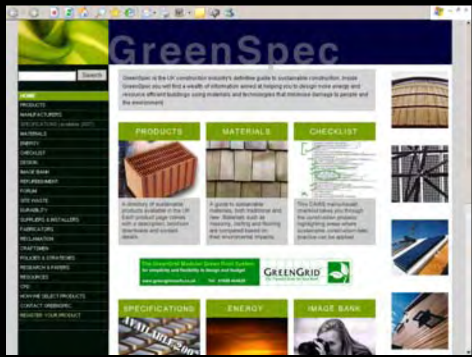

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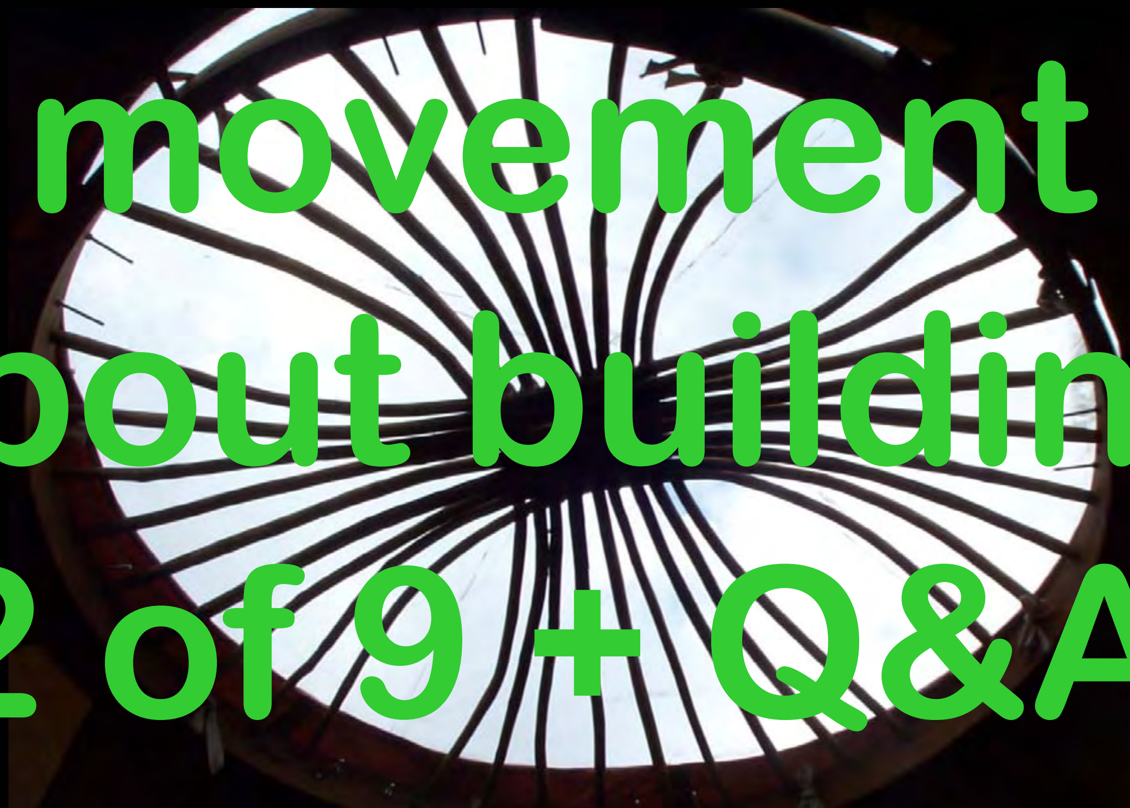

Air movement in & about buildings 2 of 9 + Q&As

 CPD in 10 parts

GreenSpec CPD Seminar Series

- Educational Objective:
  - Comprehensive introduction to subject: from wind to air-conditioning and a lot more in between
  - emphasis on environmentally sustainable solutions
  - design primer: addressing principles and solutions
  - technically rich: materials, construction, services & testing
  - Related GreenSpec CPD Seminars indicated
  - Questions and answers for each subtopic in file 10
- Audience:
  - Architecture Students Part 1 Year 2
  - CPD update for all levels of experience & knowledge
- Delivery:
  - 3 to 4 hours depending upon audience participation
  - Reading 1 hour
  - 26 subject breaks to enable subdivision

Air Movement in Buildings: 2 of 9 Sub-topics in 10 separate files

- Principles of Element Design
- Climate Change
- Wind
- Wind Tunnel Testing
- Wind Turbines
- Natural Ventilation
- Moisture Vapour & Condensation
- Thermal Insulation
- Breathing Construction
- Airtightness
- Wind & Airtightness Testing
- Building Elements
- Passive Ventilation
- Active Ventilation
- Stack Effect
- Atrium
- Solar Orientation & Solar Gain
- Conservatories
- Thermal mass
- Conduction, Convection, Radiation
- Solar Shading
- Thermal mass, Passive and active cooling
- Fluid dynamics
- Mechanical Ventilation
- Air-Conditioning
- Questions and Answers

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Wind

Affects on buildings

Wind

- Wind can be very destructive
- Wind can be beneficial if we know how
- Wind brings clouds, rain and fresh cooling air
- We can use wind to dry crops and clothes
- Rain is good for crops, washing and a source for drinking water
- Wind can drive water pumps and turbines (electricity generators)

Barn doors opposite for wind to separate threshing from seed
Threshold holds thresh at door

Grain Barn

perforated walls let wind dry grain

Outskirts of Sandy Bedfordshire

Listed Grade I Barn
slot windows ventilate cattle stalls

Wiltshire

Untreated Unseasoned Unfinished Durable Species Boarding. Tall plinth protects timber from ground water. Irregular pavement protects from rain splash. Wind & air dries timber

Aberystwyth Arts Centre: Architect: Smith Roberts: Peter N Roberts

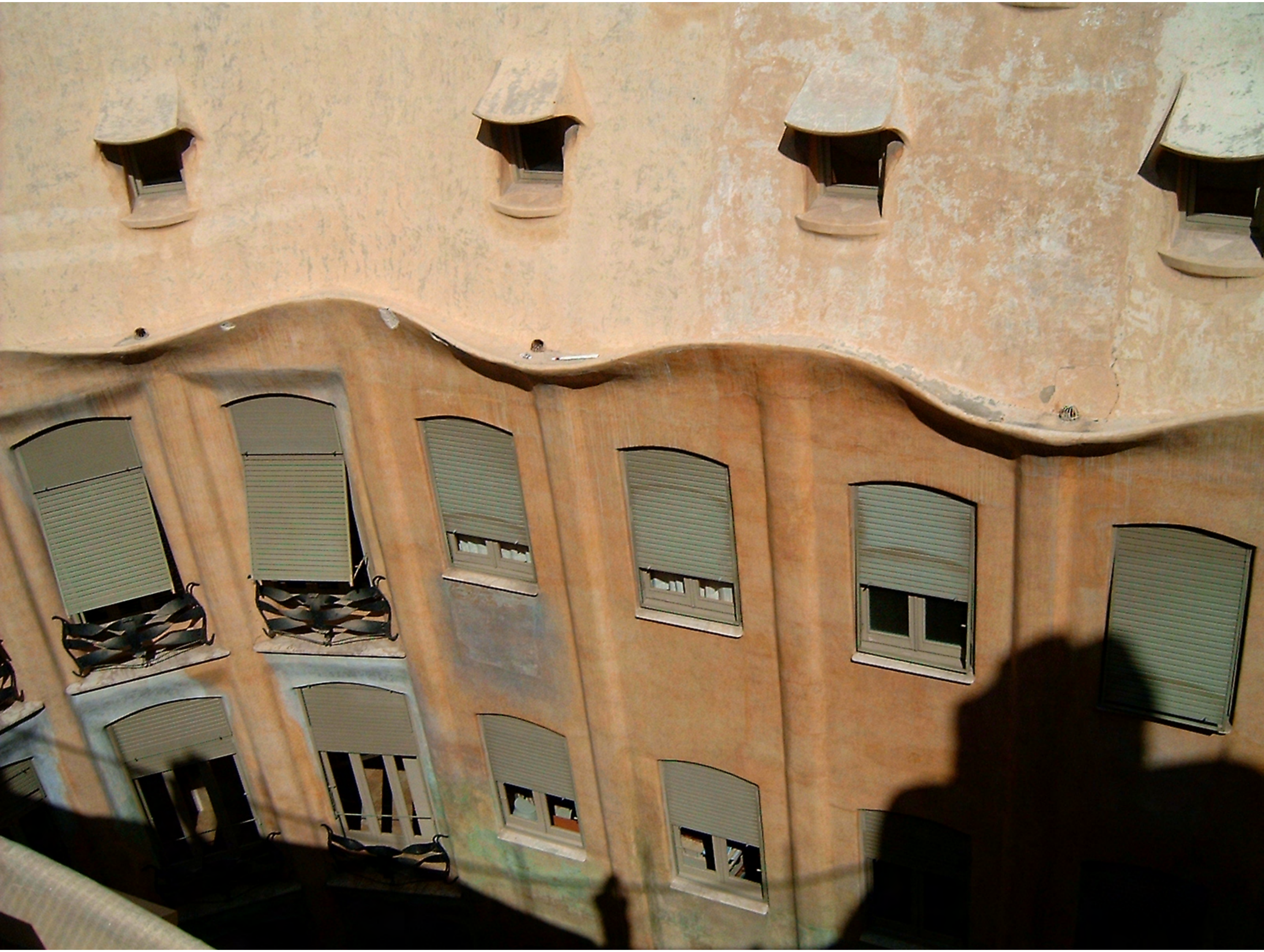
Wind shelter: Buildings

- Buildings create some shelter on the leeward side away from the wind
- But create strong winds around sides and down alleyways between
- Wind direction changes: sheltered spot moves
- Prevailing wind usually from SW in UK means shelter is usually on the NE
- Ensuring solar penetration into the sheltered spot is not always easy

Wind shelter: Courtyards

- Courtyards create shelter most of the time from most directions
- Courtyards need views out and they can provide routes for fresh air if too sheltered
- Air could become stagnant if too sheltered, too deep or two narrow
- Tall, small area courtyards are light wells used for light and ventilation

Courtyard Shelter & Sun penetration



Wind shelter: Towers

- Smaller buildings on the windward side of nearby Towers push the air flow up so it hits the tower and spreads in all directions
- The down drafts can be considerable stronger than the original wind
- Edie currents are set up around the edges of the tower
- Creating a hostile environment that can be dangerous for pedestrians
- Podium, Shelf, Skirts around the towers above pedestrian level will deflect much of the wind and create a comfortable place to walk and linger.

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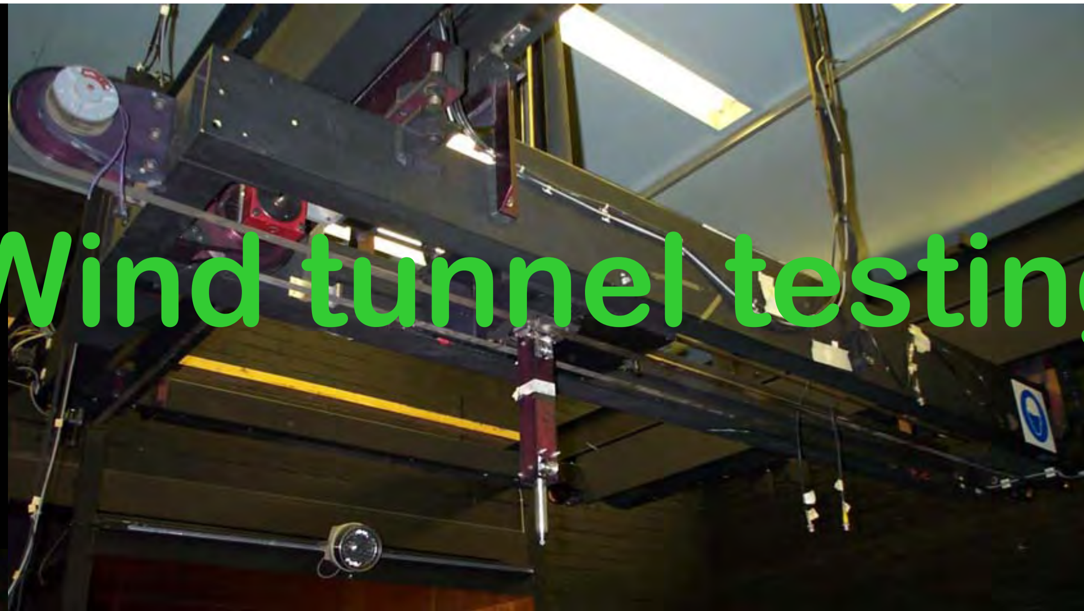
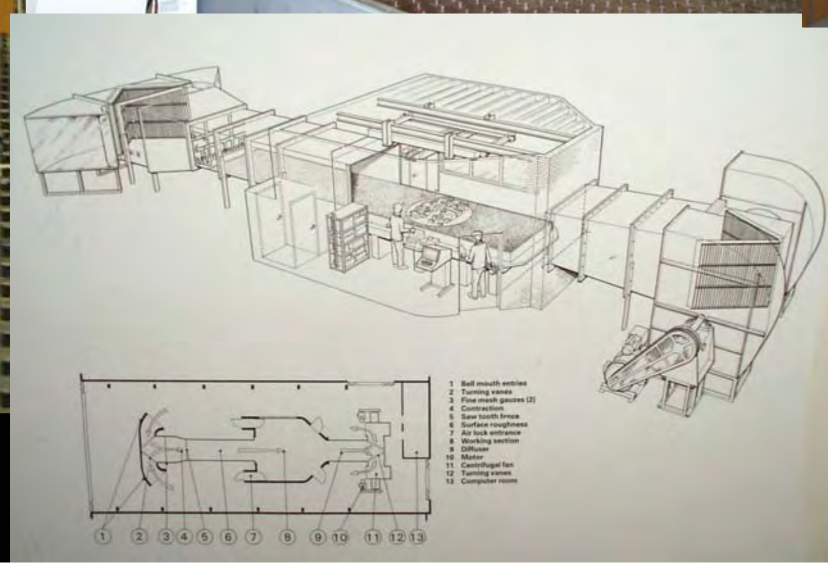
Wind Tunnel Testing

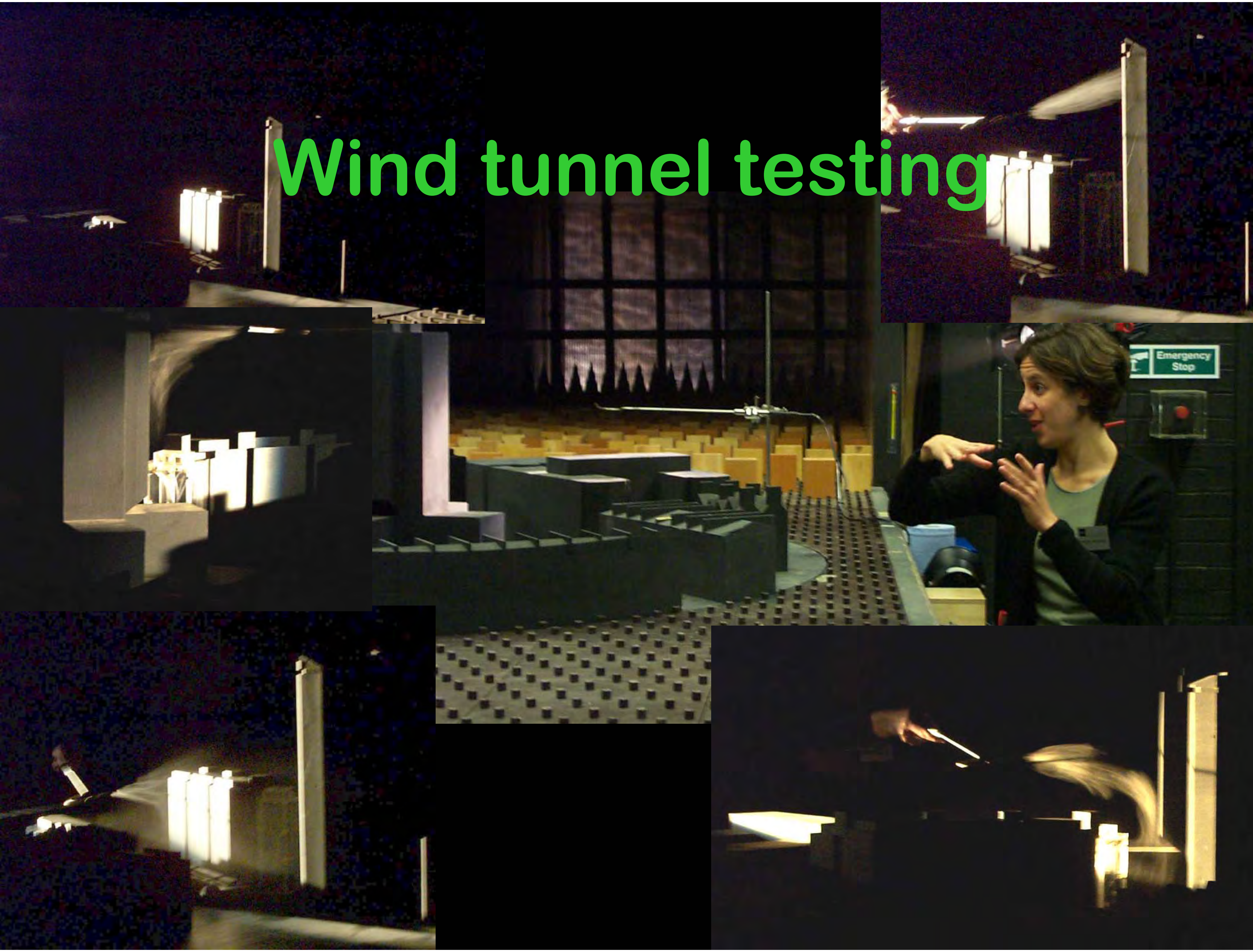
Renewable Energy: Wind

Wind tunnel testing



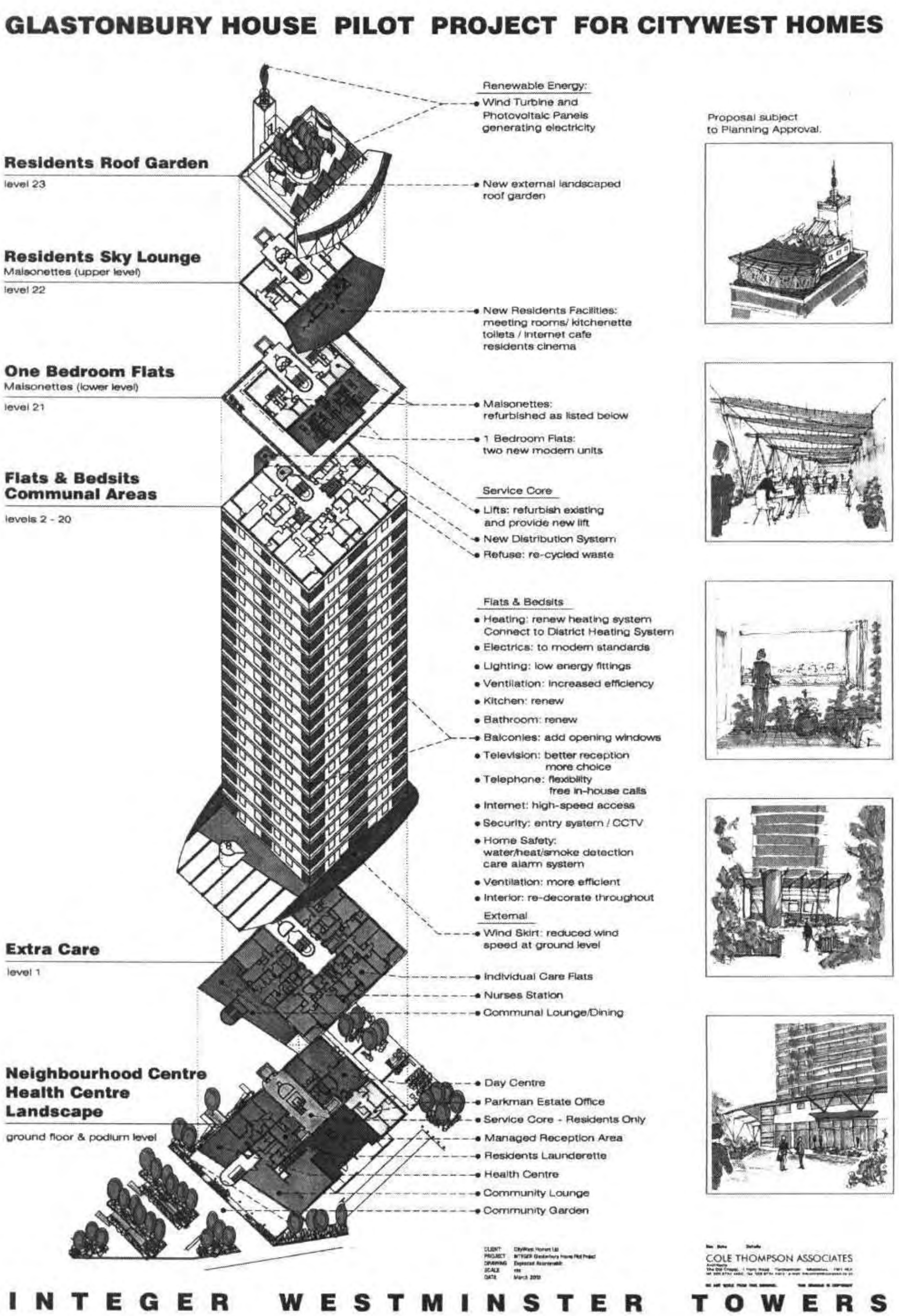


Wind tunnel testing



Towers: turbulence at ground level

Hostile Wind Conditions



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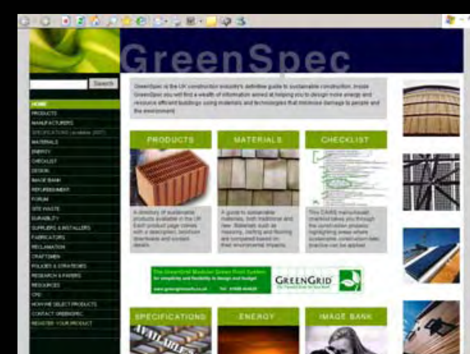
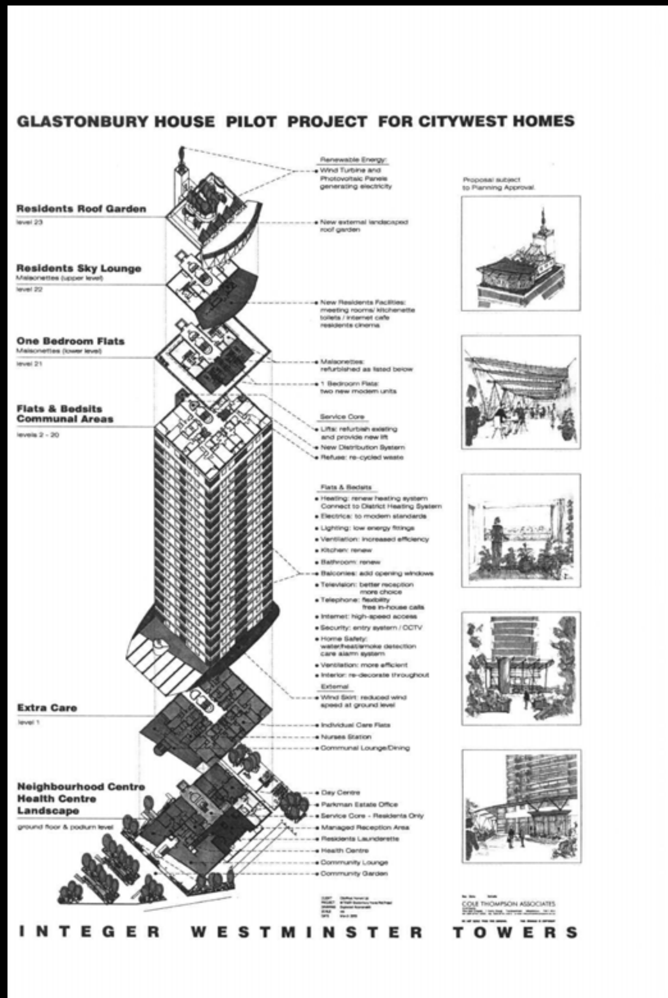
21st C Refurb

1NTEGER

Intelligent and Green

1960’s Tower





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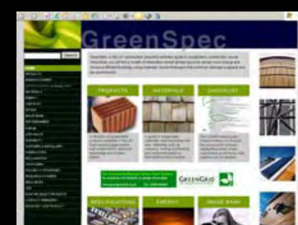

Another GreenSpec CPD seminar to consider

No corners
less resistance
less turbulence
less eddy
currents
No Shelf needed

Wind Orientation: UK

- SW prevailing wind from Atlantic Gulf Stream warm and/or wet, mild in winter
- Northerly cold winds in winter
- Easterly from Mainland Europe very cold and snow bearing in winter
- Southerly warm dry, occasionally sand bearing in summer

Wind orientation: Buildings

- Turn the building away from the northerly cold winds
- Less windows, doors and air bricks on the northerly side
- Well insulated and airtight walls to the northerly winds
- Courtyard buildings protect from the winds

Wind shelter: Landscape Trees

- Local trees, hedges and bushes have a sheltering effect on a building
- They are permeable so most wind passes through and some goes over and around
- It takes some of the pressure out of the wind without too much disturbance
- Deciduous trees to the east, south and west, coniferous to the north
- Fences being solid disturb the air flow

Wind shelter: Creepers & Vines

- Offer little effect on wind loading
- But create a micro-climate sheltering the wall
- Shelter from rain, wind and sun
- Haven for insects, spiders, bugs, birds

Micro-climate & Sheltered space

Trees: Wind shelter, summer solar shading, winter solar penetration

RHS Wakehurst Place Visitors Centre Walters & Cohen

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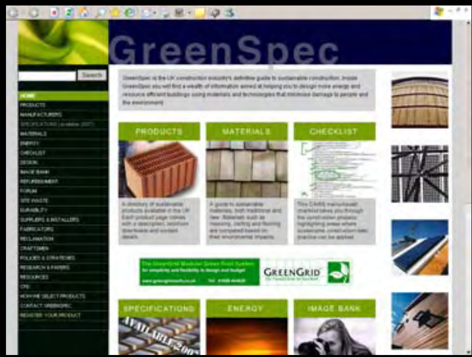
Wind Turbines



Wind turbines:

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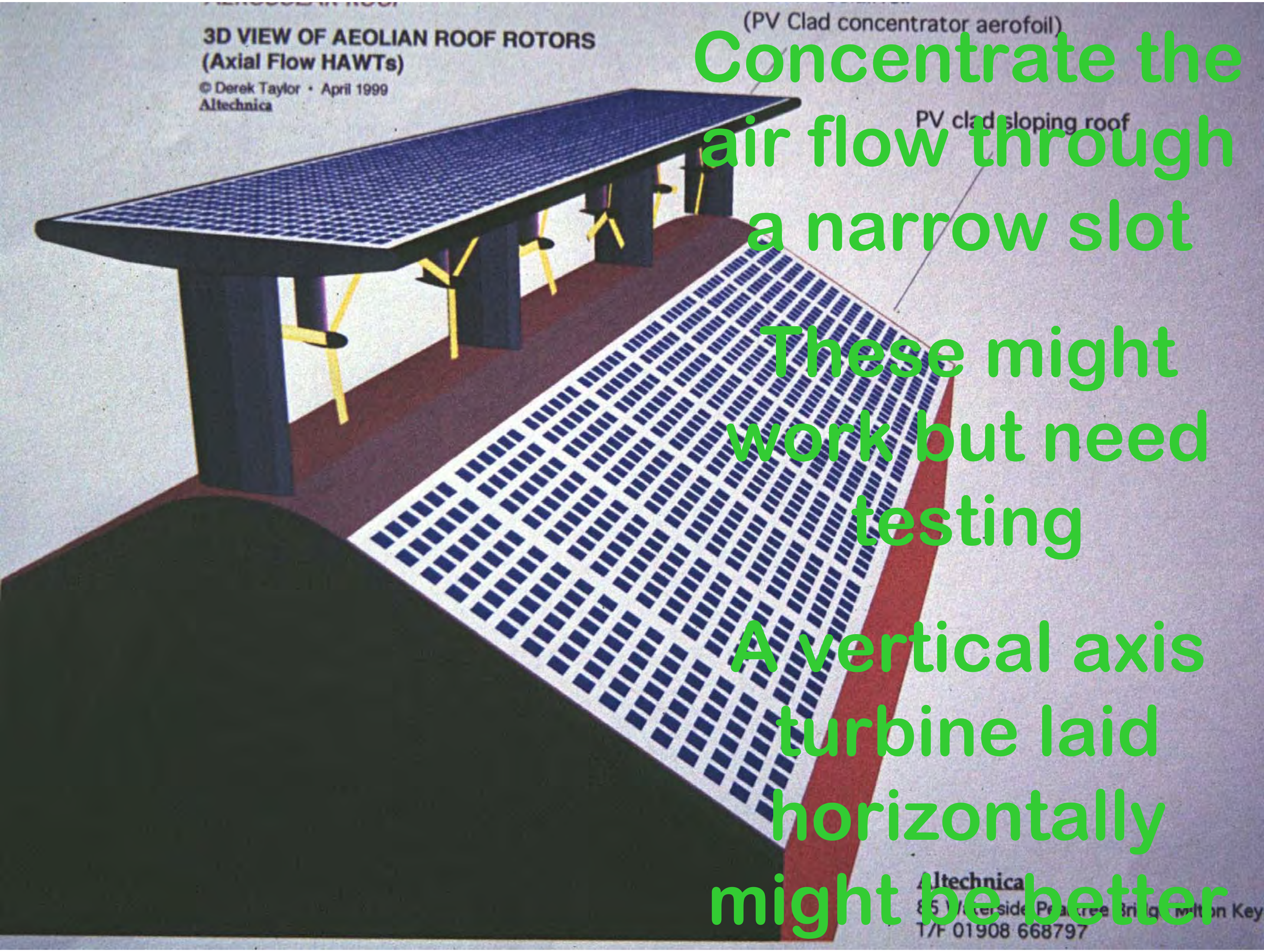
- Attached to building: rarely work efficiently
- Close to buildings: same applies
- Need to be outside of the bubble of displaced air around the building
- High enough or far enough away to receive clean undisturbed air flow

Wind turbines on buildings

Don't work efficiently close to disturbed air flows

Wind turbine

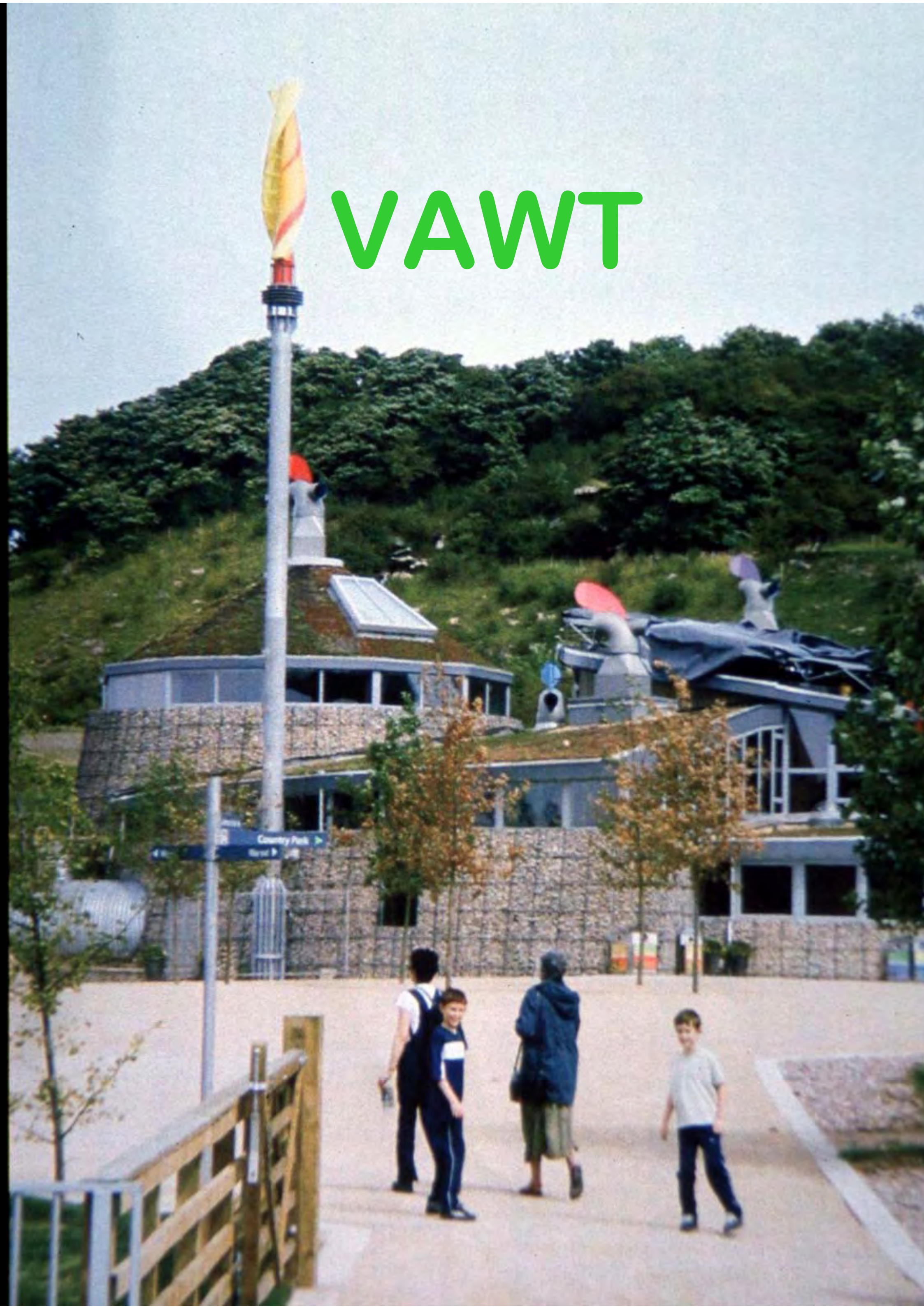
Wind turbine



Concentrate the air flow through a narrow slot

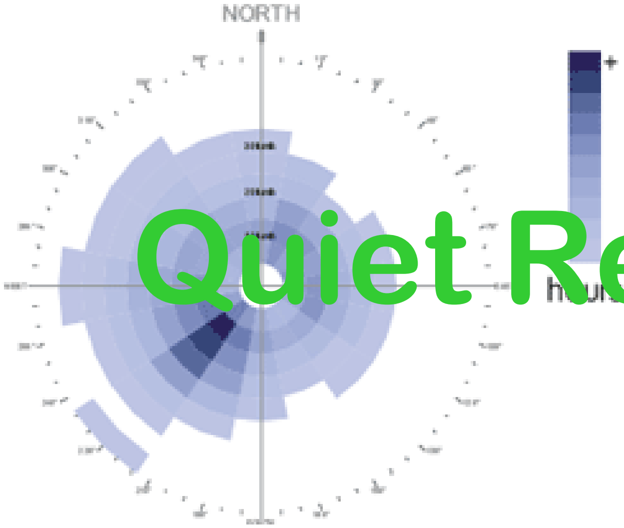
These might work but need testing

A vertical axis turbine laid horizontally might be better


VAWT

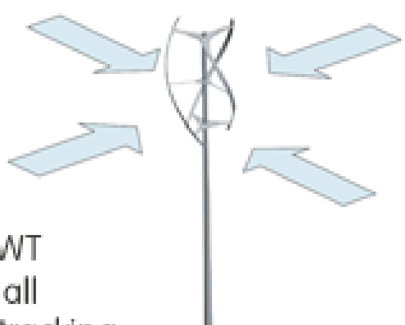

A Vertical Axis Wind Turbine on a tall post
Earth Centre Doncaster

Quiet Revolution™ by XCO_2

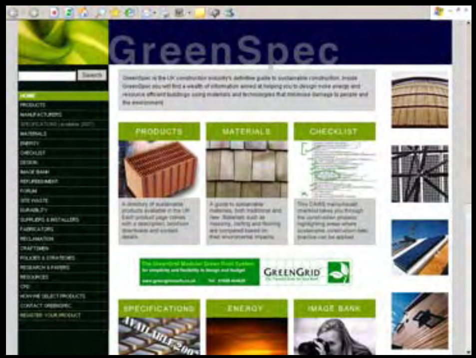


typical U.K. wind distribution

traditional HAWT
has to rotate to track wind



quiet**revolution** VAWT
collects wind from all
directions without tracking



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GreenSpec Design Guidance Articles

Renewable Energy: Wind

NGS GreenSpec Homepage - Windows Internet Explorer

http://www.greenspec.co.uk/index.html

GreenSpec

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- FABRICATORS
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- POLICIES & STRATEGIES
- RESEARCH & PAPERS
- RESOURCES
- CPD
- HOW WE SELECT PRODUCTS
- CONTACT GREENSPEC
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GreenSpec is the UK construction industry's definitive guide to sustainable construction. Inside GreenSpec you will find a wealth of information aimed at helping you to design more energy and resource efficient buildings using materials and technologies that minimise damage to people and the environment.

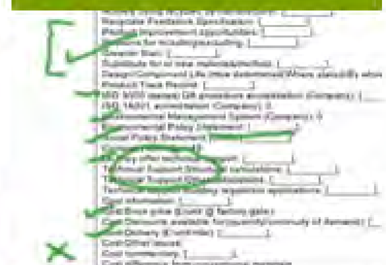
PRODUCTS

A directory of sustainable products available in the UK. Each product page comes with a description, brochure downloads and contact details.

MATERIALS

A guide to sustainable materials, both traditional and new. Materials such as masonry, roofing and flooring are compared based on their enviromental impacts.

CHECKLIST

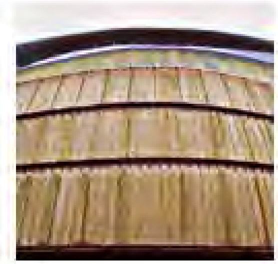


This CAWS menu-based checklist takes you through the construction process highlighting areas where sustainable construction best practice can be applied.

SPECIFICATIONS

ENERGY

IMAGE BANK



NGS GreenSpec - Energy - Contents - Windows Internet Explorer

http://www.greenspec.co.uk/html/energy/energycontent.html

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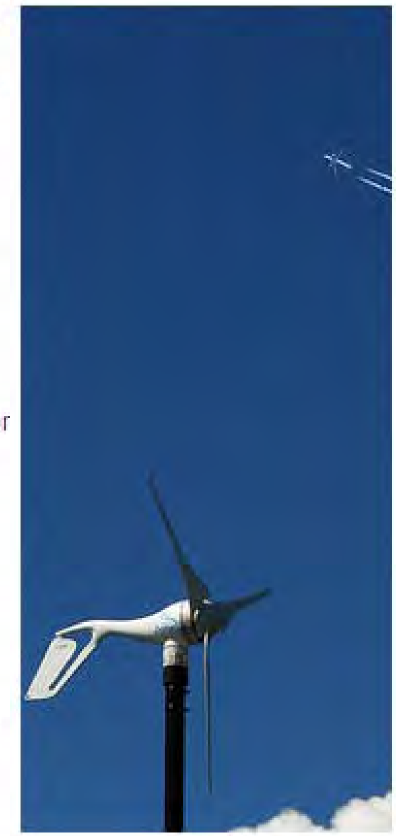
Energy - Contents

- Hot water solar collectors
- Photo Voltaic (PV) Cells
- Ground Source Heat Pumps (GSHP)
- Small Scale Wind Turbines 1 - 6kW
- Mandatory energy calculations

Small scale wind turbines 1 - 6kW

1 Introduction



Of all renewable energies, wind power holds the most promise to make a significant impact on reducing carbon output. The UK is the windiest area of Europe. Commercial windpower, produced by turbines rated at between 1 – 2.5 MW, currently accounts for around 2 GW capacity in the UK. This is expected to expand to 8GW by 2010. The Sustainable Development Commission further estimates that a combination of onshore and offshore generation could theoretically produce a 'practical' maximum of 150,000 gigawatt hours. This figure is just less than half the 345,000 gigawatt hours consumed in the UK in 2005.

Whereas the dynamics of wind power generation are reasonably transparent at the large commercial scale, the same cannot be said for the domestic scale. The current market is marked by turbine performance claims and counter-claims. Most of the take-up of this generation of turbines has been from urban householders keen to cut their electricity bills and/or to do their 'bit' for climate change. The sad fact is that for many their first experience of 'micro generation' has been anything but happy with actual performances often dramatically undershooting expectations.

If used appropriately, domestic wind turbines can generate useful electricity that would otherwise be drawn from the grid - thus reducing the carbon footprint.

For the majority of property owners living in urban areas, installing wind turbines on or close to buildings with overall windspeeds of less than 5m/s is probably not a realistic proposition. Electricity generation will be disappointing and pay-back periods are likely to recede into the distant future.

2 Siting

- **wind power $\propto$ wind speed^3** (eg 2x the wind speed provides 8x the power)

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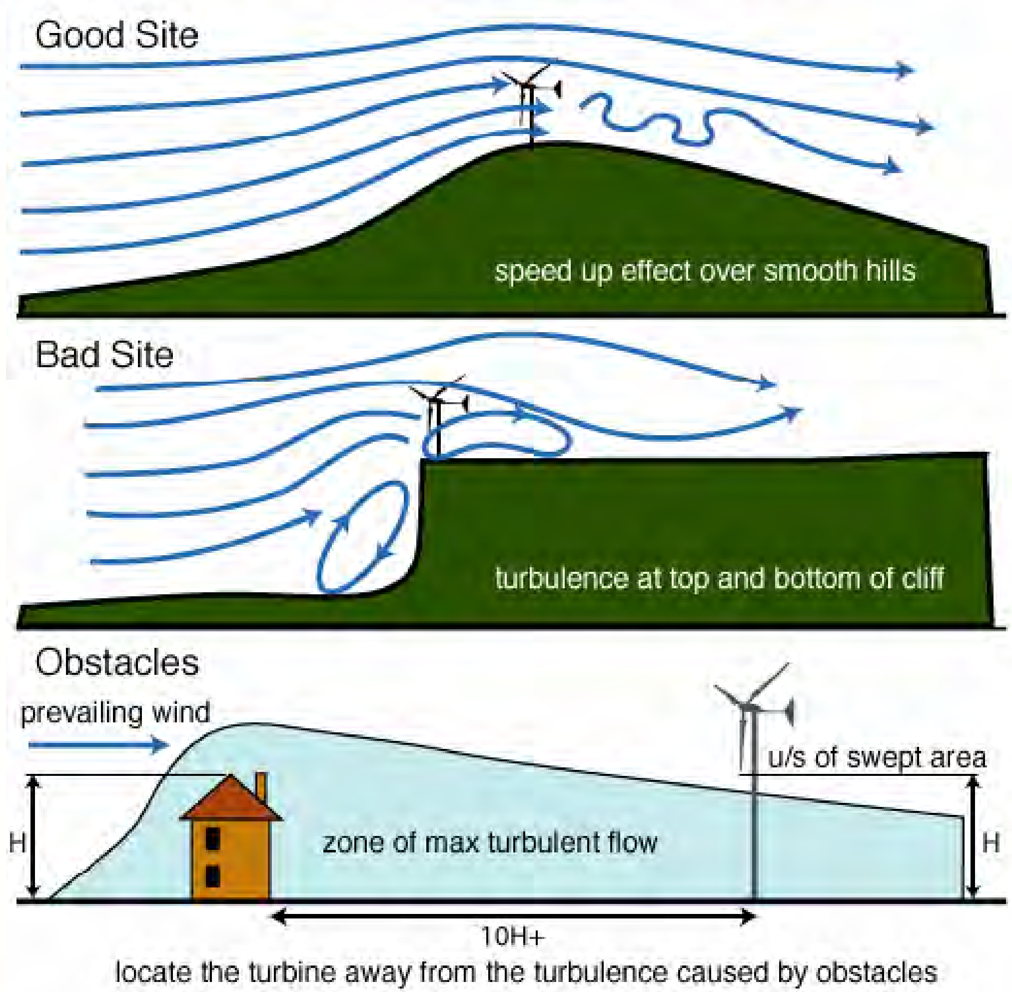
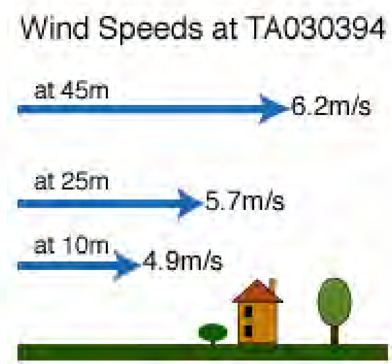
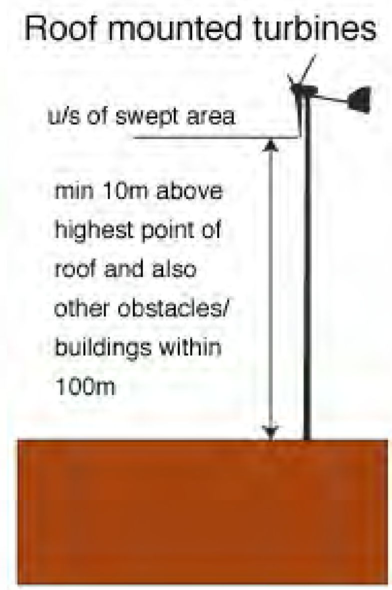






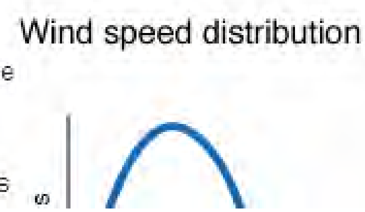
3 Turbine output

Determined by:

1 Quantity of wind at hub height

• Overall windspeeds for a particular site can be found here at the DTI wind data site. Note that these speeds are an overall average for the area. Particular sites can vary according to local topography.

• Frequency Distribution: The number of hours that the wind blows at different speeds. This distribution will be different for each site. When calculating output a mathematical function known as



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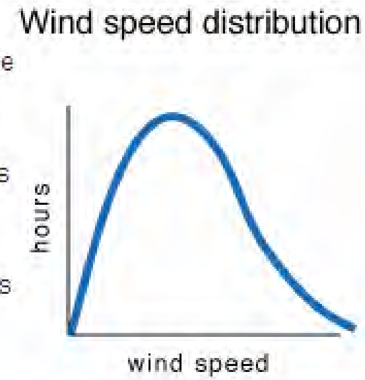
• Frequency Distribution: The number of hours that the wind blows at different speeds. This distribution will be different for each site. When calculating output a mathematical function known as the 'Raleigh Distribution' is used (The Raleigh distribution is a special case of the Weibull distribution which is commonly used for approximating the wind speed probability distribution.

• When designing for an obstacle-rich environment, the height of the obstacles effectively represents ground level for wind speed calculations.



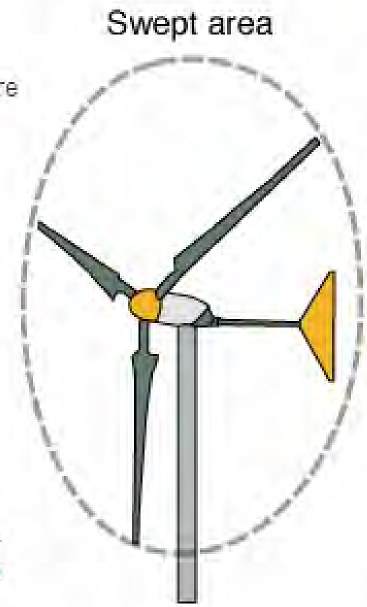
2 Quality of wind

• Obstacles cause turbulence. Turbulence reduces the efficiency of a turbine.

• Ensure that the turbine is set at a height above ground level to avoid turbulence.

• Consider too the direction from which the prevailing wind flows. Obstacles in the path of the prevailing wind are more important to avoid than obstacles in other areas of the wind rose.

• When finely calculating turbine output the nature of the landscape over which the wind travels is considered. This is known as 'Roughness'. It is rated in terms of class with values from 0 to 4 where the sea's surface is '0' and a landscape with many trees and buildings is '4'.



3 Losses due to yaw

• Consider the site's proclivity to wind gusting. Conventional turbines need to turn into the wind to function. Gusts of wind can move a turbine (yaw) erratically around its axis but do little to generate power. Worse, they can seriously contribute to mechanical failure.

4 Swept area of the rota

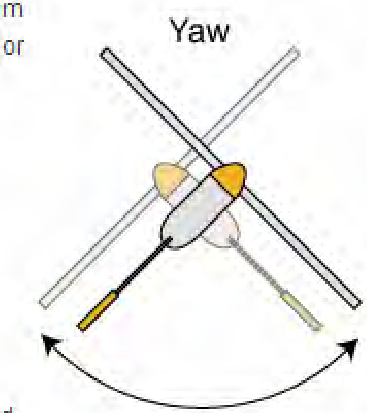
• The swept area of the rota determines the energy capture of the turbine.

• note that the area is not necessarily linked to the size of the generator – the generator cannot generate more power than the rotor can capture. This should be considered when examining manufacturers' output claims.

5 The efficiency of the blade design.

• The maximum efficiency of a turbine in capturing energy from the wind is determined by Betz' Law. The law states that a design can only convert a maximum of 59% of the kinetic energy in the wind to mechanical energy.

• The efficiency of the turbine is determined by the design of the rotor blade. In practice the maximum efficiency obtainable at optimal rotation speed (the aerodynamic power coefficient) is nearer 35% (or 0.35) with efficiency dropping off either side of that speed.



6 Efficiency of the generator

• Generators convert rotational to electrical energy. This process results in energy loss.

• The generator's resistance to the rotor implies that the rotor will only start spinning at a certain speed, this is known as the 'cut in' speed and is usually much lower than the optimal speed at which most power is generated.

7 Cabling losses

• Energy is always lost through transmission (a fact well-known about the national grid).

• Cabling should be carefully specified and designed to minimise losses over distance.

• There is a difference between cabling designed to deliver power to a battery and cabling designed to link in with a grid (ie either directly to a domestic distribution unit or larger grid).

7 Cabling losses

• Energy is always lost through transmission (a fact well-known about the national grid).
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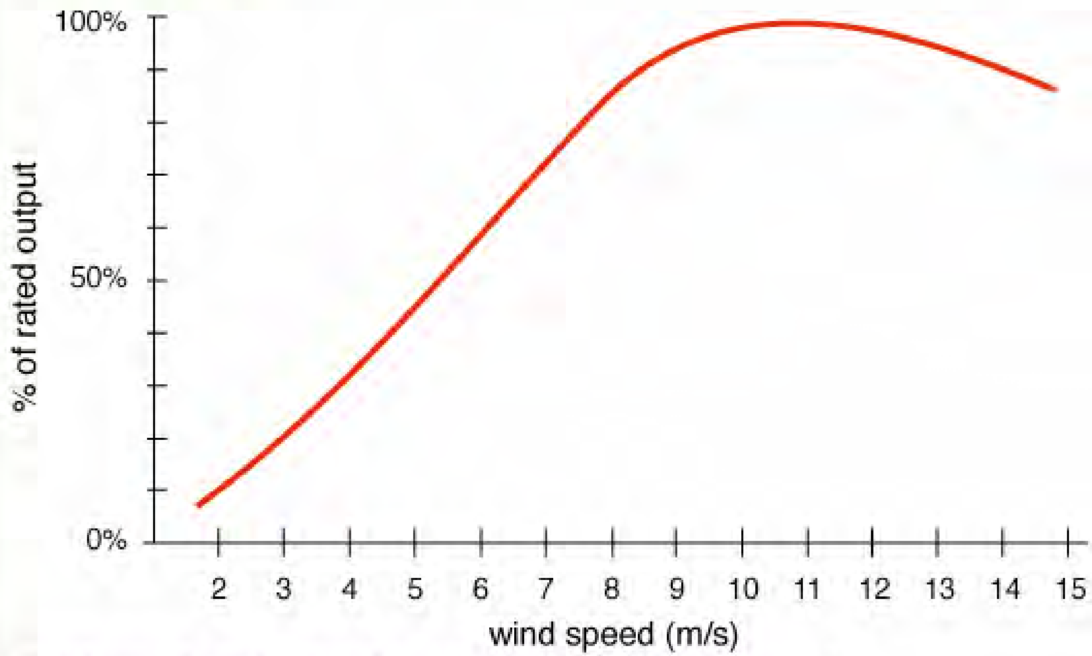
8 Conversion and conditioning losses

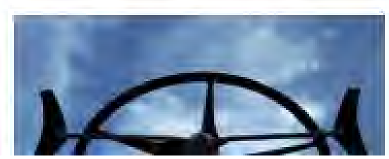
• Turbines connected to batteries energy a voltage regulator is used to prevent overcharging. Energy is lost both in this process and that of exporting the DC supply through an inverter for domestic AC use.
• Likewise turbines that are grid connected require the energy to pass through a grid controller, an isolator and then to a synchronous inverter – all leading to a reduction in energy delivered.

The 'Power Curve'



• To determine the likely output of any one turbine, a 'Power Curve' is used.
• The power curve illustrates the power output at a given wind speed.
• The power curve is distinctive for every model of wind turbine.
• A power curve should be calculated by an independent third-party.

Calculating the power output



A- Using the DWIA calculator

• For accurately determining the likely output from a turbine use the Danish Wind Industry Association's power calculator (www.windpower.org/en/tour/wres/guidep.htm). The calculator works by combining the turbine's power curve (above) with the distribution of wind speeds at a

Calculating the power output

A- Using the DWIA calculator

• For accurately determining the likely output from a turbine use the Danish Wind Industry Association's power calculator (www.windpower.org/en/tour/wres/guidep.htm). The calculator works by combining the turbine's power curve (above) with the distribution of wind speeds at a particular site (the Weibull curve, above). The calculation provides a prediction of the average power output.

• Multiplying the average output by the number of hours in the year (8,766) will give the total energy output for an average year.

or B Using power output equation

• **Output** = CPoa x A x PA x G

Where:

- CPoa is the aerodynamic power coefficient (efficiency of the rotor to convert energy)
- A is the swept area of the blade
- PA is the power density of the wind = 0.6125 x S^3 where S is the wind speed in m/s
- G is the generator efficiency

• *Example:*

For a turbine with a 1.75 diameter rotor at a wind speed of 10m/s with a power coefficient of 0.35 (generous!) and a generator effiency of 90%:

Output = 0.35 x (3.1416 x $(1.75/2)^2$) x (0.6125 x 103) x 0.9 = 464W

Using the same equation but for a wind speed of 5m/s would give an output of 58W

• **Annual output** = output at average wind speed x 1.9 (wind speed variation function) x 8766 (hours in the year)

• *Example:*

Following on from the above example, the annual output for a turbine with 1.75 diameter rotor at an average overall windspeed of 5m/s would be:

Annual output = 58 x 1.9 x 8766 = 966,000 W or 966 kWhrs/pa

4 Assessing manufacturers' claims

4 Assessing manufacturers' claims

The output 'Rating'

- The turbine manufacturers rate their turbines as providing a certain output at a given wind speed. Some rating definitions are those wind speeds providing maximum output whilst others are less than maximum outputs at different wind speeds. There is no industry standard.
- The rating for a turbine is unlikely to be an indication of its actual energy production.

Checking the claimed output rating against the likely efficiency

We know from the above that the maximum practical efficiency is around 35%. Most turbines work at efficiencies of between 22% - 31% at 10m/s and between 17% - 26% at speeds of 12m/s. If we take the manufacturers output rating for a given wind speed and insert it into the above output equation and calculate the assumed efficiency, we can judge the manufacturer's claim.

• *Example:*

If a manufacturer of a 1.75m diameter turbine claims a rating of 1kW for a wind speed of 12.5m/s, we can easily determine his assumed efficiency:

CPoa (Efficiency) = Output / A x PA x G

$= 1000/(3.1416 \times (1.75/2)^2) \times (0.6125 \times 12.5^3) \times 0.9$

or 38%

38% is a long way off from the circa 26% max. expected from others at the same wind speed!

Checking the annual % of household electricity consumption

By calculating the annual expected actual output from a wind turbine, it is then but a short step to be able to determine the likely percentage of household electricity consumption that the turbine will provide.

• *Example:*

Taking the above example of a 1.75m diameter turbine. We have calculated, given generous parameters, that the turbine could be expected to provide around 966 kWhrs/pa at an average overall windspeed of 5m/s. Let us assume that the annual domestic consumption is around 5,000 kWhrs/pa. Then the % of annual consumption to be reasonably achieved would be:

• *Example:*
Taking the above example of a 1.75m diameter turbine. We have calculated, given generous parameters, that the turbine could be expected to provide around 966 kWhrs/pa at an average overall windspeed of 5m/s. Let us assume that the annual domestic consumption is around 5,000 kWhrs/pa. Then the % of annual consumption to be reasonably achieved would be:
966/5000 x 100 = 19%

This can be easily compared with the manufacturer's claim.

Costs and Savings

a Darius rotor

• The installed costs of small scale turbines can vary from around £2,500 for a 1.5kW rated turbine though to around £5,000 for a 5kW.
• The payback time is the amount of time it takes to pay for the installation through electricity saved from the grid – a time after which electricity becomes free. The payback time is depends on the initial installation cost, the price of electricity and the power output from the turbine.

Example:
Taking the above example of a 1.75m diameter turbine generating a realistic 966 kWhrs/pa at an average wind speed of 5m/s and given the current cost of electricity at around 12 pence per kWh the payback time would be calculated as follows:

966 x 0.12 = £115 saved per year (excluding maintenance)
Therefore the number of years required to payback = £2,500 / 115 = 21 years.

21 years might be close to or exceed the life expectancy of the turbine.

• However, it should be noted that this calculation is based on current purchase and installation costs along with current electricity prices.
- Higher average wind speeds would reduce the pay back period.
- In the near future unit costs are expected to reduce and electricity costs are likely to rise.

Wind Tubine products

L742 wind turbines / generators - including Windsave, Iskra and Swift turbines

Downloads

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a Darius rotor

Example:
Taking the above example of a 1.75m diameter turbine generating a realistic 966 kWhrs/pa at an average wind speed of 5m/s and given the current cost of electricity at around 12 pence per kWh the payback time would be calculated as follows:

966 x 0.12 = £115 saved per year (excluding maintenance)
Therefore the number of years required to payback = £2,500 / 115 = 21 years.

21 years might be close to or exceed the life expectancy of the turbine.

• However, it should be noted that this calculation is based on current purchase and installation costs along with current electricity prices.
- Higher average wind speeds would reduce the pay back period.
- In the near future unit costs are expected to reduce and electricity costs are likely to rise.

Wind Tubine products

L742 wind turbines / generators - including Windsave, Iskra and Swift turbines

Downloads

• Wind Power in the UK - *Sustainable Development Commission, 2005* (pdf)
• Small Wind Energy Systems - *British Wind Energy Association, 2006* (pdf)
• Potential for Microgeneration, Study and Analysis - *DTI, 2005* (pdf)

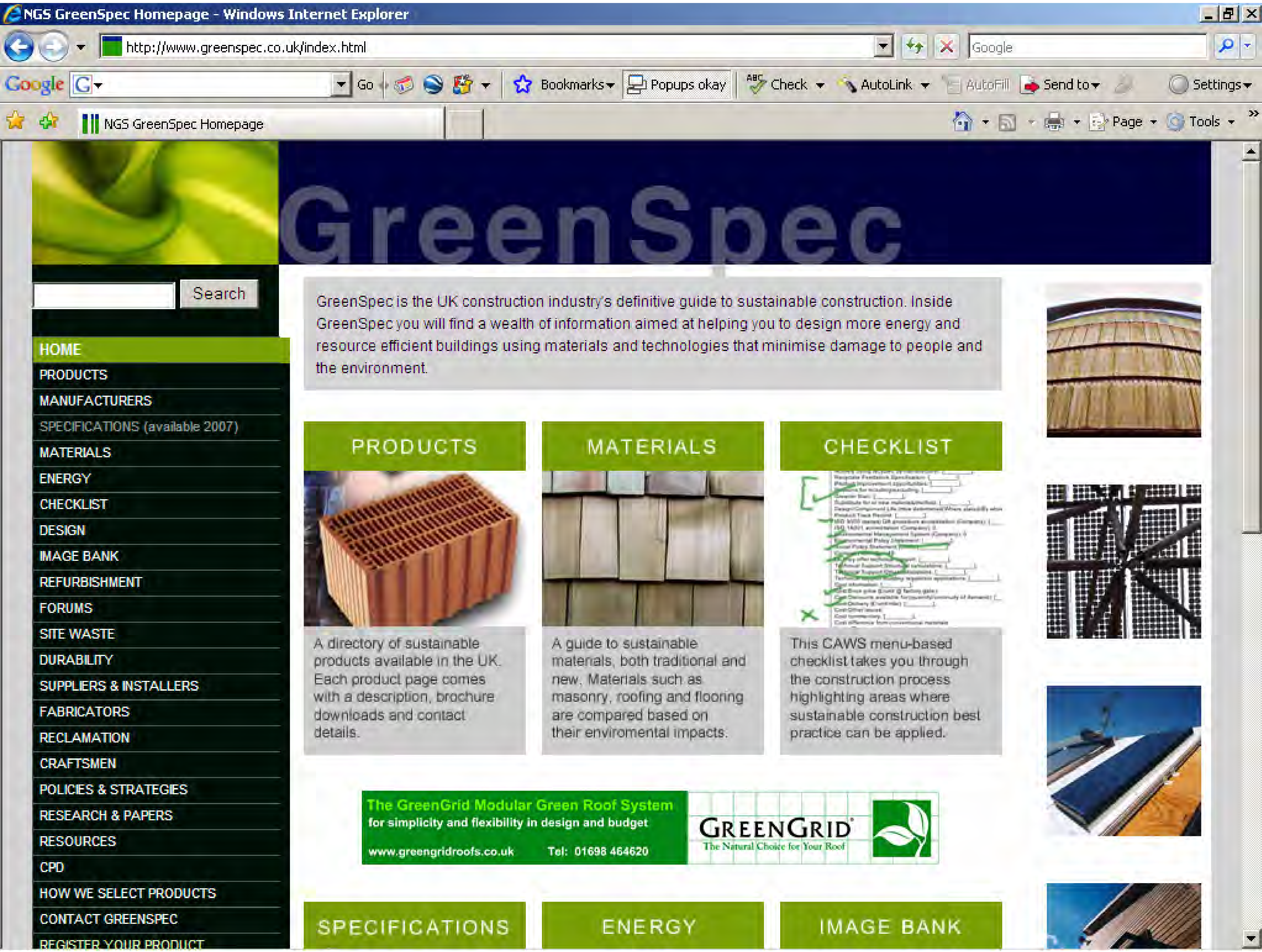
Further information

• British Wind Energy Association
• Danish Wind Industry Association - everything you ever wanted to know about wind energy

www.greenspec.co.uk

GreenSpec Products

Renewable Energy: Wind


NGS GreenSpec Homepage - Windows Internet Explorer
http://www.greenspec.co.uk/index.html
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GreenSpec is the UK construction industry's definitive guide to sustainable construction. Inside GreenSpec you will find a wealth of information aimed at helping you to design more energy and resource efficient buildings using materials and technologies that minimise damage to people and the environment.
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A directory of sustainable products available in the UK. Each product page comes with a description, brochure downloads and contact details.
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A guide to sustainable materials, both traditional and new. Materials such as masonry, roofing and flooring are compared based on their enviromental impacts.
CHECKLIST
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L742 Transformation devices

wind turbines / generators

Manufacturer	Product	Type	
Swift Turbines	Swift Rooftop Wind Energy System	1.5kW wind turbine	✓
Iskra	Iskra AT5-1	5kW wind turbine	✓
Windsave	Windsave	1kW wind turbine	✓

photovoltaic cells / coverings, modules, glazing

roof coverings

Manufacturer	Product	Type	
Atlantis	Sunslates	PV slate, 13.3W output per tile	✓
Uni-Solar	Solar Shingles	PV slate, 17W output per tile	✓
solarcentury	C21e: Solar electric roof tiles	PV slate, 52W output per tile	✓

modules

Manufacturer	Product	Type	
Sanyo	HIP-200, HIP-205, HIP-210	PV modules, monocrystalline, 200, 205 & 210W ratings	✓
Sharp	80W, 123W, 160W, 165W PV modules	PV modules, polycrystalline, 80, 123, 160 & 165W ratings	✓
	'175W & 185W PV' modules	PV modules, monocrystalline, 175 & 185W ratings	✓
solarcentury	Solar Electric 'Sunstation'	PV roof module system for domestic use	✓
Uni-Solar	Framed Solar Modules	freestanding PV framed modules 62W & 124W ratings	✓
	Flexible Solar Laminate	flexible PV laminate with a 5, 11 & 32W ratings	✓
Kaneka	Kaneka 60W	Roof-mounted PV thin-film module, 60W rating	✓

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Iskra AT5-1

5kW wind turbine

The energy capture of the Iskra AT5-1 turbine is unusually high at low wind speeds, thus making wind energy generation feasible at locations where the average wind speed is low.

At a particular location, the wind speed will vary about an annual mean value. The expected energy yields for the AT5-1 at various annual mean wind speeds (AMWS) have been estimated, based on the measured power curve.

Figures show that the the performance of the AT5-1 exceeds that of other machines in its class. Put into perspective, the annual electricity consumption of a medium size home is in the region of 4 to 6 MWh. This is equivalent to a daily consumption of 11 to 16 kWh.

Clearly, therefore, an AT5-1 wind turbine is capable of keeping domestic or small commercial premises fully supplied with electricity. It can also make a substantial contribution to the needs of larger consumers, such as farms, visitor's centres, campsites etc. '

Manufacturer's evidence rating:*	★
Material/s:	blade: glass-plastic composite
Environmental statement:	yes
BRE Ecopoints:	unrated
BRE Environmental profile:	unrated
Other environmental standards:	none
3rd party accreditation:	none
3rd party product endorsement:	none
Reusability / Recyclability:	partly recyclable
% of post consumer waste:	unknown
Life expectancy	unknown

Air Movement in Buildings: 2 of 9
Sub-topics in 10 separate files

- Principles of Element Design
- Climate Change
- Wind
- Wind Tunnel Testing
- Wind Turbines
- Natural Ventilation
- Moisture Vapour & Condensation
- Thermal Insulation
- Breathing Construction
- Airtightness
- Wind & Airtightness Testing
- Building Elements
- Passive Ventilation
- Active Ventilation
- Stack Effect
- Atrium
- Solar Orientation & Solar Gain
- Conservatories
- Thermal mass
- Conduction, Convection, Radiation
- Solar Shading
- Thermal mass, Passive and active cooling
- Fluid dynamics
- Mechanical Ventilation
- Air-Conditioning
- Questions and Answers

Test Yourself Part 2

- How can wind be exploited in buildings
- How can wind turbulence be avoided around tower block bases
- What are the pitfalls of wind turbines attached to buildings
- When and where are vertical axis wind turbines the better choice

How did you do? Part 2

- Opening up the building for passive ventilation, cross flows to refresh the air and remove moisture
- Podium, Shelf, Skirts around the base above pedestrians
- Being too close the building inside the turbulence bubble, efficiency drops off
- In urban area, disturbed air, wind coming from all direction