Ynni Lleol | Local Energy

Llywodraeth Cymru
Welsh Government

Briefing Paper: Refurbished & Remanufactured Wind Turbines

Disclaimer: this information is accurate as of August 2016. The content in this document is intended as guidance only.

Background

The aim of this guidance note is to aid communities and businesses looking to procure refurbished / remanufactured wind turbines. It covers factors that should be taken into account when considering refurbished / remanufactured wind turbines as a procurement choice.

This document brings together expertise of community groups who have purchased refurbished / remanufactured wind turbines, refurbished / remanufactured wind turbine suppliers in the UK, and Ricardo Energy & Environment's expertise.

What is a refurbised / remanufactured windturbine?

A **refurbished** wind turbine is a used wind turbine where failed or worn components are refurbished or replaced to the point that the wind turbine is able to operate. Refurbished wind turbines are often sold at a fraction of the cost of new turbines yet may still be capable of achieving design performance for many years. The expectation is that components which have not been refurbished or replaced will fail at some point during operation. As such, O&M contracts, downtime cover / response time is key to financial success.

A **remanufactured** wind turbine is a used wind turbine which has been restored to original manufacturer specifications which is achieved by replacing all key components of the turbine system with quality parts via an approved company. Remanufactured wind turbines are often more expensive than equivalent (i.e. same make/model) refurbished wind turbines but are often more reliable (i.e. low potential for failure).

Used wind turbines (prior to refurbishment or remanufacturing) are widely available for purchase across Europe and vary by manufacturer (e.g. Vestas, Nordex, Enercon, etc.), model and country of previous operation. Used wind turbines are sold, either directly to operators or to refurbishment/remanufacturing companies, for a variety of reasons including financial, expiration of land lease or planning permission, failure wind turbine components, etc.

Refurbishment / remanufacturing companies look to procure used turbines which they can refurbish/remanufacture and sell. The intensity of restoration work carried out will depend on the history of the wind turbine - varying from a significant overhaul to basic repairs.

Why procure a refurbished / remanufactured wind turbine?

- Procurement of a refurbished / remanufactured turbine will likely provide higher return on investment – refurbished / remanufactured wind turbines are often sold at a fraction of the cost of new wind turbines
- Refurbished / remanufactured wind turbines can offer the same performance as new turbines
- Warranty and insurance packages are available for some refurbished / remanufactured turbines
- Financing options are available for refurbished / remanufactured turbines – though options are limited and not as straightforward as for new turbines
- Use of refurbished / remanufactured turbines supports the circular economy.

Who refurbishes / remanufactres wind turbines?

Used wind turbines are purchased by a variety of companies including traders, operators, developers, and engineering companies. Those who purchase used wind turbines may wish to sell the used wind turbine, use it, refurbish it, or remanufacture it. Trading websites give an indication of who buys and sells used wind turbines.

There are numerous companies who specialise in the refurbishment and/or remanufacturing of used wind turbines across the UK (see list in Appendix). Refurbishment / remanufacturing companies will often specialise in a particular turbine make (e.g. Vestas).

There are more than 100 refurbished wind turbines installed across the UK on farms and estates and by community groups.

Example: CRAIL Wind Project – Achieving project profitability using remanufactured turbines[1]

- Community group installed an 18 year old remanufactured Vestas V39 wind turbine in East Neuk of Fife
- The refurbishment process included complete turbine disassembly, inspection of all parts and refurbishment as per manufacturers' specifications and tolerances (carried out by ex-Vestas engineers)
- As part of the refurbishment process, the wind turbine height was reduced to 35m (from 45m) to comply with planning permission. The turbine was de-rated to 400kW (from 500kW) to meet grid connection limitations
- In addition to refurbishing the wind turbine the supplier delivered, constructed and commissioned the turbine
- A5 year warranty with 5 year operations and maintenance agreement as was provided by the supplier

[1] http://www.localenergyscotland.org/media/88705/Achieving-Project-Profitability.pdf

What happens during refurbishment?

Turbines can be restored to operational capacity but without changing all components other than those that are obviously worn. There is no industry wide standard for what work must be done on a used turbine to qualify as refurbishment. As such, it is especially important to understand what checks, repairs and replacements have been carried out on the refurbished turbine.

Companies who refurbish wind turbines should be, at the very least, paying special attention to the condition of critical components that could result in catastrophic failure e.g. tower, tower bed frame and blades. Various testing equipment is available to check for component flaws or fatigue (e.g. ultrasonic NDC, tap test, infrared thermography, etc.). Some key components are listed in Table 1 below.

All other components, if failure occurs, will result in downtime but are repairable or replaceable. Nevertheless, downtime may result in loss of revenue and additional costs depending on the warranty and insurance package. Note that even with extensive warranty and insurance coverage, downtime due to failure may have implications on cash flow. Figure 1 illustrates main components of one type of wind turbine.

What happens during remanufacturing?

Turbines can also be remanufactured - fully restore the turbine to original manufacturer specification - which can increase cost of the turbine to around 80-90% of the original purchase price. This is typically more expensive option than the refurbishment. The advantage over refurbished turbines being that the wind turbine in fitted with nearly all new components reducing the likelihood of component failure and associated downtime.

Figure 1 Main components of wind turbine (source: NREL)

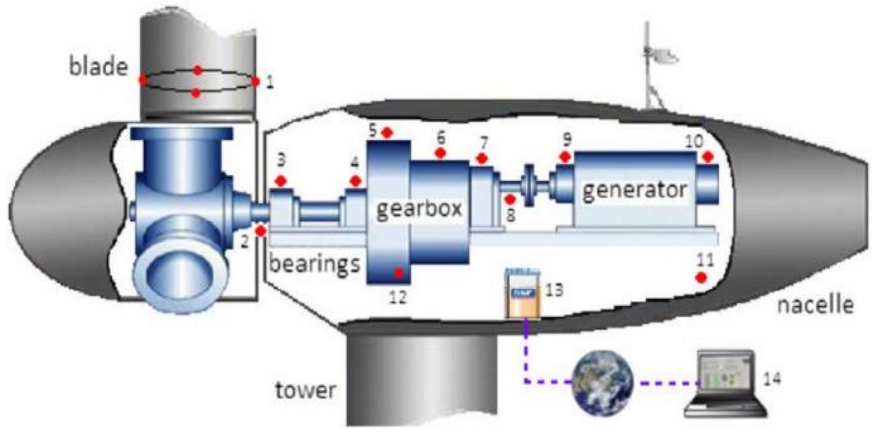


Table 1 List of key components[2]

Key Components	Considerations
Tower	Towers are often over designed - high safety factor
Tower Bed Frame	This is a large cost item and often the last item to wear out
Blades	Blade cracking and the pitting of blade leading edge
Gearbox - Bearings	Rate of failure depends on type of shaft i.e. high-speed shaft (HSS) systems are the often the most problematic
Gear box - Gears	Rate of failure depends on type of gear system i.e. helical gears are often the most problematic
Generators	Failure modes include magnetic wedge loss, contamination and electric arc damage

Key factors to consider

Price and return on investment

With the ever decreasing feed in tariff, it is becoming increasingly important to manage project costs. Refurbished / remanufactured turbines have the potential to deliver this as they are often significantly cheaper than new wind turbines (of similar make and model) ranging between 50-90% of the new wind turbine price.

Not all key components of the refurbished turbine system will be refurbished or replaced and therefore fault occurrence for a refurbished wind turbine will likely be higher than for a remanufactured or new wind turbine. This will have implications on financial performance, maintenance requirements and should be understood and modelled.

The price of refurbished / remanufactured, second hand turbines will vary based on a number of factors:

- Wind turbine design i.e. make and model
- Original date of manufacture – duration of previous operation and age of components
- Previous operating conditions i.e. environment
- Maintenance history
- Supply and demand – the market for second hand wind turbines in volatile and prices are often negotiable. Some refurbishment companies may be more willing than others to negotiate on price

[2] http://www.nrel.gov/docs/fy15osti/64027.pdf http://www.nrel.gov/docs/fy15osti/63868.pdf

An advantage of procuring refurbished / remanufactured wind turbines is the flexibility of price (often negotiable). This allows purchasers to determine their maximum turbine price that would result in project financial viability, and negotiate accordingly.

Financial modelling for a refurbished wind turbine has been carried out using indicative costs to demonstrate the financial attractiveness of some refurbished wind turbines (available on the market) despite the ever decreasing FiT rates (see Table 2). A similar scheme with a new turbine (costing approximately £1.5 million) would have an IRR considerably lower at 7.86% with total dividends of less than the cost of the turbine (£1,473,317).

It is worth noting that wind turbines with capacities that align with higher UK FiT tariff bands may command a premium. For example, updates in the FiT banding may add a premium to 1.5MW turbines, although it is too early to say.

Table 2 Indicative cost / performance figures for refurbished wind turbine

Refurbished Nordtank 1.5MW wind turbine	
Costs	
Project Development costs	£100,000**
Refurbished turbine	£300,000*
Other construction costs	£687,000**
Operating costs	£20,000** per year
Key parameters	
Predicted FiT tariff	2.80 p/kWh
Export tariff	4.91 p/kWh
Duration of operation	20 years
Capacity factor	25%
Plant availability	95%
Senior loan rate	7%
Financial outputs	
Project IRR %:	18.97%
Total dividends	£3,499,103
Net present value	£1,137,709

Source: *Provided by wind turbine refurbishment company in the UK **Based on Ricardo's analysis of multiple wind turbine project costs in UK.

Performance

Refurbishment companies state that refurbished / remanufactured wind turbines are capable of operating in line with the manufacturer's original power curve. Refurbished / remanufactured wind turbines will have already proven their performance capability during previous use. As such, the manufacturer's performance specifications and wind turbine performance logs should give a strong indication of the refurbished / remanufactured wind turbines potential performance.

Operators of refurbished / remanufactured wind turbines have reported performance against manufacturer power curves of over 98% availability and with outputs higher than P90 predictions[3]. Some will warrant the performance of the turbine.

Operational life

Operational life of a refurbished / remanufactured wind turbine will depend on design, quality of manufacturing, and the turbines operational history. With regards to design, generally speaking, simpler (more mature) technologies e.g. simple Danish concept are statistically more reliable and fail less frequently than less mature technologies such as direct-drive wind turbines.[4] Choosing turbines based on reputation of make and model with proven record of high performance and reliability is important. Lastly, the history of the used wind turbine is of

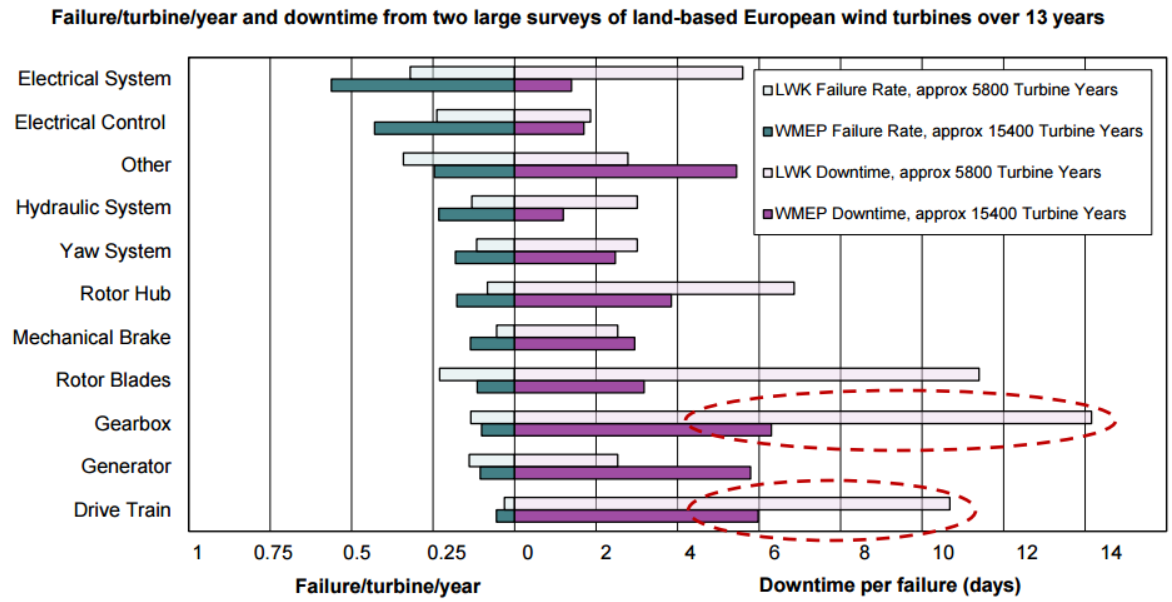
[3] P90 – metric of probable annual generation often requested by financers.
[4] http://www.nrel.gov/docs/fy13osti/59111.pdf

significant importance, particularly specificities like environmental conditions (e.g. turbulent conditions and operation in coastal areas) and details of its operation and maintenance regime.

Turbines that are de-rated, are never operating at full design capacity, so in general components may last longer. There can be an additional cost to de-rate a turbine.

A component which has been refurbished or replaced should be capable of functioning as if it was new. Frequency of wind turbine failure and the associated down time for repair varies by component. Figure 2 gives an indication wind turbine component “failure rate”, the Mean Time Between Failure (MTBF) and the Mean Time To Repair (MTTR). For example, based on the WMEP data set MTBF, or the average failure rate of a wind turbine generator is every 8 years (ie 0.125 failures per turbine per year). MTTR, or the amount of time to repair the turbine is out of operation is just under 6 days.

Figure 2 Rate of failure and associated downtime by wind turbine component (Source: NREL)[5]



Operation and maintenance

There are numerous companies who are qualified to carry out servicing and maintenance of refurbished / remanufactured wind turbines.

Servicing and maintenance requirements tend to be the same for all wind turbines, new, refurbished and remanufactured. It should be kept in mind that fine tuning of refurbished / remanufactured wind turbines after commissioning may take a few months requiring a qualified technician to ensure optimal operation of the machine (e.g. aligning voltage and frequency with the grid, adjustment of sensors, etc.). This can take more time than with a new turbine as the turbine parameters are tweaked to perform optimally when connected to the UK grid. This may have implications on the wind turbines availability for generation and

[5] http://www.nrel.gov/docs/fy13osti/59111.pdf
Note that WMEP (Wissenschaftliches Mess-und Evaluierungsprogramm) and LWK (Landwirtschaftskammer Schleswig-Holstein) are the sources of data used by NREL to create the figure.

capacity factor directly after commissioning and should be kept in mind when carrying out financial forecasting.

Choosing a widely available turbine, will ensure a more reliable supply chain for spare parts.

Warranty

Refurbished wind turbine suppliers may provide warranties on the parts that have been refurbished or replaced. Standard 1-2 year warranties and extended warranties may also be awarded depending on the suppliers experience and confidence with the machine that they have refurbished. As a comparison, new wind turbines warranty periods will depend on the type of wind turbine and the business model of the company offering the warranty and can be anywhere from 2 to 10 years[6]. The level of turbine refurbishment specification and cost will define the warranty being offered.

Note that in some instances manufacture warranties may become void after refurbishment works. On the other hand, some refurbishment / remanufacturer companies work with manufacturers' who are able to provide manufacturer warranties for the refurbished wind turbines based on agreed refurbishment standards. As a result, some refurbishment / remanufacturing companies are able to provide 5 year O&M warranties, directly from the manufacture, which guarantee performance against the original power curve.

Furthermore, the higher specification achieved during remanufacturing will include a better warranty (when compared to a refurbished turbine) and normally involves a recommended refurbishment company providing response time to faults with 48 hours. This is more attractive for investors but costs rise accordingly.

It is important to understand what the warranty covers:

- What happens if the supplier (refurbishment / remanufacturing company) goes out of business?
- Who is responsible for each component? Is it just one company or are there several?
- Does the warranty cover the removal, replacement and shipping of faulty parts?
- Are there any additional costs involved, such as a renewal fee?
- What is the duration of the warranty?
- Will there be a performance warranty against predicted power curve?

Insurance

Typically, insurance provided for refurbished / remanufactured wind turbines is identical to that which would be provided for wind turbines. However, this will likely be considered by insurers on a case by case basis. Insurance range of coverage can extend beyond normal accidental damage to include employer and pubic liability, material damage, mechanical

[6] https://www.renewableenergyhub.co.uk/warranty-insurance-and-maintenance-for-wind-turbines.html

breakdown and loss of revenue. Northern Alliance Insurance (UK) has provided insurance for refurbished / remanufactured wind turbines in the past[7].

Not all insurance companies with experience in insuring new wind turbines are comfortable insuring refurbished / remanufactured wind turbines. However, there are some who will base their decision to insure (and associated fees and rates) on the reputability of the manufacturer, regardless of whether the wind turbine is new, refurbished or remanufactured.

Securing Finance

In general, securing finance for refurbished / remanufactured wind turbines is more difficult than for new turbines. This is partly due to a smaller pool of financers comfortable with this market space.

There are a few key differences between securing finance for a refurbished / remanufactured wind turbine compared to a new wind turbine:

Firstly, refurbished / remanufactured wind turbines are bespoke generating plants with unique histories and prices will vary accordingly. Prices may also be negotiable and subject to market demand. This means that it may not be possible to secure a refurbished / remanufacture wind turbine without making a deposit. Furthermore, sellers often require a statement confirming project finance is in place before they will sell a turbine. This could have implications on the financing process where some financers want to know the exact cost and turbine make/model that financing is sought for.

Secondly, financing of refurbished / remanufactured wind turbines will not be supported by all private and institutional debt providers. However, some financers who are uncomfortable with financing the supply and installation of refurbished / remanufactured wind turbine may consider refinancing, after the wind turbine has proven its successful installation and operation.

Crowd funding is one way to obtain unsecured debt finance to cover supply and installation costs of a refurbished / remanufactured wind turbines. ThinCats, FundingKnights, and CoAssets are some examples of crowd funding platforms providing peer to business lending. Crowd funding may provide more flexibility with repayment terms (i.e. not fees for early payback).

Some examples of other financers who may be willing to finance refurbished / remanufacture wind turbines include EcoSource, RM capital, Social Investment Scotland, Assetz Capital and CO_2Sense.

Due diligence costs may be higher for a refurbished / remanufactured turbine as the commercial and technical checks required may be more comprehensive.

Planning permission

Refurbished / remanufactured wind turbines will need to meet the same Local Authority requirements that apply to new wind turbines. Planning considerations are generally concerned with the development's (i.e. wind turbine(s), electrical room, etc.) physical

[7] http://www.northernalliance.co.uk/wind-turbine-insurance/

presence and corresponding potential impact on the environment, air traffic, surrounding communities (e.g. noise and visual), etc. As such, it is not expected that there would be any additional complications due to the selection of a refurbished / remanufactured wind turbine. Nevertheless, as for any proposed wind turbine development, it is advisable to contact relevant Local Authority to discuss the details of your proposed development.

Impact on FiT eligibility

It is possible to receive FiT accreditation for a refurbished / remanufactured wind turbine. It would be advised to liaise with Ofgem prior to purchasing a refurbished remanufactured wind turbine to ensure that it is an eligible.

To gain full accreditation Ofgem you will need to provide evidence that any part of the installation has not been part of a feed in tariff scheme in the UK. Furthermore, it is advised to state at the beginning of the accreditation process that the turbine is refurbished / remanufactured.

Ofgem will want to know whether the total installation capacity (TIC) and declared net capacity (DNC) of the refurbished wind turbine has been changed in any way as they would with a new turbine. This is important information for ensuring the wind turbine is accredited under the correct tariff band.

Transporting turbine

Transportation of refurbished wind turbine may be included in the cost of wind turbine supply and installation. This should be agreed with the refurbished turbine supplier to verify who is responsible for route access survey, dismantling, delay warranty, etc. Sellers may require contingency amount to cover unforeseen issues with transportation that result in delays and extra costs being incurred. Note that the buyer may choose to arrange all transportation logistics.

What to look for in a second hand turbine

Experience

There are numerous companies who are able to carry out the sourcing of used wind turbines, refurbishment, installation and operation and maintenance.

Purchasers should look for refurbishment / remanufacturing companies that:

- Have a proven track record for the services that they intend to provide (e.g. experience with the turbine brand being refurbished / remanufactured)
- Are experienced at refurbishing / remanufacturing the turbine in question
- Have a robust and transparent methodology for refurbishment / remanufacturing
- Ideally, have a proven track record for securing finance for refurbished / remanufactured wind turbines

Liability

It is important to determine who takes on responsibility for the performance and safe operation of the refurbished / remanufactured wind turbine, as well as the duration of this responsibility. Suppliers may have standard terms and conditions that should be understood. It may be possible to negotiate.

Turbine

The history of a used wind turbine should be understood by the refurbishment / remanufacturing company and the purchaser of the refurbished / remanufactured wind turbine – this impacts the work that should be carried out as part of the refurbishment / remanufacturing process and the overall value of the wind turbine. Refurbishment / remanufacturing companies will likely have their own criteria for procuring used wind turbines.

The following details about the history of a used turbine are important:

- **Country of previous operation:** requirements for servicing and maintenance vary by country e.g. Sweden, Denmark and Germany have higher standards/requirements for servicing and maintenance
- **Location of operation:** operating conditions will give an indication of past environmental stresses on the turbine. Turbines which have operated in coastal regions (e.g. exposure to saline environment) and regions of significant turbulence should be avoided
- **Generation records:** has the turbine been operating as per the manufacturer performance curve?
- **Down rating:** wind turbines which have been down rated (e.g. due to grid restrictions) will have been subjected to less stress due to alteration of the max power output
- **Service records:** records of servicing carried out on the used turbine should be available and inspected to ensure that routine servicing has been carried out as per the manufacturer guidance and that any previous component failures (refurbishment/replacement) are understood
- **Detailed assessment of turbine:** indicate component wear and necessary refurbishment schedule

Certain companies offering second hand turbines will complete a detailed assessment of the turbine prior to purchase to indicate component wear and necessary refurb schedule etc. Price per turbine in region of £5k including site visit to turbine location

It is important to understand whether sufficient refurbishment has been carried out on the used turbine. Ideally, refurbished / remanufactured wind turbine suppliers should provide a checklist (and supporting evidence if possible) to show that each component has been checked/tested and that repairs and replacements have been carried in line with a robust criteria (e.g. scale of acceptability) based on knowledge of the turbine and/or manufacturer

tolerances and specifications (e.g. through collaboration with manufacturers, based on own experience, with warranty providers).

As with new turbines, selecting a refurbished / remanufactured turbine with easily accessible replacement parts may reduce the downtime due to full or partial component failure.

Further information

List of wind turbine refurbishment companies

http://www.mpgwind.com/turbines-available/

http://www.boythorpewindenergy.co.uk/second-hand-wind-turbines/

http://www.greenenergywind.co.uk/installations/refurbished-turbines

Other useful companies i.e. brokers, traders

http://dutchwind.com/

More details

Insurance provider (Norther Alliance Insurance) – who offers insurance on reconditioned wind turbines. http://www.northernalliance.co.uk/wind-turbine-insurance/

http://www.rm-energy.co.uk/refurbished-remanufactured-vestas-wind-turbines-by-rm-energy/

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