Small Wind Turbine
Energy and Payback Estimates

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1 Summary

This booklet is a rough guide to small wind turbine economics. Use the information for outline guidance only. Get in touch if you need further information. It looks pretty good printed as an A5 booklet and only uses one sheet of A4 paper. Small wind turbines can be surprisingly large, with overall diameters of up to 16 m. Medium sized machines have diameters of up to 32 m.

2 Estimate the Average Wind Speed

Using an online wind map, e.g. the SEAI Wind Map in Ireland [4], find the average 20 m wind speed at the proposed site. With the table below, find the estimated average wind speed at 10 m at the same site [2]. Depending on the terrain at the site, use the corresponding open or cluttered value. Remember that the actual wind speed at a site can be lower than estimates such as these.

20 m		adjusted to:	10 m			
Wind map wind speed			Open (no trees etc.)		Clutter (trees etc.)	
0.0	m/s	is approx.	0.0	m/s	0.0	m/s
0.5		″ ″	0.5		0.4	
1.0		″ ″	0.9		0.8	
1.5		″ ″	1.4		1.3	
2.0		″ ″	1.9		1.7	
2.5		″ ″	2.3		2.1	
3.0		″ ″	2.8		2.5	
3.5		″ ″	3.3		2.9	
4.0		″ ″	3.7		3.4	
4.5		″ ″	4.2		3.8	
5.0		″ ″	4.7		4.2	
5.5		″ ″	5.1		4.6	
6.0		″ ″	5.6		5.0	
6.5		″ ″	6.1		5.5	
7.0		″ ″	6.5		5.9	
7.5		″ ″	7.0		6.3	
8.0		″ ″	7.5		6.7	
8.5		″ ″	7.9		7.1	
9.0		″ ″	8.4		7.6	

3 Estimate the Annual Energy Production and Annual Income

With this wind speed estimate at 10 m, use the closest lower wind speed in the tables below to obtain rough numbers for: (i) the annual energy production (AEP) from a typical small machine at that site; (ii) the annual income from the machine; (iii) the simple payback period.

The AEP and annual income estimates are based on a typical 5 kW small wind turbine with a (high) efficiency of 0.35. The grid power purchase price is assumed to be €0.25 per kWh with a sale price to the grid of €0.09 per kWh.

Average annual income for several scenarios are given: it's most profitable if all the energy can be used to offset grid power (Use 100%). It's least profitable to sell all the power to the grid (Sell 100%).

Wind speed		AEP	Annual Income			
			Use 100%	Use 50%	Use 50% Sell 50%	Sell 100%
		kWh	€	€	€	€
0.00	m/s	0	0	0	0	0
0.50		9	2	1	1	1
1.00		70	18	9	12	6
1.50		238	59	30	40	21
2.00		563	141	70	96	51
2.50		1100	275	138	187	99
3.00		1901	475	238	323	171
3.50		3019	755	377	513	272
4.00		4507	1127	563	766	406
4.50		6417	1604	802	1091	578
5.00		8803	2201	1100	1496	792
5.50		11716	2929	1465	1992	1054
6.00		15211	3803	1901	2586	1369
6.50		19340	4835	2417	3288	1741
7.00		24155	6039	3019	4106	2174
7.50		29709	7427	3714	5051	2674
8.00		36056	9014	4507	6130	3245
8.50		43248	10812	5406	7352	3892
9.00		51338	12834	6417	8727	4620
9.50		60378	15095	7547	10264	5434
10.00		70422	17606	8803	11972	6338

4 Estimate Simple Payback

The simple payback period depends on three main parameters: the cost per kW installed of the small wind turbine, its efficiency and the value of the electricity produced. If these three parameters remain constant, then the payback period remains constant, even for different sized machines. The payback period is approximately independent of the turbine size [3].

Typically, the cost per kW installed for a small wind turbine ($<$ 10 kW - 50 kW) is about €5,000 per kW installed, i.e. a 5 kW machine costs about €25,000 installed and a 10 kW machine costs about €50,000 installed. See appendix note on wind turbine ratings.

For this reason, unless there is information to the contrary, the payback periods indicated below are probably representative for most machines in the small domestic segment in Ireland where a grid connection already exists, i.e. where the value of the energy produced is no greater than cost of purchase from the grid.

Finally, we can normalise the payback numbers above to years payback per €1000 / kW installed. So, for example, if you paid €20,000 for a 5 kW wind turbine, this is an installed cost of €4000 / kW, i.e. 4$\times$ €1000 / kW . Using the table below, the payback for this machine at a site with an average wind speed of 5 m/s will be (2.3×4) years, i.e. 9.2 years.

The normalised number is given inside the brackets.

Wind speed		Typical Payback Period for a Small Wind Turbine			
		Use 100%	Use 50%	Use 50% Sell 50%	Sell 100%
		Years (Years per €1000/kW)	Years (Years per €1000/kW)	Years (Years per €1000/ kW)	Years (Years per €1000/kW)
0.00	m/s	-	-	-	-
0.50		-	-	-	-
1.00		-	-	-	-
1.50		-	-	-	-
2.00		-	-	-	-
2.50		-	-	-	-
3.00		-	-	-	-
3.50		33 (6.6)	-	49 (9.7)	-
4.00		22 (4.4)	44 (8.9)	33 (6.5)	-
4.50		16 (3.1)	31 (6.2)	23 (4.6)	43 (8.7)
5.00		11 (2.3)	23 (4.5)	17 (3.3)	32 (6.3)
5.50		9 (1.7)	17 (3.4)	13 (2.5)	24 (4.7)
6.00		7 (1.3)	13 (2.6)	10 (1.9)	18 (3.7)
6.50		5 (1.0)	10 (2.1)	8 (1.5)	14 (2.9)
7.00		4 (0.8)	8 (1.7)	6 (1.2)	11 (2.3)
7.50		3 (0.7)	7 (1.3)	5 (1.0)	9 (1.9)
8.00		3 (0.6)	6 (1.1)	4 (0.8)	8 (1.5)
8.50		2 (0.5)	5 (0.9)	3 (0.7)	6 (1.3)
9.00		2 (0.4)	4 (0.8)	3 (0.6)	5 (1.1)
9.50		2 (0.3)	3 (0.7)	2 (0.5)	5 (0.9)
10.00		1 (0.3)	3 (0.6)	2 (0.4)	4 (0.8)

It's worth pointing out that the installed cost per kilowatt makes a big difference; large wind turbines have installed costs of less than €1500 / kW, with correspondingly lower payback periods. The estimates above hold well enough for larger machines. In addition, the value of the electricity produced is key. If you have no grid connection, e.g. at a remote arctic site, the value of the electricity produced settles close to the cost of running a remote diesel generator. The economics become much better for relatively expensive, smaller wind turbines.

These numbers neglect factors that are not easily assigned monetary value. If a farmer wants a small wind turbine for reasons other than simple financial gain, e.g. owning an independent and renewable energy supply, this changes the calculation. People do buy new cars, after all, with little to be gained financially. The trick then is to buy the machine with the best annual energy output for a given financial outlay. In the UK and US, government backed initiatives list independently certified small wind turbines. The independent certification is required to provide evidence of claimed performance [5].

References

[1] P. Gipe, *Wind Turbine Rating*, 2013. http://www.wind-works.org/.

[2] J. F. Manwell, J. McGowan, and A. Rogers, *Wind Energy Explained: Theory, Design and Application*, Wiley, New York, 2 ed., 2009.

[3] N. McMahon, *Are Larger Wind Turbines Paid for Faster?*, 2015. http://niallmcmahon.com/discon/4-are-larger-wind-turbines-paid-for-faster/.

[4] Sustainable Energy Authority of Ireland, *Irish Wind Map*, 2015. http://www.seai.ie/.

[5] The Microgeneration Certification Scheme (MCS), *Product Search*, 2016. http://www.microgenerationcertification.org/.

Note on Wind Turbine Rating

How a machine is rated, i.e. whether it's a 5 kW machine or 10 kW machine, differs between manufacturers. In general, the rating is the peak output power of the machine. For a small wind turbine, it can be taken as the smaller of either the manufacturer's rating or the power output from the machine in a wind speed of about 11 m/s. Overall diameter is the key parameter.

The power from a wind turbine is given by: $P = \frac{1}{2}\rho C_p \pi r^2 U^3$, where ρ is the air density, C_p is the efficiency of the machine, r is the machine radius, and U is the wind speed.

Smaller machines often reach peak power around 11 m/s. ρ is around 1.225 kg/m^3, the efficiency is hardly ever better than 0.35 on average - this is optimistic! Using these numbers,

$P = 0.5 \times 1.225 \times 0.35 \times \pi \times r^2 \times 11^3 = 896 \times r^2$.

A machine with an overall diameter of 5 m will probably have a peak power at 11 m/s of something less than 5.5 kW. A 10 m machine will probably have a peak power at 11 m/s of less than 19 kW, and so on.

Look for an experimental power curve and, better, a complete independent power performance report from a certification body. Rating can be contentious and it's always better to talk about expected annual energy output at typical wind speeds. Paul Gipe has a good discussion about this [1].

Licence and Legals

There are the usual legal considerations[1].