Individual Wind Turbines

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AECOM

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Energy, power and carbon

- Energy – kWh, MWh, GWh
  - (plus kJ, MJ, GJ, cal, BTU, therm, etc…)
- Power – kW, MW, GW
- Carbon – kg, tonnes, Mt
  - (Depends on fuel type used/offset)
- Money - £!
  - Depends on fuel type used/offset & export tariffs

The scale of generation

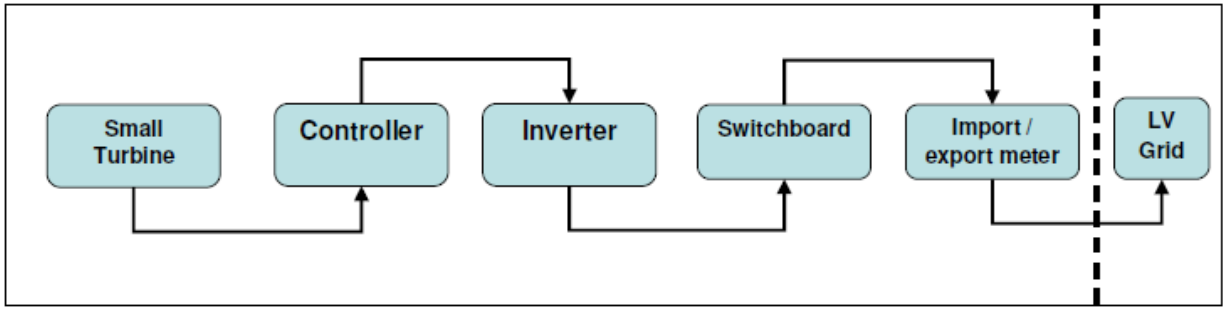
- Domestic micro wind
  - 1kW
  - £2,000
  - 0.1 tonnes CO_2 per annum
- Small/medium wind
  - 25kW
  - £75,000
  - 12 tonnes CO_2 per annum
- Large wind
  - 2.3MW
  - £2,200,000
  - 3,300 tonnes CO_2 per annum

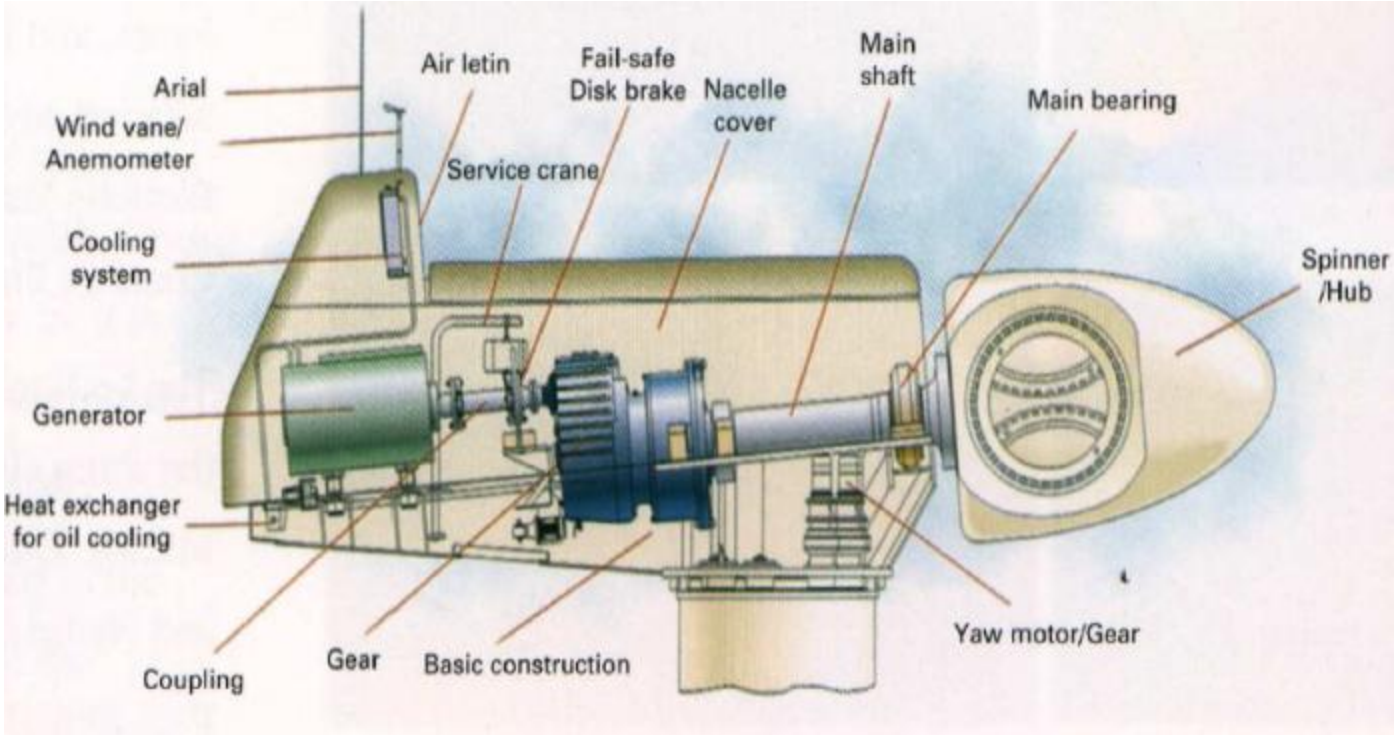
Individual Wind Turbines

- Most effective at a large scale
- Horizontal axis or vertical axis
- Small (domestic) scale or large wind farm scale (approx 1kW – 2.5MW)
- Building-mounted or free-standing
- Included in the Government's proposed Feed in Tariff – likely to benefit from considerably reduced payback periods under this scheme
- Potential planning issues
  - Noise
  - Visual appearance
  - Flicker
  - Topple distance

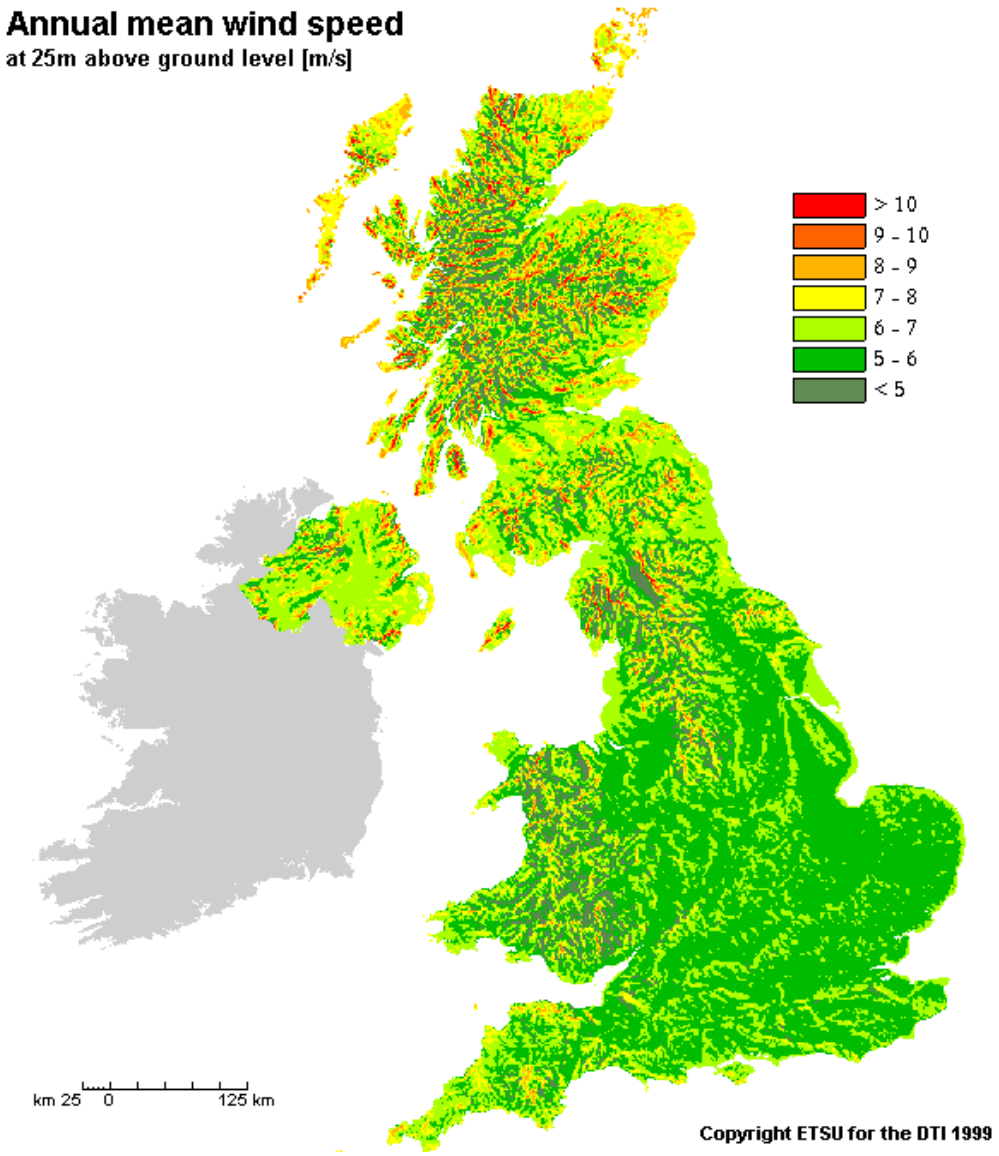
Key Components

- Wind turbine (blades, mast, gearbox, generator)
- Supporting structure
- Connecting cables
- Inverter
- Export meter





Wind as a resource

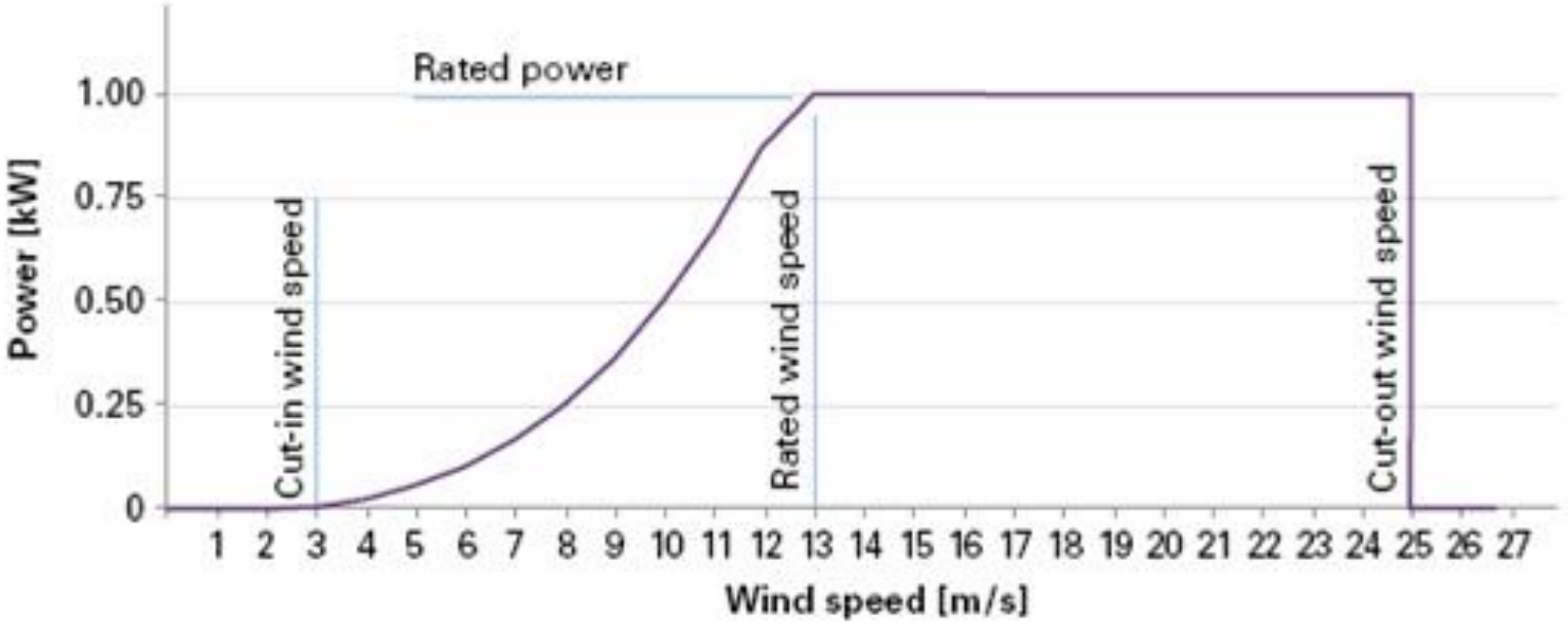


The physics…

$$P = \frac{1}{2} \times A \times \rho \times V^3$$

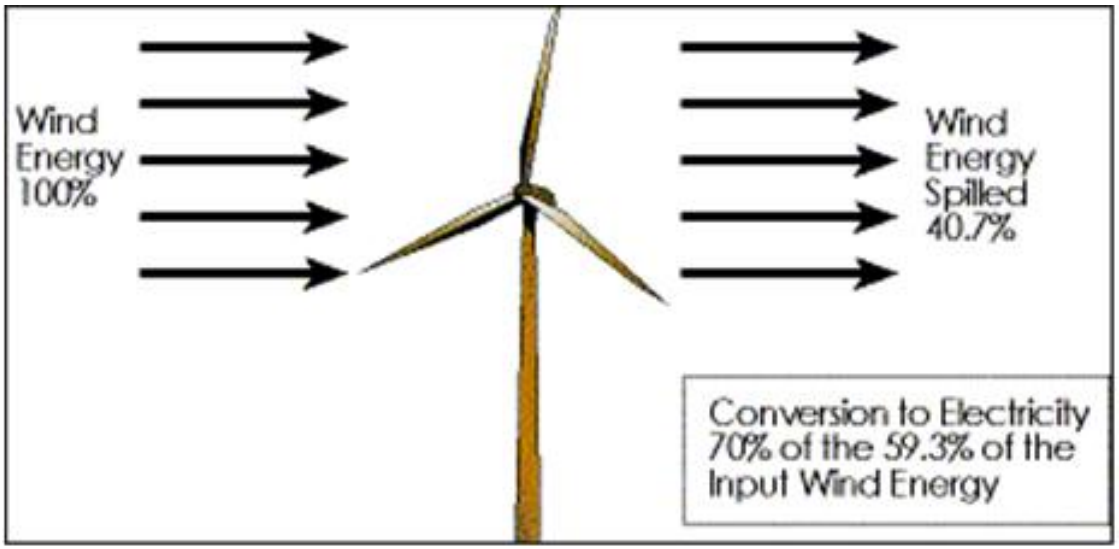
Power = 0.5 x Swept Area x Air Density x Velocity^3

Plus an efficiency factor as the turbine convert the potential energy available into electrical energy



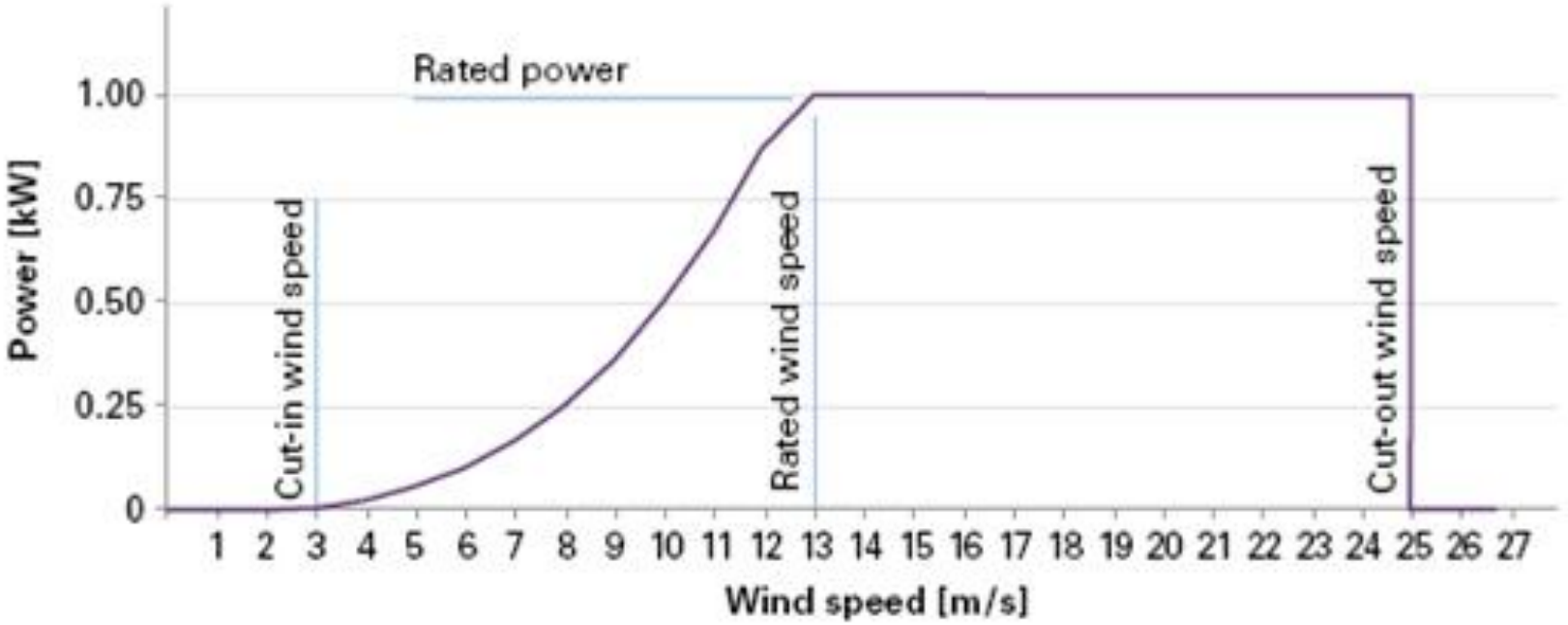
Betz limit

- Quantifies the amount of energy that can actually be taken “out of” the wind
- Betz limit: 59.3%
- Real-world maximum: 35-45%



$$P = \frac{1}{2} \times A \times \rho \times V^3$$

Control at high wind speeds



- All turbines have a maximum wind speed (survival speed) at which they can operate to protect from damage and large wind loads on the structure
  - Stalling the blade
  - Pitch control
  - Yawing (turning)
  - Electrical braking
  - Mechanical braking

Design issues

- Average wind speeds
- Wind speed consistency (micro: >5m/s; large: >8m/s)
- *Rated* wind speed varies depending upon turbine size
- Laminar/turbulent flow/gusting
- Turbine type (horizontal/vertical axis)
- Proximity to electrical connection (and capacity available on the connection)
- Distance from surrounding buildings and infrastructure
- Maintenance access
- Cable routing
- Protection from damage
- Wind load on supporting structures

Types of wind turbine

- Horizontal axis
  - Requires rotor to be positioned into the wind and is therefore sensitive to changes in the wind direction and turbulence
  - Therefore require open areas with smooth laminar air flow and few obstacles
- Vertical axis
  - Developed for urban environments
  - Unaffected by changes in wind direction
  - Generally less efficient and therefore lower power output
  - Generally lower energy output
- Variation in number of blades
  - Low speed/high speed
  - Aesthetics
- Range of scales

Turby 2.5kW VAWT

Proven 6kW turbine, Kirklees Civic Centre

Choosing the right turbine

- Factors to consider:
  - Power output
  - Electrical connection available
  - Turbine position and scale - building mounted or standalone
  - Rotor diameter
  - Weight
  - Noise
  - Visual characteristics
  - Performance (capacity factor)
  - Surrounding environment
  - Wind characteristics
- Accreditation
  - Clear skies – expired end of 2009
  - MCS – current certification scheme for registered installers and registered products

Choosing the right location

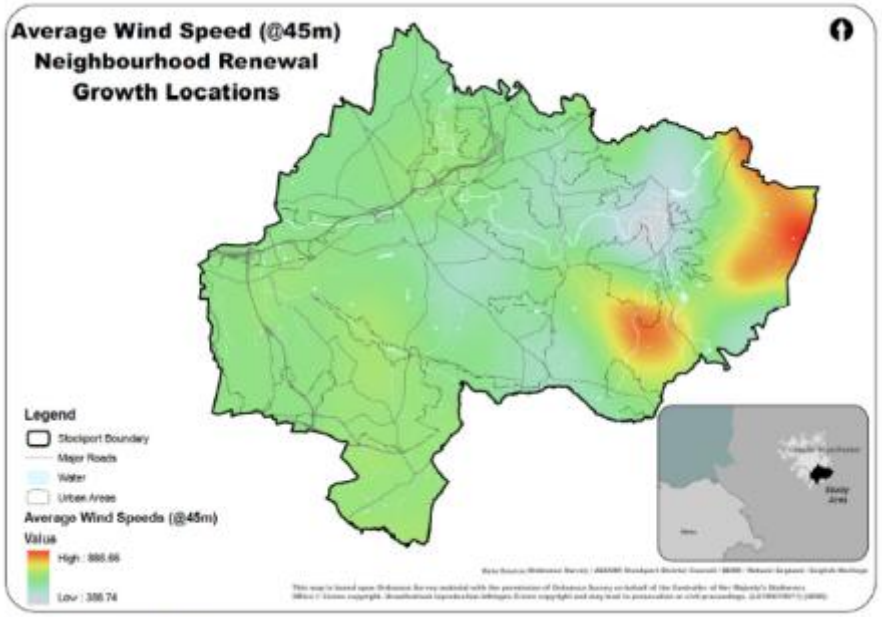


Figure 27. Wind Speed Distribution .

- Noise
- Visual appearance
- Flicker
- Topple distance
- Aircraft flight paths
- Military bases

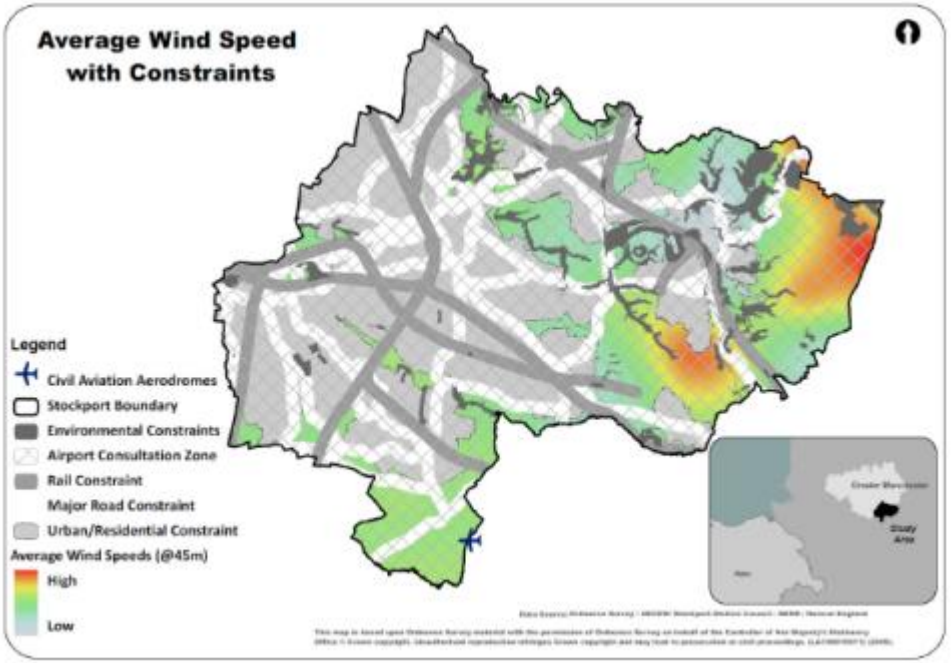
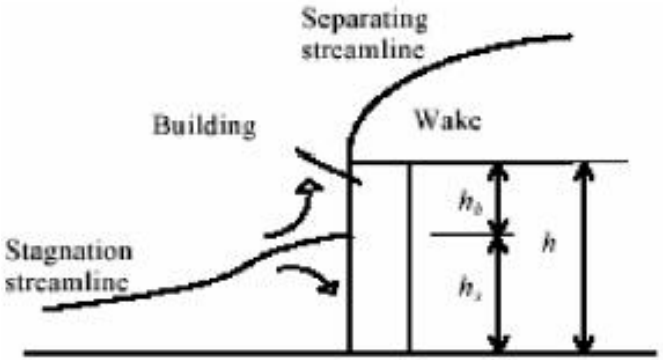
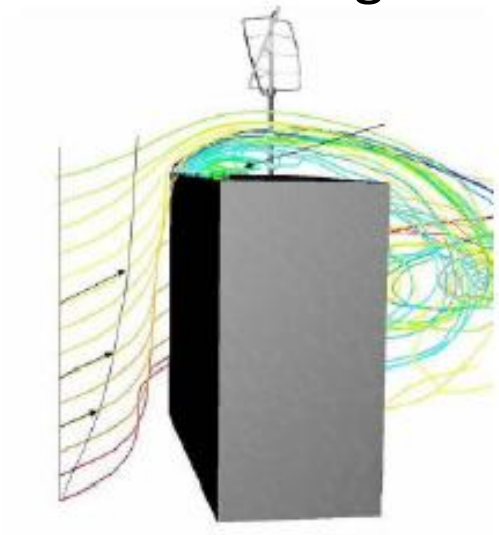


Figure 28. Wind Energy Opportunities and Constraints

Power output & turbine positioning

- Power output and associated CO_2 emissions is likely to be insignificant in the context of most developments for turbines of less than 2.5kW. Multiple installations may be necessary to achieve a particular renewables target.
- Avoid areas of turbulence nearby to buildings, trees or severe landscaping features
- Minimise the effects of noise and vibration through considering mounting position



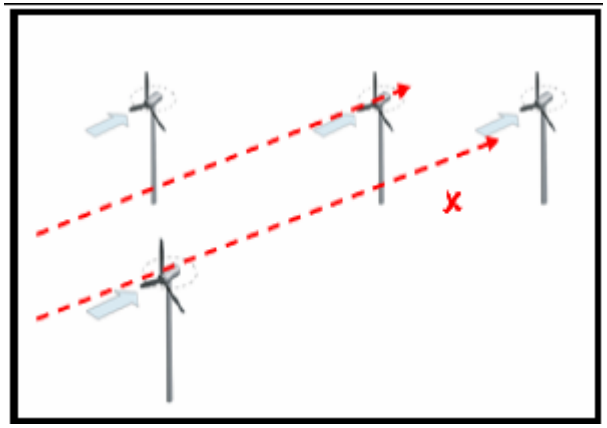


Turbine positioning – general principles

- Site – annual mean wind speed should be >5m/s as a minimum (depends on height above ground and therefore hub height of turbine)
  - DECC wind speed database
  - Onsite wind monitoring
  - Consider future development that may change the surrounding area
- Exclusion areas:
  - Sites of historic interest (including ancient woodland)
  - Roads and rail lines
  - Built up area
  - Airports and airfields
  - Military areas and training grounds
  - ‘Topple distance’ – typically tip height + 10%

Turbine positioning

- Turbines to be located on exposed faces (avoid shielding from surrounding buildings/landscaping etc.)
- Take measures to prevent shadow flicker and noise
- Ensure there is maintenance access to the turbine
- Cable routing from each turbine to grid connection



Avoid wind shading

Variation in scale

£2,170,000

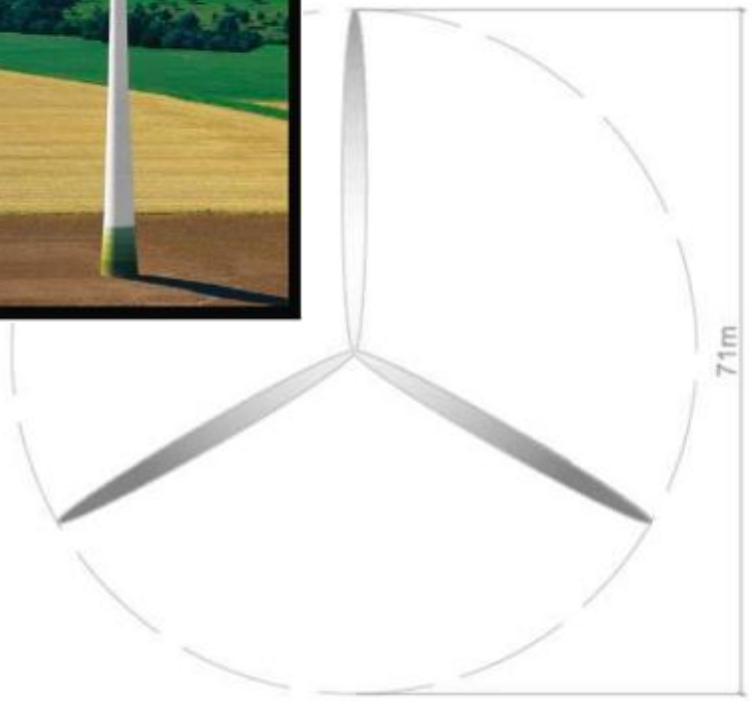
$$P = \frac{1}{2} \times A \times \rho \times V^3$$

£485,000

The 2.3MW turbine has a swept area over 1,600 times greater than the 1kW turbine!

£75,000

£1,900



Enercon E70
2.3 MW

Enercon E33
330kW

Eoltec
Windrunner
25kW

Windsave
WS-1000
1kW

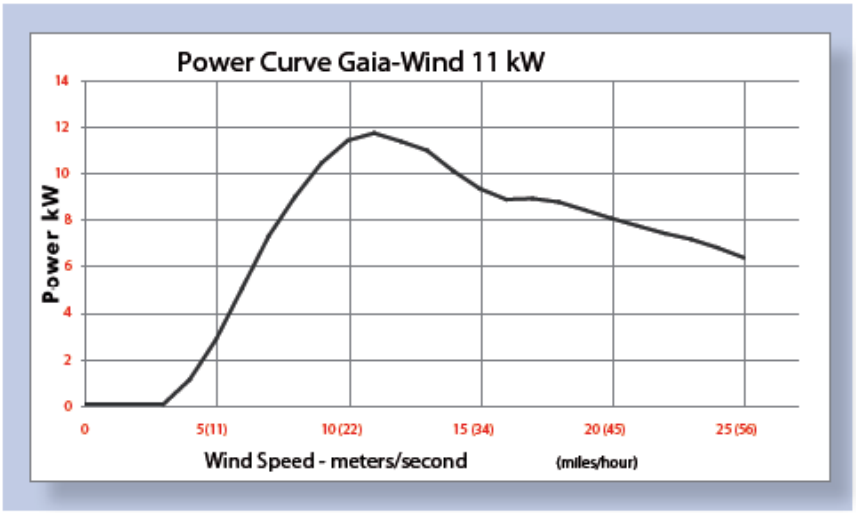
Evance ISKRA R9000 (5kW)

- No. rotors: 3
- Blade diameter: 5.4m
- Blade material: Glass fibre reinforced composite
- Rated power: 5kW @ 12m/s
- Cut-out speed: N/A
- Survival speed: 60m/s
- Cut-in speed: 2.5m/s
- Pole height: 9-15m
- Typical annual energy generated: 9,012kWh (@ AMWS 5m/s)
- Annual carbon saved: approx 5 tonnes per annum
- Generator: Brushless direct drive permanent magnet generator
- Yaw control: passive – tail vane and rotor
- System weight: approx 300kg excluding pole
- Noise level: 45dB @ 60m

Gaia Wind-133 (11kW)

- No. rotors: 2
- Blade diameter: 13m
- Blade material:
- Rated power: 11kW @9.5m/s
- Cut-out speed: 25m/s
- Survival speed: unavailable
- Cut-in speed: 3.5m/s
- Pole height: 18m
- Typical annual energy generated: 30,000kWh
- Annual carbon saved: 16 tonnes per annum
- Generator: 3-phase 400V connected to two stage gearbox
- Yaw control: unavailable
- System weight: 900kg (excl. tower)
- Noise level: 45dB @ 60m

Wind Speed (m/s)	Power kW
3	0.0
4	1.1
5	2.8
6	5.0
7	7.3
8	8.9
9	10.4
10	11.4



Proven 35-2 (12kW)

- No. rotors: 3
- Blade diameter: 8.5m
- Blade material: unavailable
- Rated power: 12.1kW
- Cut-out speed: N/A
- Survival speed: 54m/s
- Cut-in speed: 3.5m/s
- Pole height: 15-20m
- Typical annual energy generated: 23,200kWh (@5m AMWS)
- Annual carbon saved: 13 tonnes per annum
- Generator: Direct drive with permanent magnet
- Yaw control: self-regulating rotor
- System weight: unavailable
- Noise level: unavailable

It’s not all plain sailing…

Furniture Matters: Proven 15kW

- Clear Skies funding approved Dec 05
- Planning permission received Oct 06
- Turbine withdrawn for technical reasons
- Grid connection: additional costs and delays
- Funding deadlines: new sources found
- Turbine installed March 2009: technical problems
- Turbine head taken away for 9 months
- Re-installed Oct 2010: limited running time
- Due to be fully operational March 2011
- *Output slightly above predictions: expecting 34,000 kWh/year when fully running*

Performance characteristics

- Typical capital costs: £1,000-£3,000/kW
- Typical energy output: 400-2,500 kWh/kW_{peak}
  - Utilisation/load factor typically 5% - 30%
- Typical system size: 1kW – 3MW
  - Small-medium scale: 5-100kW (5m – 25m blade diameter)
- Typical payback period: 10-50 years
  - FiT intended to provide approx 18 yr payback for suitable sites
  - Depends largely on site suitability and energy yield
  - Large scale lower, micro scale higher

FiT for Wind

Technology	Scale / Scheme Year	Tariff level for new installations in period (p/kWh) [NB tariffs will be inflated annually]											Tariff lifetime (years)
		1 1/4/10 – 31/3/11	2 to 31/3/12	3 to 31/3/13	4 to 31/3/14	5 to 31/3/15	6 to 31/3/16	7 to 31/3/17	8 to 31/3/18	9 to 31/3/19	10 to 31/3/20	11 to 31/3/21	
Wind	≤1.5kW	34.5	34.5	32.6	30.8	29.1	27.5	26.0	24.6	23.2	21.9	20.7	20
Wind	>1.5-15kW	26.7	26.7	25.5	24.3	23.2	22.2	21.2	20.2	19.3	18.4	17.6	20
Wind	>15-100kW	24.1	24.1	23.0	21.9	20.9	20.0	19.1	18.2	17.4	16.6	15.9	20
Wind	>100-500kW	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	20
Wind	>500kW-1.5MW	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	20
Wind	>1.5MW-5MW	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	20

Financial analysis

- Key financial sensitivities:
  - Feed in Tariff (FiT)
  - Electricity price
  - Electricity offset tariff
  - Generation and demand alignment (time of day of usage)
  - Existing wiring and structural configuration – additional infrastructure required?
  - Structural modifications required

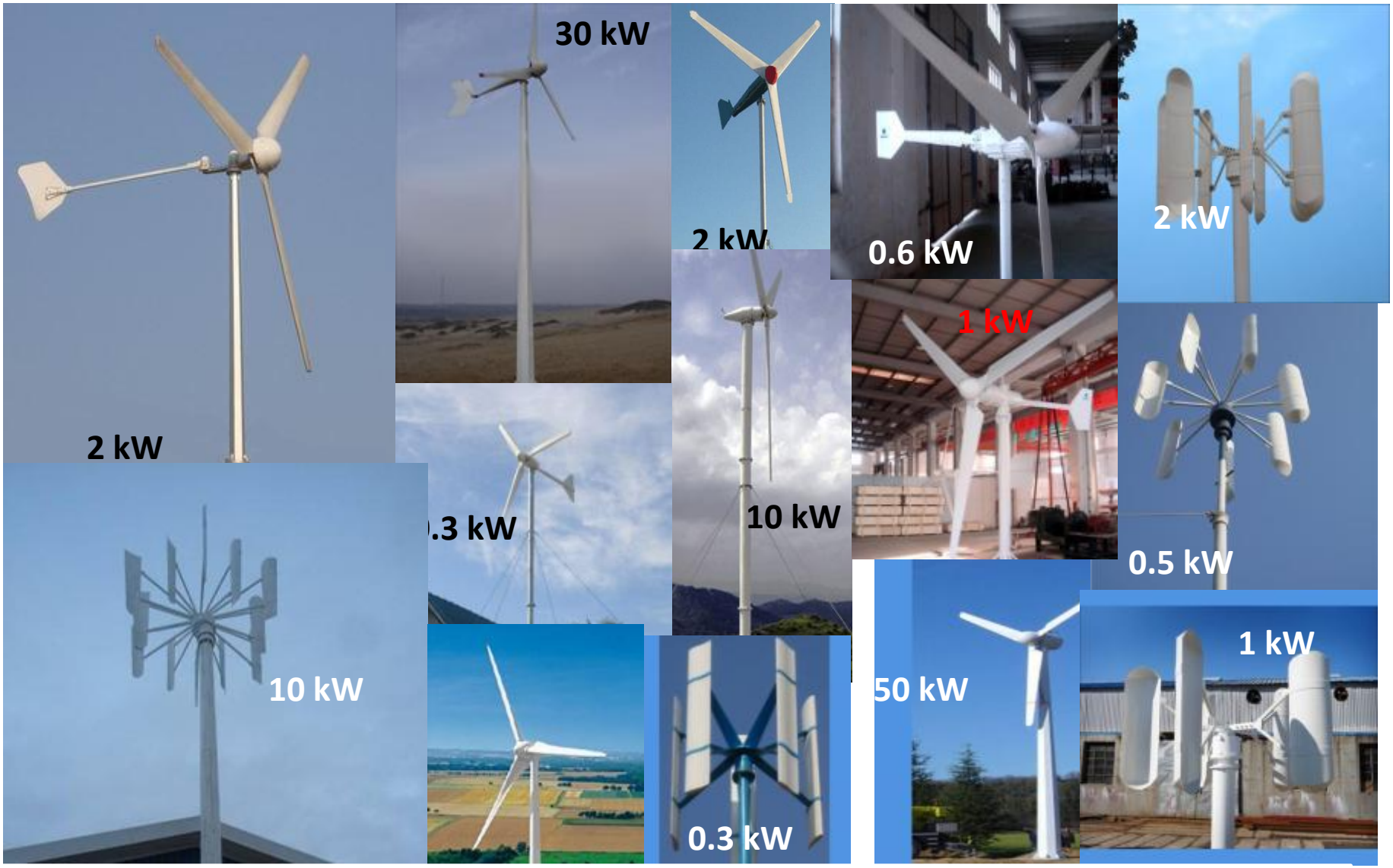
Example – "Agricultural-scale" wind turbine installation

System type and size:	25	kW
Total system capital cost:	£75,000	
Typical utilisation factor:	10%	
Annual energy generated:	21,900	kWh
Annual carbon saved:	12,439	kgCO2
Annual carbon saved in context:	Offset all carbon emissions from approx 4 new houses	
Feed in Tariff rate:	24.1	p/kWh
Annual payments received from Feed in Tariff:	£5,278	
Assumed elec offset:	25%	
Assumed elec export:	75%	
Assumed elec purchased cost:	12	p/kWh
Assumed elec export price:	3	p/kWh
Annual savings made from electricity offset:	£657	
Annual payments received from grid export:	£493	
Annual maintenance cost:	£125	
Total net annual savings:	£6,303	
Simple payback period:	11.9	years

Now assume it's poorly positioned…

System type and size:	25	kW
Total system capital cost:	£75,000	
Typical utilisation factor:	3%	
Annual energy generated:	6,570	kWh
Annual carbon saved:	3,732	kgCO2
Annual carbon saved in context:	Offset all carbon emissions from approx 4 new houses	
Feed in Tariff rate:	24.1	p/kWh
Annual payments received from Feed in Tariff:	£1,583	
Assumed elec offset:	25%	
Assumed elec export:	75%	
Assumed elec purchased cost:	12	p/kWh
Assumed elec export price:	3	p/kWh
Annual savings made from electricity offset:	£197	
Annual payments received from grid export:	£148	
Annual maintenance cost:	£125	
Total net annual savings:	£1,803	
Simple payback period:	41.6	years

Examples



Six word summary

Size matters…

… and so does position

Questions?

Break

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