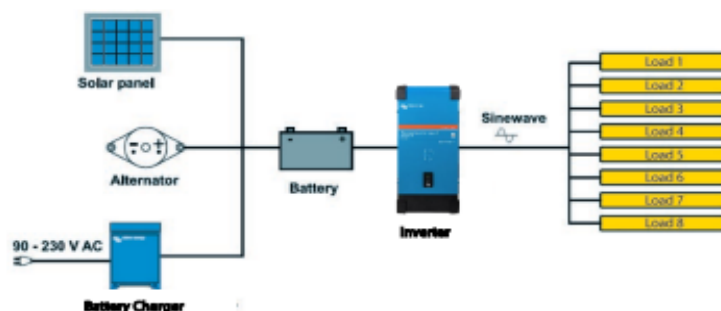
Alternatively, the H terminal (left) of the two pole connector can be switched to battery plus, or the L terminal (right) of the two pole connector can be switched to battery minus (or the chassis of a vehicle, for example).

LED diagnosis

Please see manual for a description.

To transfer the load to another AC source: the automatic transfer switch

For our low power inverters we recommend our Filax Automatic Transfer Switch. The Filax features a very short switchover time (less than 20 milliseconds) so that computers and other electronic equipment will continue to operate without disruption. Alternatively use a MultiPlus with built-in transfer switch.



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www.victronenergy.com



Inverter Smart	12/1600 24/1600 48/1600	12/2000 24/2000 48/2000	12/3000 24/3000 48/3000	24/5000 48/5000
Parallel and 3-phase operation	No			
INVERTER				
Input voltage range	9.3 – 17 V 18.6 – 34 V 37.2 – 68 V			
Output	Output voltage: 230 VAC ±2 % 50 Hz or 60 Hz ± 0.1 % (1)			
Cont. output power at 25 °C (1)	1600 VA	2000 VA	3000 VA	5000 VA
Cont. output power at 25 °C	1300 W	1600 W	2400 W	4000 W
Cont. output power at 40 °C	1200 W	1450 W	2200 W	3700 W
Cont. output power at 65 °C	800 W	1000 W	1700 W	2800 W
Peak power	3000 W	4000 W	6000 W	10000 W
Dynamic (load dependent) DC low shut down (fully configurable)	Dynamic cut-off, see https://www.victronenergy.com/live/vw-direct-phoenix-inverters-dynamic-cut-off			
Max. efficiency 12/ 24 /48 V	92 / 94 / 94 %	92 / 94 / 94 %	93 / 94 / 95 %	95 / 96 %
Zero load power 12 / 24 / 48 V	8 / 9 / 11 W	8 / 9 / 11 W	12 / 13 / 15 W	18 / 20 W
Zero load power in ECO mode	0.6 / 1.3 / 2.1 W	0.6 / 1.3 / 2.1 W	1.5 / 1.9 / 2.8 W	2.2 / 3.2 W
GENERAL				
Programmable relay (2)	Yes			
Stop & start power ECO-mode	adjustable			
Protection (3)	a - g			
Bluetooth wireless communication	For remote monitoring and system integration			
VEDirect communication port	For remote monitoring and system integration			
Remote on-off	Yes			
Common Characteristics	Operating temperature range: -40 to +65 °C (fan assisted cooling) Humidity (non-condensing): max 95 %			
ENCLOSURE				
Common Characteristics	Material & Colour: steel (blue RAL 5012; and black RAL 9017) Protection category: IP21			
Battery-connection	M8 bolts	M8 bolts	12 V/24 V: 2+2 M8 bolts 48 V: M8 bolts	24 V: 2+2 M8 bolts 48 V: M8 bolts
230 VAC-connection	Screw terminals			
Weight	12 kg	13 kg	19 kg	29 kg / 28 kg
Dimensions (h/w/d)	485 x 219 x 125 mm	485 x 219 x 125 mm	533 x 285 x 150 mm (12 V) 485 x 285 x 150 mm (24 V/48 V)	595 x 295 x 160 mm (24 V) 555 x 295 x 160 mm (48 V)
STANDARDS				
Safety	EN 60335-1			
Emission Immunity	EN 55014-1 / EN 55014-2/ EN-IEC 61000-6-1 / EN-IEC 61000-6-2 / EN-IEC 61000-6-3			
Automotive Directive	ECER10-5			
1) Non-linear load, crest factor 3:1 2) Programmable relay that can a.o. be set for general alarm, DC under voltage or genset start/stop function. AC rating: 230 V / 4 A DC rating: 4 A / 35 VDC, 1 A / 60 VDC	3) Protection key: a) output short circuit b) overload c) battery voltage too high d) battery voltage too low e) temperature too high f) 230 VAC on inverter output g) input voltage ripple too high			



Inverter Control

This panel is intended for remote on/off control of all Inverters Smart units.



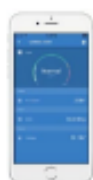
Color Control GX and other GX devices

Provides monitoring and control. Locally, and remotely on the VRM Portal.



VEDirect to USB interface

Connects to a USB port.



Bluetooth wireless communication

Connects to a smart phone (both iOS and Android).



BMV-712 Smart Battery Monitor

The BMV Battery Monitor features an advanced microprocessor control system combined with high resolution measuring systems for battery voltage and charge/discharge current. Besides this, the software includes complex calculation algorithms, like Peukert's formula, to exactly determine the state of charge of the battery. The BMV selectively displays battery voltage, current, consumed Ah or time to go. The monitor also stores a host of data regarding performance and use of the battery.

(victronenergy, n.d.)

The size of the inverter should be twice the size of the load (mercurydirect, n.d.)

power demand per day = 82.6kW

$$82.6kW \times 2 = 165.2$$

Each inverter has a peak power of 10kW

$$\frac{165.2kW}{10kW} = 16.52 \text{ or } 17 \text{ inverters}$$

£1,667.75 per inverter (climbingvan, n.d.)

$$\text{Total cost} = £1,667.75 \times 17 = £28,351.75$$

Battery calculations

For the system the inverter requires 48V so some of the batteries will need to be connected in series and others in parallel to get the desired voltage and Amperage.

$$\frac{48V}{1.2V} = 40 \text{ batteries in series}$$

$$\frac{\text{energy requirement per day} \times \text{backup days}}{\text{system voltage} \times \text{depth of discharge} \times \text{battery efficiency} \times \text{inverter efficiency}} = \text{required capacity}$$

$$\frac{1,980,000Wh \times 2 \text{ days}}{48V \times 0.9 (90\%) \times 0.8 (80\%) \times 0.96 (96\%)} = 119,358 \text{ ah}$$

$$\frac{119,358ah}{40} = 2984ah$$

$$\frac{2984ah}{100ah} = 29.84 \text{ or } 30 \text{ batteries in parrallel}$$

$$\text{total batteries} = 30 \times 40 = 1200 \text{ batteries}$$

$$\text{total cost} = 1200 \times £38.24 = £45,888.00$$

Cost of installation

Item	Price per Unit	Amount of Units	Total
Aeolos Wind turbine	£345,000.00	2	£690,000.00
Nickle-cadmium Battery	£38.24	1200	£45,888.00
Victron 48V 5000VA Inverter	£1667.75	17	£28351.75
Power lines	£150,000.00	1.84km	£276,000.00
			£1,040,239.75

Cost of maintenance

The wind farm will need 2 technicians to maintain the wind turbines

Maintenance technician salary rate	Price per technician
Per hour	£16.24
Per day	£167.00
Per month	£2,160.00
Per year	£30,514.00
Per 10 years	£305,140.00

(indeed, 2023)

Overproduction

The 2 wind turbines together will produce more energy than is required for the town. This means the that the energy left over can be sold back to the grid though the SEG (Smart Export Guarantee) scheme.

Using the rate provided from Octopus Energy of 15p/kWh we can calculate the total sale value of the excess energy.

434,000kWh annually per turbine

$$434,000kWh \times 2 = 868,000kWh$$

$$868,000kWh - 761,100kWh(\text{yearly demand}) = 106,900kWh \text{ of extra energy}$$

$$106,900kWh \times 15p = 1,603,500p \text{ or } £16,035.00$$

(vision2030, 2023)

maintenance cost 2% of original installation price (windmeasurementinternational, n.d.)

$$£1,040,239.75 \times 0.02 = £20,804.80$$

Expense	Price per year	Price per 10 years
Maintenance technician	£30,514.00	£305,140.00
Maintenance technician	£30,514.00	£305,140.00
Maintenance hardware	£20,804.80	£208,048.00
SEG scheme	-£16,035.00	-£160,350.00
	£65,797.80	£657,978.00

Payback period

Annual cost of energy from natural gasses = £206,692.20

$$£206,692.20 - £65,797.80 = £140,894.40 \text{ saved annually}$$

$$\frac{£1,040,239.75}{£140,894.40} = 7.4 \text{ or } 8 \text{ years}$$

Environmental impact

There are many benefits for utilizing wind power not just for the town but also for the environment. Wind energy is by far one of the best power sources for the environment but how does it compare to other common sources. Compared to energy from natural gasses wind energy does not require fossil fuels, reducing pollution. Nor does it require water in order for cooling or to rotate a turbine like with hydropower.

However, there are still some drawbacks that come with wind power. One of these drawbacks being the wind itself, wind is a temperamental source and there is not always a guarantee that it will be windy that day and whilst you can heighten the chances by building the turbine in an often-windy location it is still up to mother nature.

Another issue that arises with wind turbines is its size, often being large structures requiring far more land space when compared to fossil fuels, this can have some negative effects on the surrounding environment. Wind turbines have been caught catching fire as well as leaking lubricant which can lead to devastating effects on the nearby wildlife (eia, 2022). They're tall nature and rotating blades have often lead to the death of flying animals such as birds and bats (ucsusa.org, 2013). However these effects are not exclusive to wind energy with options like solar farms taking up large amounts of land as well.

An issue solar farms don't face that wind farms do is noise pollution. Wind turbines have been known to make some noise that comes with the spinning blades which can become irritable to locals (maine, n.d.), however in the case of Llanrwst the turbines are set up far from local housing and so this should not be an issue.

References

alibaba, n.d. *Nickel-Cadmium-Rechargeable-Battery 1.2 volt KPL GN 100ah NiCd Battery*.
[Online]
Available at: https://www.alibaba.com/product-detail/Nickel-Cadmium-Rechargeable-Battery-1-2_1600099755870.html
[Accessed 16 November 2023].

Arnold, B., 2014. *Collecting and Storing Energy from Wind Turbines*. [Online]
Available at: <https://www.azocleantech.com/article.aspx?ArticleID=488>
[Accessed 9 November 2023].

Brechfa Forest Connection, 2014. *Lifetime Costs Report*, Brechfa Forest: National Grid.

calcmaps, 2023. *calcmaps*. [Online]
Available at: <https://www.calcmaps.com/map-distance/>
[Accessed 6 November 2023].

calderelectricalservices, n.d. *Wind turbine battery storage system*. [Online]
Available at: <https://calderelectricalservices.co.uk/wind-turbine-battery-storage-system/#:~:text=When%20it%20comes%20to%20the,batteries%20are%20made%20with%20lead>
[Accessed 11 November 2023].

checkatrade, 2023. *Wind turbine cost guide*. [Online]
Available at: <https://www.checkatrade.com/blog/cost-guides/wind-turbine-cost/#:~:text=Buying%20and%20installing%20a%20commercial,less%20you%20pay%20per%20kW>
[Accessed 9 November 2023].

climate-data, n.d. *LLANRWST CLIMATE*. [Online]
Available at: <https://en.climate-data.org/europe/united-kingdom/wales/llanrwst-9555/>
[Accessed 2 November 2023].

climbingvan, n.d. *Victron 48V 5000VA Inverter – Pure Sine Wave Phoenix Inverter Smart*. [Online]
Available at: https://climbingvan.co.uk/product/victron-48v-5000w-inverter-pure-sine-wave-phoenix-inverter-smart/?gclid=Cj0KCQiA4NWrBhD-ARIsAFCKwWujT-M4ae9GFjfcWn-D0Djzaz6fBV05psmsd9PAQAJnIfOIFO3HP1YaAnfqEALw_wcB
[Accessed 23 November 2023].

Crail, C., 2023. *Everything You Need To Know About Solar Batteries*. [Online]
Available at: <https://www.forbes.com/home-improvement/solar/what-is-a-solar-battery/#:~:text=The%20four%20main%20types%20of,nickel%20cadmium%20and%20flow%20batteries>
[Accessed 16 November 2023].

David, L., 2023. *How Much Power Does a Solar Panel Produce? (2024)*. [Online]
Available at: [https://www.marketwatch.com/guides/solar/power-solar-panels-produce/#:~:text=The%20average%20solar%20panel%20has,to%20eight%20kilowatts%20\(kW\)](https://www.marketwatch.com/guides/solar/power-solar-panels-produce/#:~:text=The%20average%20solar%20panel%20has,to%20eight%20kilowatts%20(kW))
[Accessed 2 November 2023].

earthmill, 2023. *Endurance E3120 50kW*. [Online]
Available at: <https://www.earthmill.co.uk/wind-turbines-for-sale/endurance-e-series/e3120-50kw-wind-turbine/>
[Accessed 9 November 2023].

eia, 2022. *Wind explained*. [Online]
Available at: <https://www.eia.gov/energyexplained/wind/wind-energy-and-the-environment.php#:~:text=Wind%20is%20a%20renewable%20energy,not%20require%20wat>

er%20for%20cooling
[Accessed 4 December 2023].

Gallizzi, B., 2023. *Comparing energy prices by region*. [Online]
Available at: <https://www.uswitch.com/gas-electricity/guides/regional-energy-prices/>
[Accessed 29 October 2023].

globalwindatlas, 2023. *globalwindatlas*. [Online]
Available at: <https://globalwindatlas.info/en>
[Accessed 6 November 2023].

globalwindatlas, n.d. [Online].

Google Maps, 2023. *Google Maps*. [Online]
Available at: <https://www.google.com/maps/place/Llanrwst/@53.1447258,-3.8064852,12z/data=!4m6!3m5!1s0x48651428c40271fb:0x73d957689a178f07!8m2!3d53.137033!4d-3.795732!16zL20vMDJ4Y3ox?entry=ttu>
[Accessed 29 October 2023].

Grogg, K., 2005. *Harvesting the Wind: The Physics of Wind Turbines. Physics and Astronomy Comps Papers*.

hitwind, 2014. *Endurance E3120*. [Online]
Available at: <https://www.hitwind.com/product/endurance-e3120-50kw-wind-turbine-for-sale/>
[Accessed 9 November 2023].

indeed, 2023. *Wind turbine technician salary in United Kingdom*. [Online]
Available at: <https://uk.indeed.com/career/wind-turbine-technician/salaries>
[Accessed 25 November 2023].

Krisciunas, K., 2023. How solar panels work, in theory and in practice. *AIP Advances*, 13(8).

maine, n.d. *FACTS ABOUT WIND ENERGY AND NOISE*. [Online]
Available at:
https://www.maine.gov/dacf/lupc/projects/windpower/redington/redingtonrevised/Documents/Section05_Sound/AWEA_Turbine_Noise_FAQ.pdf
[Accessed 4 December 2023].

mercurydirect, n.d. *Finding the Best Inverter Size for Your Home's Energy Requirements*. [Online]
Available at: <https://mercurydirect.com.ng/finding-the-best-inverter-size-for-your-homes-energy-requirements/#:~:text=With%20the%20total%20load%20calculated,run%20the%20risk%20of%20overloading>
[Accessed 23 November 2023].

midsummerenergy, n.d. *PWM or MPPT? Choosing the right regulator for off*. [Online]
Available at: <https://midsummerenergy.co.uk/choosing-correct-regulator-off-grid-systems/#:~:text=The%20most%20important%20function%20of,when%20the%20batteries%20are%20full>
[Accessed 16 November 2023].

renolit, n.d. *Wind turbines maintenance and reparation*. [Online]
Available at: <https://www.renolit.com/en/industries/wind-energy/renolit-cp/wind-turbines-maintenance-and-reparation/wind-turbines-maintenance-and-reparation#:~:text=On%20average%2C%20this%20requires%20about,up%20to%20a%20few%20days>
[Accessed 20 November 2023].

renugen, 2023. *Canadian Solar CS3W-400P-MC 400W Solar Panel*. [Online]
Available at: <https://www.renugen.co.uk/canadian-solar-cs3w-400p-mc-400w-solar-panel/>
[Accessed 4 November 2023].

Rooij, D. D., n.d. *Nickel Cadmium Batteries*. [Online]
Available at: <https://sinovoltaics.com/learning-center/storage/nickel-cadmium-batteries/>
[Accessed 20 November 2023].

Spiers, D., 2012. *Batteries in PV Systems*. [Online]
Available at: <https://www.sciencedirect.com/topics/earth-and-planetary-sciences/nickel-cadmium-battery#:~:text=It%20is%20therefore%20usual%20to,use%20at%20low%20discharge%20rates>
[Accessed 20 November 2023].

ucsusa.org, 2013. *Environmental Impacts of Wind Power*. [Online]
Available at: <https://www.ucsusa.org/resources/environmental-impacts-wind-power>
[Accessed 21 December 2023].

victronenergy, n.d. *Inverters Smart*. [Online]
Available at: <https://www.victronenergy.com/upload/documents/Datasheet-Inverter-Smart-1600VA-5000VA-EN.pdf>
[Accessed 23 November 2023].

vision2030, 2023. *Smart Export Guarantee: How to choose the right tariff*. [Online]
Available at: https://vision2030.co.uk/2023/03/21/smart-export-guarantee-seg-how-to-choose-the-right-tariff/?gclid=Cj0KCQiA4NWrBhD-ARIsAFCKwWsNgb-V7oDzIQEzt20s_siAXWDhLoOakVEWt6-JeUxuUktgc2tHPMaAsU3EALw_wcB
[Accessed 26 November 2023].

windmeasurementinternational, n.d. *Operational and Maintenance Costs for Wind Turbines*. [Online]
Available at: <http://www.windmeasurementinternational.com/wind-turbines/om-turbines.php>
[Accessed 26 November 2023].

wind-turbine-models, 2023. *Bonus B44/600*. [Online]
Available at: <https://en.wind-turbine-models.com/turbines/698-bonus-b44-600>
[Accessed 9 November 2023].

windturbinestar, n.d. *Aeolos Wind Turbine 100kW Specification*. [Online]
Available at: <https://www.windturbinestar.com/100kwh-aeolos-wind-turbine.html>
[Accessed 9 November 2023].

windustry, n.d. *How much do wind turbines cost?*. [Online]
Available at: https://www.windustry.org/how_much_do_wind_turbines_cost
[Accessed 9 November 2023].

