The study of integration of vertical wind power system into a UK business building.

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1.) Introduction

Rayleigh Technical Design Ltd (RTD, hereafter referred to as 'the company') is situated in Southend-On-Sea, in the South-East of England. The client's priorities for this assessment were to identify cost effective ways in which to reduce their use of grid electricity and cost, as well as improving their energy and environmental performance (eco-friendliness).

The company wishes to reduce the greenhouse gas emissions of its industrial building by 50%. Integrating a wind power system into their property is the most suitable solution, due to the company's location near the coast.

Wind energy technologies fall into two main categories – macro wind turbines, for large-scale energy generation (such as wind farms) and micro wind turbines, generally reserved for local electricity production. Micro wind turbines are well suited to installations at the building scale and are known as 'Building Integrated Wind Turbines', of which one type are known as 'Vertical Axis Wind Turbines' (VAWTs). The main components of a wind turbine are: blades, rotor, gearbox and generator. Small wind turbines, originally designed with a horizontal rotor axis are referred to as 'Horizontal Axis Wind Turbines' (HAWTs). In order to reduce the need for a high tower and to permit installation on rooftops, where HAWTs might be precluded, VAWTs have become increasingly popular for integrated building applications.

2.) System description

We will install vertical wind turbines on the company's roof, connected to their energy storage. The storage will store the energy from wind turbines at night time or during weekends and discharge in peak hours. The company will not notice any change for their energy consumption, but the electricity costs will decrease by using the energy that have been stored in the energy storage, instead of using electricity from the microgrid.

3.) Company energy consumption

The company's operating hours are from 7.00am to 5pm, Monday to Friday. They specialise in the production of plastics using a space area of 371.6 m^2. Due to their machinery, the energy consumption is substantial, with a peak usage of 100 kW. Swalec is the electricity supplier of the company with an annual electricity cost of £26,590.54 with 225,343.6 kWh of annual energy consumption. The baseline electricity performance in shown in the table below.

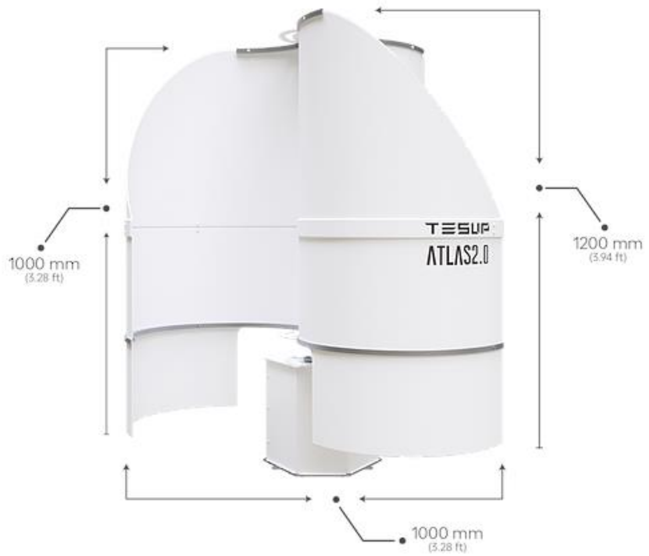
Annual energy use(kWh)	225,343.60
Annual energy cost(VAT+CCL)	26,590.54
Unit cost (p/kWh)	11.8
kWh/m2 floor area per year	606.41
CO2 emission(kg)	52,505.06
CO2 per area(kg/m2)	141.30

4.) wind turbine integrated into the building

4.1) Vertical Wind turbine

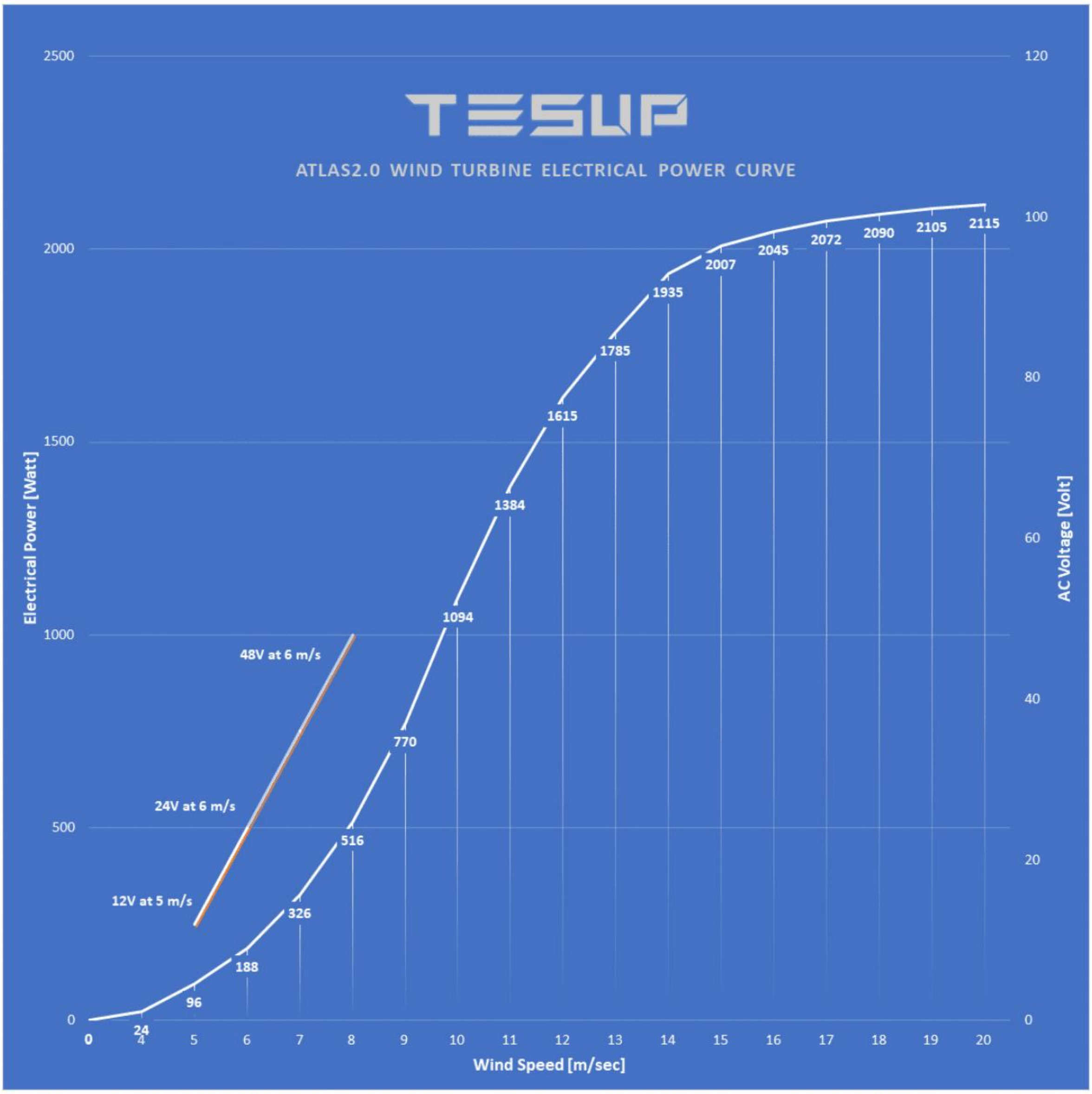
ATLAS2.0 Wind Turbine

The proposed wind turbine for this installation is the ATLAS2.0 Wind Turbine, manufactured by TESUP UK (TESUP ELECTRONICS LTD). This is an affordable, Vertical Axis Wind Turbine, capable of generating up to 2 KW with a footprint of only 1 m^2 [1].



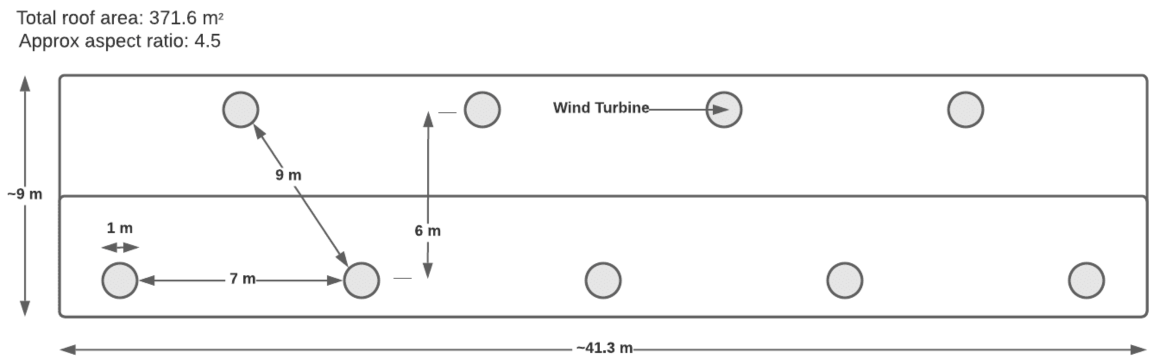
The ATLAS2.0 Wind Turbine, manufactured in the UK by TESUP ELECTRONICS LTD.

Weighing only 24 kg, with an operating wind speed of 4 m/s up to to 50 m/s, this turbine is robust and relatively easy to install. We can install multiple of these turbines on the property's roof to meet the company's needs. However, the device's data sheet, nor its user manual mentions a suggested 'buffer zone' around the device, in order to avoid reduced efficiency due to the turbulent wake of running multiple turbines near each other.



Power curve of the ATLAS2.0 Wind Turbine [1].

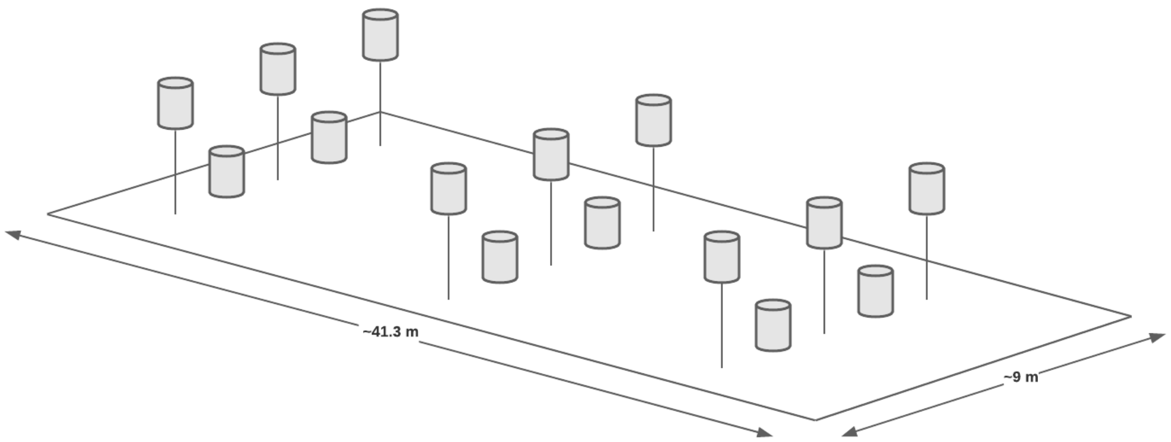
In place of a simulation of the effects of turbulence in a multi-turbine setup, we will make an assumption that at least a 3 m gap between each turbine should be maintained to keep turbulent wake effects minimal - more if possible. From the given area of the property's roof (371.6m2) and (from satellite photographs) its aspect ratio of about 4.5, we will assume the roof dimensions are approximately 9 x 41.3 m. If we only needed to install 9 ATLAS2.0 Wind Turbines on the property's roof, the layout might look something like the diagram below.



Roof diagram showing suggested arrangement of wind turbines.

Note that the arrangement of turbines in the diagram above is staggered to maintain a large 'buffer zone' around each turbine, minimising the adverse effects of turbulent wakes between adjacent turbines on their operational efficiency.

Another way to maximise the 'stacking' of turbines to make use of the property's roof space would be to also stagger the turbines in 3 dimensions, by installing them at different heights. The diagram below shows an example layout. We can surmise that the maximum feasible number of these turbines we might be able to install on the property's roof is probably around 50 - possibly more if at 3 height levels of 'stacking' were used, before the turbines' efficiency falls off due to wake effects from adjacent turbines.



Roof diagram showing suggested arrangement of wind turbines.

However, from our calculations, the company would need 96 of these turbines to meet its target of 50% of its energy demands from an off-grid, renewable source. And, although the ATLAS2.0 turbines are very affordable, there is probably not enough roof space to accommodate this. Such an installation may be possible if both space around the company's car park and some of the spare land pictured at the back of the company's property could be used to house more turbines.

4.2) Power generation from mean wind speed

The table below shows the annual power generation from 96 Altas turbines based on the power output from the turbine's power curve. The calculations are in the excel spreadsheet.

Wind mean speed(m/s)	No. hours/yr	Power output(kWh/yr) (1 turbine)	Power output (kWh/yr) (96 turbines)
0	94	0	0
1	634	0	0
2	1487	0	0
3	1410	0	0
4	1393	33.432	3209.472
5	1208	115.968	11132.928
6	983	184.804	17741.184
7	654	213.204	20467.584
8	442	228.072	21894.912
9	232	178.64	17149.44
10	93	101.742	9767.232
11	40	55.36	5314.56
12	25	40.375	3876
13	10	17.85	1713.6
14	3	5.805	557.28
15	1	2.007	192.672
16	1	2.045	196.32
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	0	0	0

22	0	0	0
23	0	0	0
24	0	0	0
25	0	0	0
16857	50	0	0
Total	8760	1179.304	113213.184

4.2.1) Capacity factor of the system that can be incorporated into the building

Capacity factor = (Actual power output(kWh/yr))/(The maximum possible output(kWh/yr))

Capacity factor = 0.064

4.2.2) The annual energy production and energy saving

The annual energy production from wind turbines is 113,213.184 kWh/yr.

Company's annual energy consumption is 225,343.6kWh/yr

The company saves 112,130.416 kWh/yr from installing wind turbine system.

4.2.3) The annual energy cost, saving and CO_2 emission

The price of electricity is 11.8p/kWh (£0.118/kWh)

The annual electricity price from wind turbines equals to £13,359.156/yr

The company saves £13,231.384/yr in total.

And the CO_2 reduction is 26,378.67 kgCO_2/yr

4.2.4) Payback period

In order to decide whether this installation would be cost-effective, we need to estimate the payback period. That is, how long until the installation pays for itself in terms of electricity costs saved. A breakdown of this calculation follows:

Existing electricity costs

At electricity price of 11.8 p/kWh, 50% of the company's electricity demand (113.2MWh) annual electricity bill will equate to £13,231.38 per year.

Hardware costs

Turbines = 96 x £550 = £52,800

Controllers = 96 x £90 = £8,640

Grid inverter (assume for now that the company is OK to directly use the 3-phase power generated and the engineering cost is part of the 'installation cost' below)

Total hardware cost = £61,440

Installation cost

Assume 20% installation cost = 1.2 x £61,440 = £73,728

Maintenance

First 2 years covered by manufacturer's warranty = £0

We will assume the lifespan of a turbine is optimistically between 15-20 years, but that 1 turbine breaks down each year after the first 2 years, needing repair/replacing at the company's expense = £550

Maintenance labour cost estimate per year = £2000

Total maintenance cost for first 8 years (first 2 year are cost-free to the company) = £15,300

Total installation/maintenance cost (first 8 years) = £89,028

113 MWh of grid electricity would cost the company £105,851.04 over 8 years (even if capped at today's prices). So we can say that the installation should pay for itself within around 7 to 8 years. Although some real-world costs may have been omitted, we also haven't taken into account any possible discounts available for bulk-ordering 96 turbines upfront, nor any discounts for a feed-in tariff from the electricity supplier, were the company later to invest in inverters in order to supply any excess power back to the grid.

Additionally, since the turbines are very affordable (and work is distributed among so many turbines), we can say that 1 turbine breaking down completely will have an insignificant effect on power generation, even enabling us to isolate the defective turbine and repair/replace it without an interruption in service. Therefore, the life span of the installation is theoretically unlimited, if turbines are simply replaced cheaply, as and when they break. This is unlikely ever to cost a significant fraction of the ever-increasing grid-electricity costs.

5.) Conclusion

The system decreases CO_2 emissions and electricity cost by 52% with an 8 year payback period.

This vertical wind turbine system is feasible to achieve RTD's goal to reduce their greenhouse gas emissions by 50% by using free space around the company's property. The system is also eco-friendly, low noise, low emission and the appearance of the building is acceptable.

Advantages of Building Integrated Wind Turbine technologies:

- Improved reliability and efficiency at low wind speeds, with lower capital cost.
- Advances in materials science and design of wind turbines now makes them more lightweight and efficient, able to generate electricity from very low wind speeds, of typically just a few m/s
- Anecdotally, modern designs for micro wind turbines are more aesthetically pleasing than their traditional counterparts and usually benefit from lower noise operation
- Recent developments in hybridising solar and wind power, known as solar-wind hybrid systems, means these two intermittent energy sources can be coupled to reduce power unreliability, effectively 'smoothing out' peaks and troughs in power generation, or the fact that the sun does not shine at night.
- Certain new designs of micro wind turbines integrate the inverter into the turbine's nacelle (which houses the gearbox) making for simpler installation.

6.) Recommendation

Solar-Wind Hybrid option

In addition to the proposed wind turbine system, the company may wish to invest in solar panels, to make more use of its roof space and space around its car park. As mentioned, coupling solar and wind power generation systems will help to 'smooth out' the intermittent nature of wind power. However, we do not go into detail about the possible design and costs of this in this report. But it is an option in which the company could invest at a later stage.

7.) References

[1] ATLAS2.0 Wind Turbine manufactured by TESUP UK https://www.tesup.co.uk/product-page/atlas20-48v-2kw-wind-turbine-generator-for-homes-battery-energy-amazon-uk