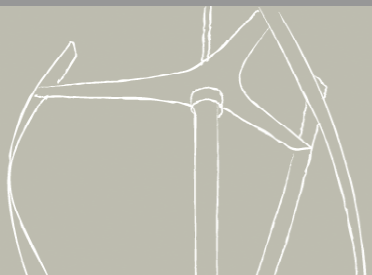


Evaluating Wind Resource

Presentation to explain issues and complexity. It is to be used to gauge level of wind resource rather than to make firm conclusion on any specific site.



UNCERTAINTY

Year to Year

$\pm 17\%$ from mean

qr fleet ave. 6 months old

$\pm 12\%$ seasons

we do not know if 2008 was a windy or calm year

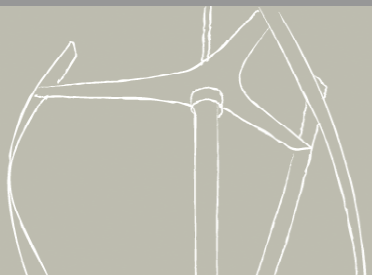
we do not know within 2008 which months were above / below average

Easy to make errors using desktop tools

$\pm 25\%$

INACCURACY

$\pm 40\% !$



Wind - The Big Picture

Continental scale : 3 major factors:

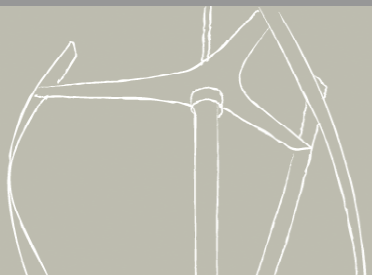
- Large temp difference between polar air and subtropical air to south
- Distribution of land and sea – Atlantic to the west and large land-mass of Asia to east, Mediterranean sea and Africa to the south
- Orographical barriers: alps, Pyrenees, and Scandinavian mountain chain.

Dominant weather system :

- Cyclones and anticyclones moving east or north east across the Atlantic to Europe.
- As cyclones move to land from sea they become weakened, i.e. generally the further from the Atlantic the lesser the general effect of the cyclone systems.

Variation Across Europe

- The available energy from the highest wind resource country – the UK is 10x that of the country with the smallest wind resource.



Weather

- Dominated by weather systems crossing atlantic from west to east
- Wind resource above boundary layer far more consistent

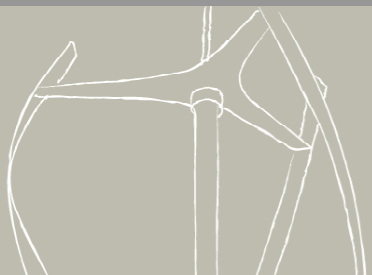
UK Wind Climate

- Ocean, coastal sites and hill top sites with small daily variation through the year
- Inland sites with large daily variation in summer and small daily variation in winter.
- Substantial variations occur not only on the continental scale, but far more locally. Generally the more complex the terrain the more localised the variation will be.

World survey of climatology [landsberg and wallen 1970, 1977]

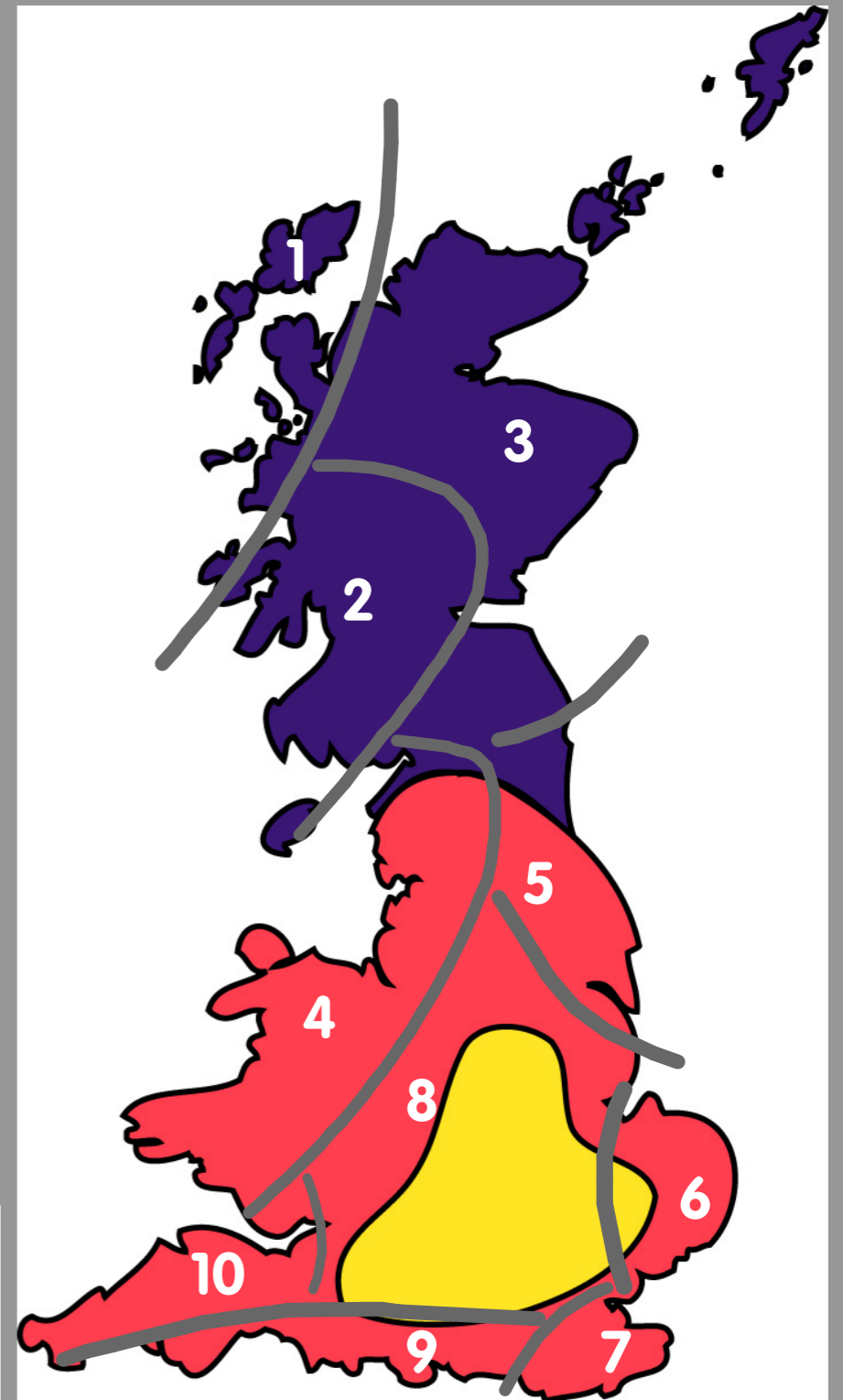
Climate period

- Seasonal variation
- Year on year changes



Regional Wind Climate

1. Western Isles [Scotland]
2. West Scotland
3. East Scotland
4. Wales & NW England
5. NE England
6. East Anglia
7. SE England
8. Midlands [no coast]
9. S coast England
10. Devon & Cornwall



8

6

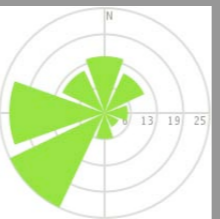
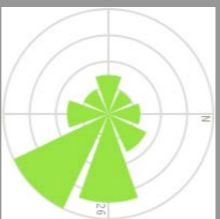
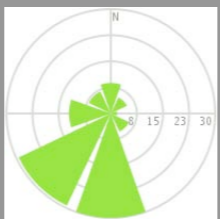
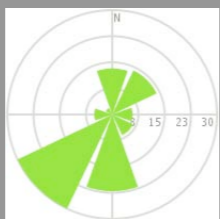
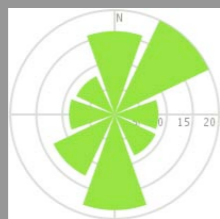
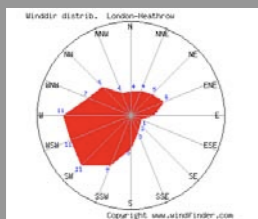
8

4

4

8

4



Heathrow - Typical ???



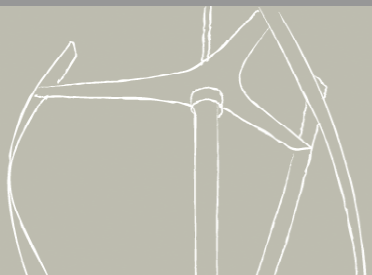
Probability Distribution

The most important statistic derived from data sets.
It is the distribution that provides the average annual energy production NOT the AMWS.

To obtain the power output for a site, one combines the wind probability distribution with the turbines power curve.

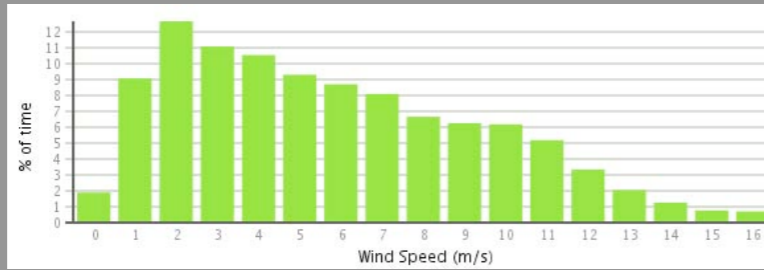
It is not possible to predict the probability distribution from the AMWS

Without detailed knowledge of a sites wind probability distribution it is usual to apply a Rayleigh distribution.

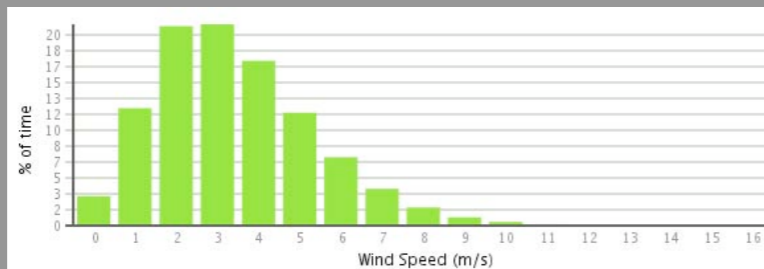


Probability Distribution

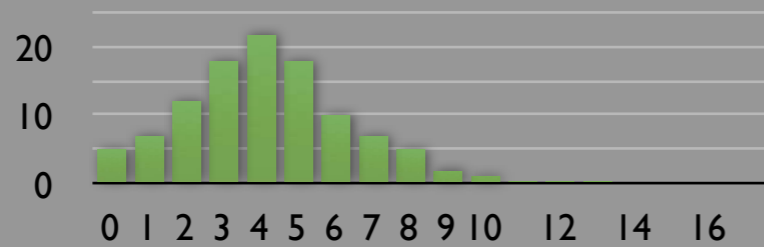
Coastal



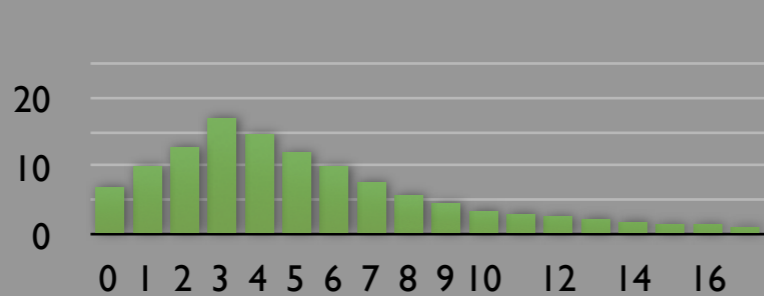
City Centre



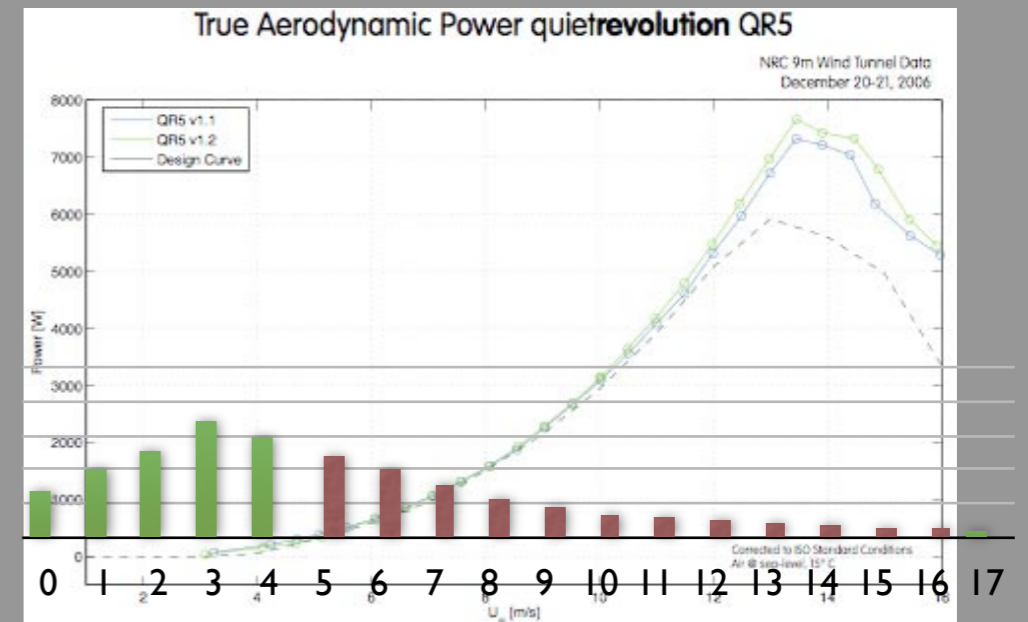
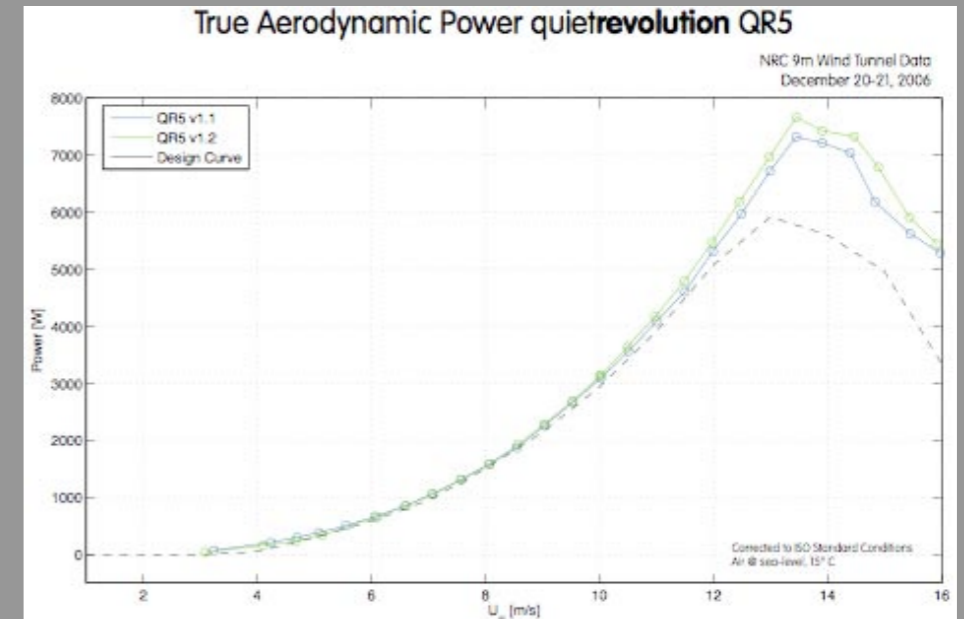
2 hypothetical sites



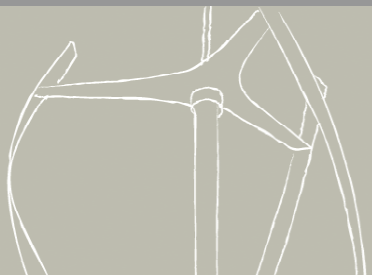
same 4 m/s
AMWS
different
power
outputs



because qr5 power curve



Red shows power generation



quietrevolution

Orography

100-200km scale

The study of the formation and relief of mountains, hills, and any part of a region's elevated terrain.

Topography

10-20km scale

The study of Earth's surface features

Concerned with local detail, primarily relief, but also including vegetative and human-made features.



Topography - single hill

10-20km scale

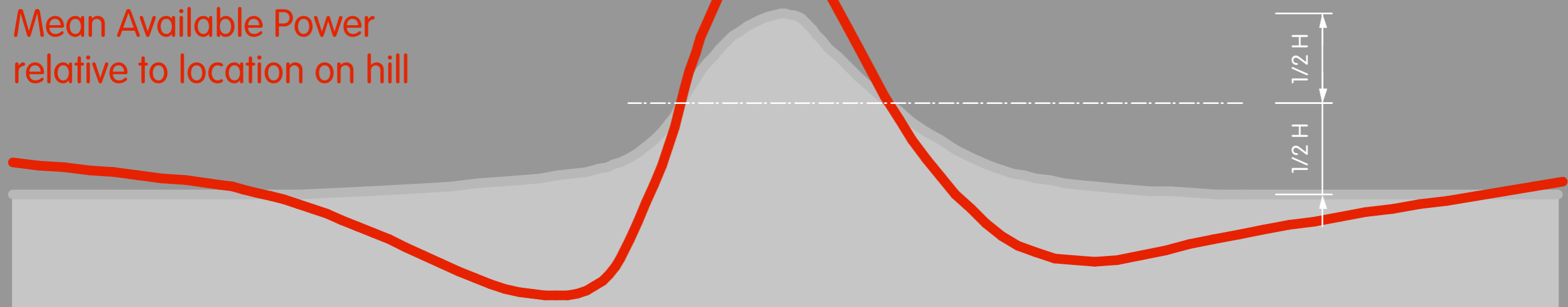
Steep slope

- Less power close to hill
- Quicker recovery away from hill

Shallower slope

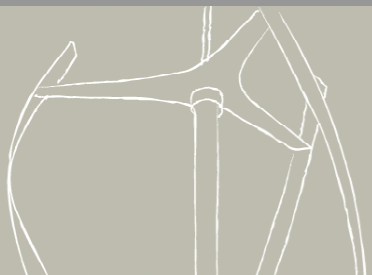
- Slower recovery

Mean Available Power
relative to location on hill



Acceleration

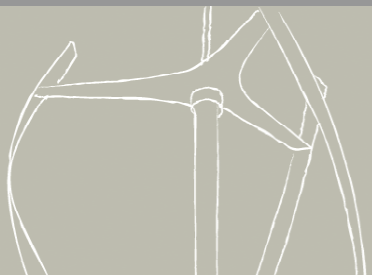
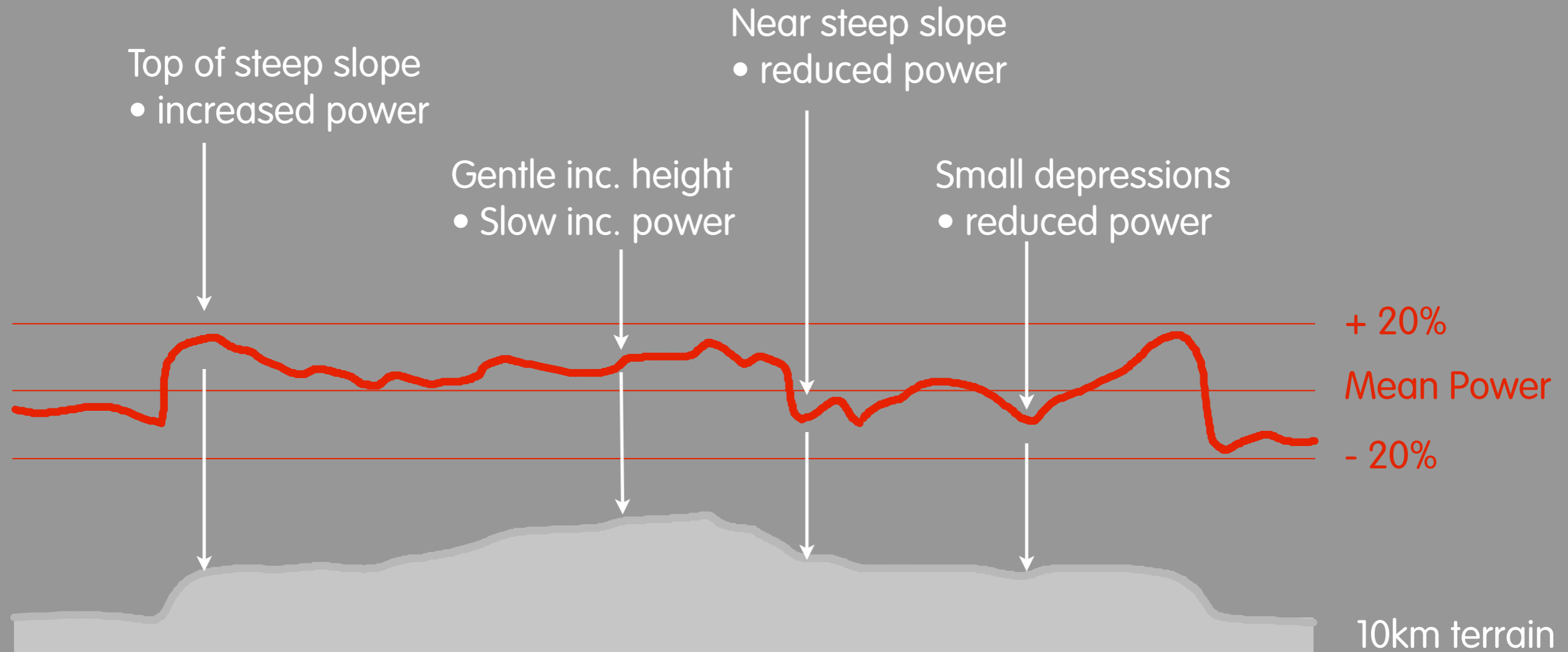
5% increase in power [not amws] for
each 5% inc. height over 1/2 height



quietrevolution

Topography - complex landscape

10-20km scale



quietrevolution

Shadowing

Buildings
Woodland
Hills

The challenge:

How to quantify the effects of obstructions and obstacles

Acceleration

Buildings
Hills

A very steeply sloping hill or a tower building can be considered as an extension to the turbine mast

A gently rising hill can be considered as a blockage causing accelerated flow



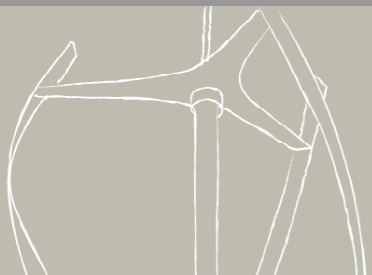
Prediction Target

From Desktop Study

Within 10% of Actual AMWS at Centre of Rotor [CoR] on 75% of sites

Within 20% of Actual AMWS CoR on remainder

Worst Case Average Error 12.5%



Information sources

qr recorded data on installed sites

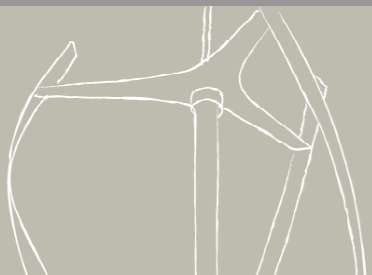
Predictions

NOABL

MIS 3003

SAP calcs [CIBSE]

Estimations



NOABL

Variation from qr recorded:	- 2.7m/s Hub Sports to + 0.1 Beam reach
Average from qr recorded:	- 1.4 m/s
Number sites within 10% of recorded	6 / 36
Number sites over 5.0 m/s - Centre of Rotor [CoR]	34 / 39



MIS 3003

Variation from qr recorded: - 2.6m/s LRC to + 0.9 Maryport

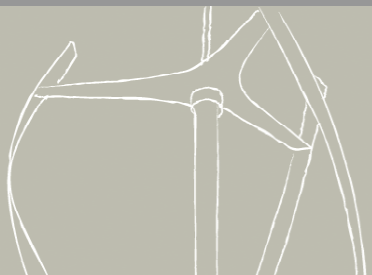
Average from qr recorded: - 0.3 m/s

Number sites within 10% of recorded 15 / 36

Number sites over 5.0 m/s - CoR 4 / 39

Using MIS 3003 = 4no. Sales

sites missed using MIS : Sainsbury
Dartmouth; Beam Reach; LRC; Blackpool;



SAP calcs [CIBSE]

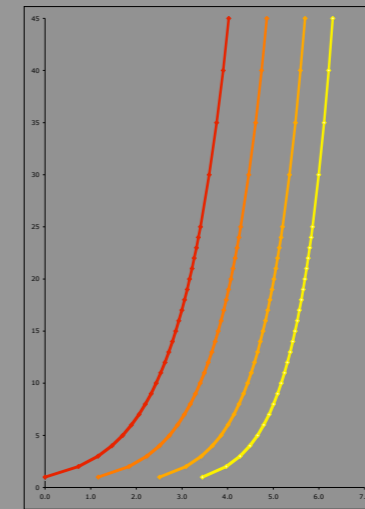
SAP Calcs Variables

Adjust for surface roughness

Definitions are subjective, too many locations do not fall neatly into categories

Need to expand categories & provide consistent definitions

Coastal
Rural
Suburban
Urban



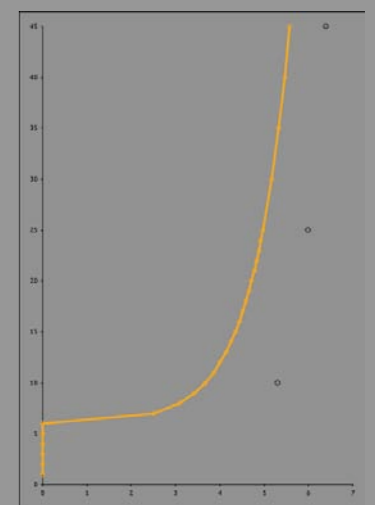
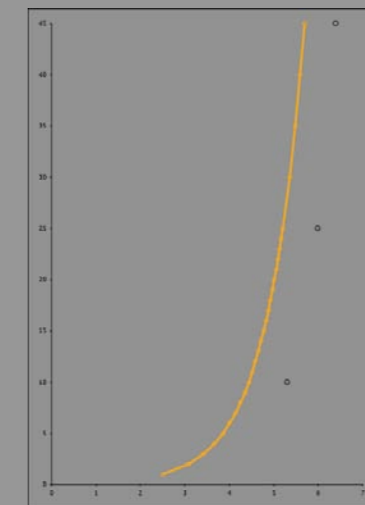
Coastal
Open Water
Rural Open
Rural
Suburban
woodland
Urban

Adjust for Boundary layer height

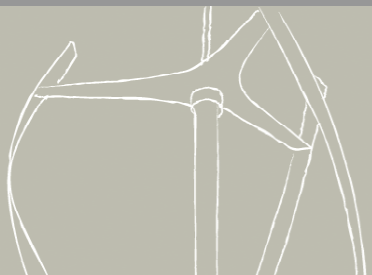
[Ground Plane Adjustment]

e.g. Suburb : roof tops 9m,
assume the surface boundary layer starts at 9m? 4m?
Danger of double adjusting

e.g. dense wood : canopy at 16m,
assume the surface boundary layer starts at 16m? 8m?
Would depend on category of surface roughness used



Measuring AMWS / Height



SAP calcs [CIBSE]

Full

R'ness

B' layer

Variation from qr recorded:

- 1.7 LRC to
+ 1.8 Leic col

- 1.5 LRC to
+ 2.7 Leic col

- 0.5 Beam R to
+ 2.7 Leic col

Average from qr recorded:

- 0.1 m/s

- 0.5 m/s

- 0.7 m/s

Number sites within 10% of
recorded:

20 / 36

10 / 36

8 / 36

Number sites over 5.0 m/s
- CoR:

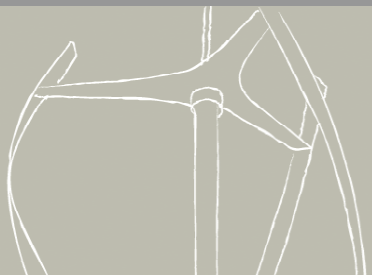
6 / 39

8 / 39

11 / 39

Using SAP = 6no. Sales

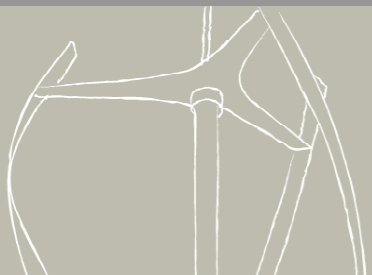
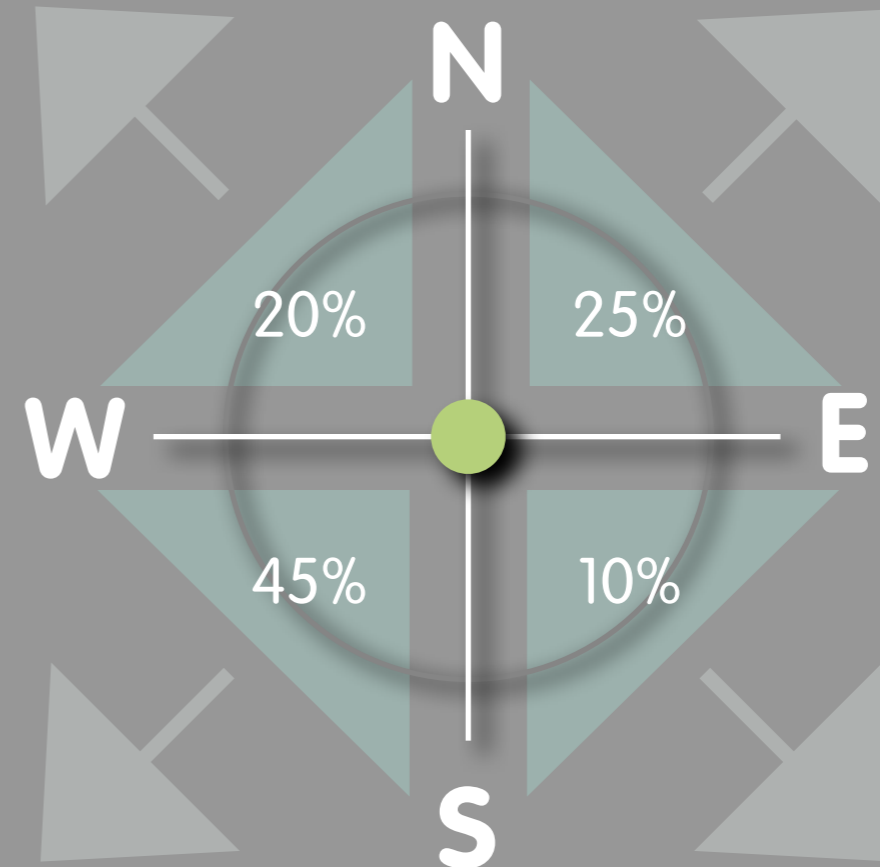
sites missed using SAP [full] : Sainsbury
Dartmouth; Beam Reach; LRC



quietrevolution

quietrevolution methodology

- Split compass into quarters
- allocate percentage of wind from each quarter
- Use SAP calculation methods as basis
- Improve SAP methodology
- adjust NOABL for terrain in each quarter [topography & roughness]
- adjust for height above / below mean over 5 km²



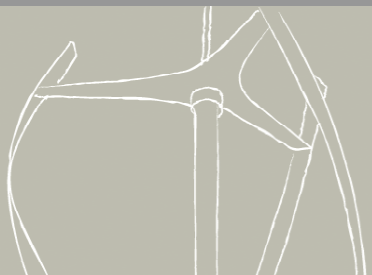
Site : East Kilbride

Description

- Turbines in grounds of store
- Location on relative high ground
- Town to South and open country to North

Site Elevations

- Falling in all directions except East
- To East land rises approx. 10m and then falls.
- To S/E, S and S/W land rises slowly from approx. 3km to 10km



Site Information

for the 1km grid square 264 656 (NS6456)

Wind speed at 45m agl (in m/s)

8.4	8	7.6
8.2	7.9	7.6
7.7	7.6	7.7

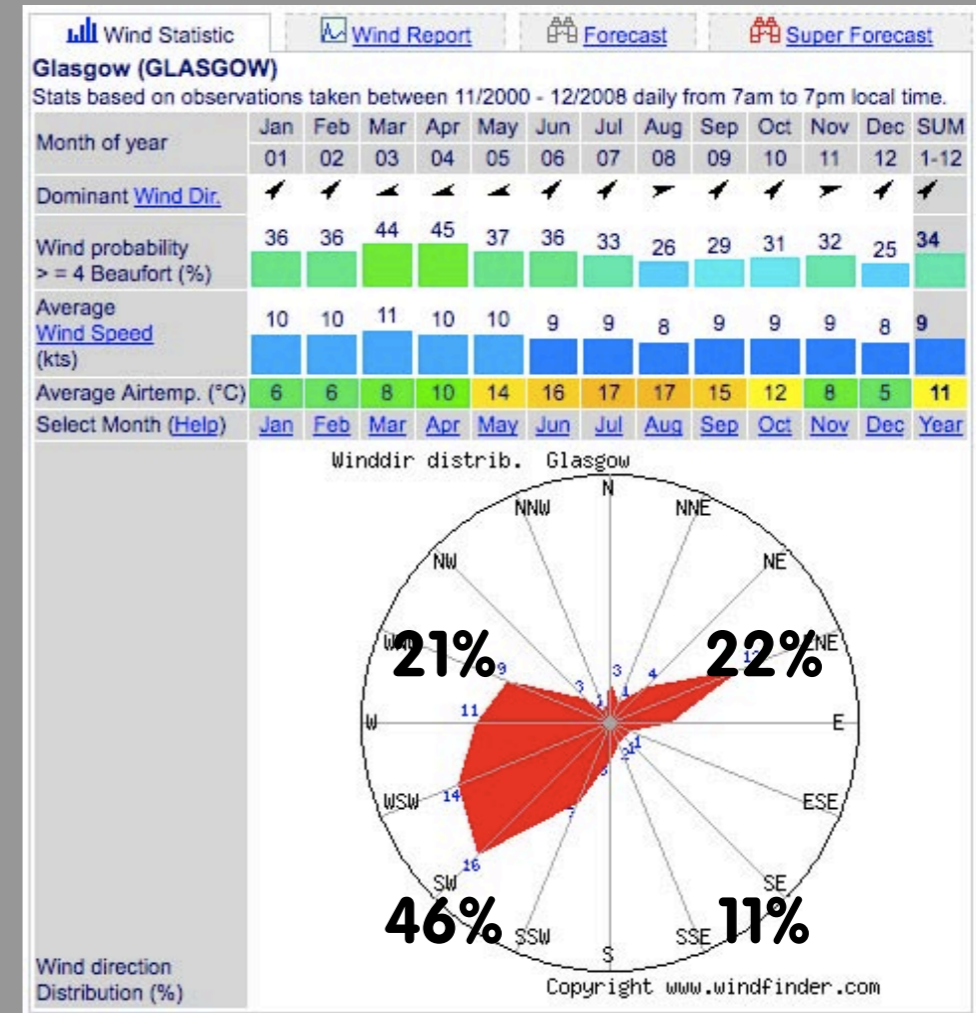
Wind speed at 25m agl (in m/s)

7.9	7.4	7
7.6	7.3	6.9
7	6.9	7

Wind speed at 10m agl (in m/s)

7.3	6.7	6.2
6.9	6.5	6.1
6.1	6.1	6.2

Grid Ref: NS640566
NOABL Database information
for 1km square at site



Wind rose
Percentages of resource by quarters

Site Information

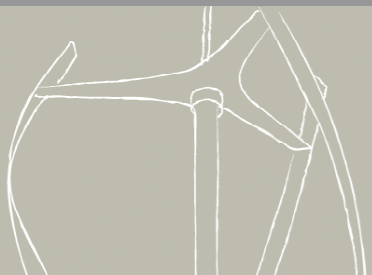
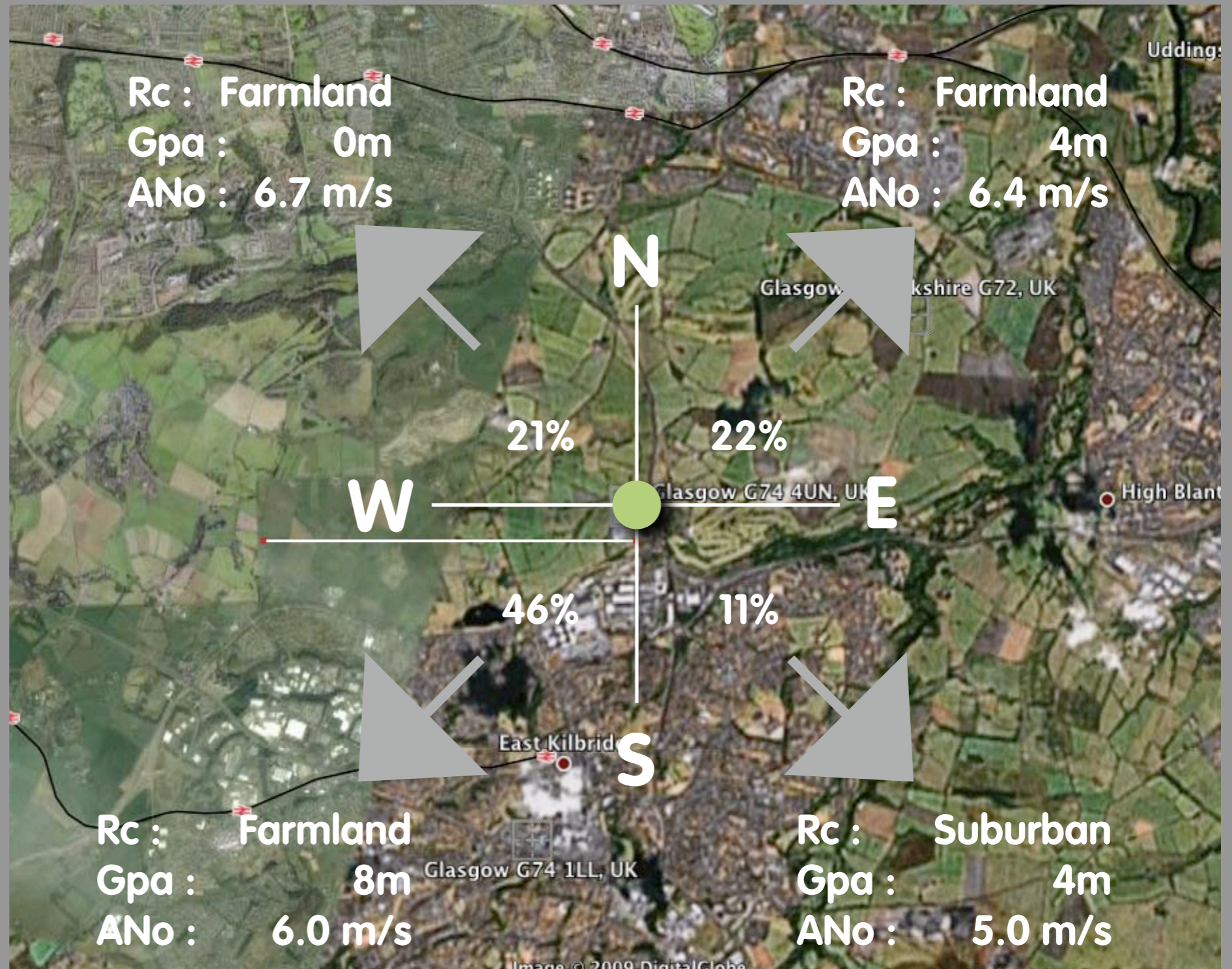
Calculations based on SAP

Centre of Rotor Height : 17.5m AGL

NOABL at CoR 6.9 m/s

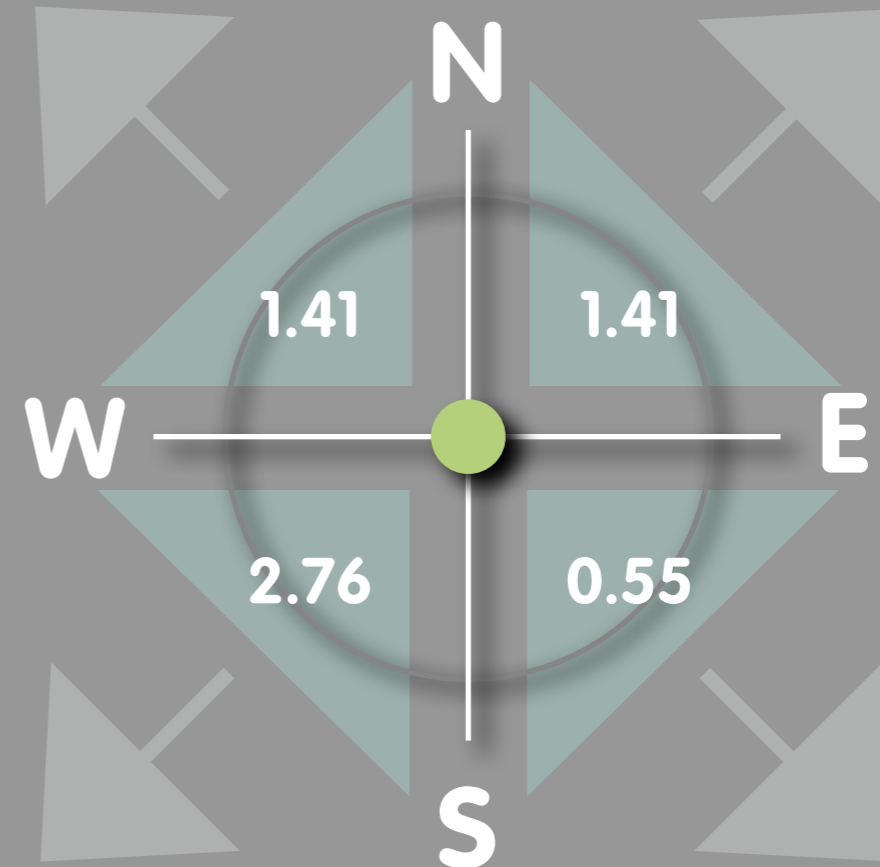
Key

- Rc Roughness Category
- Gpa Ground Plane Adjustment
- ANo Adjusted NOABL



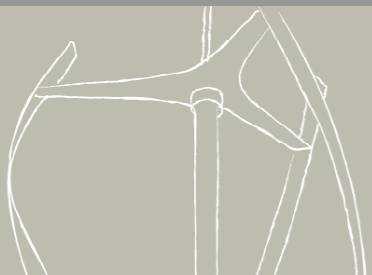
quietrevolution conclusions

- allocate percentage of wind from each quarter
- Use SAP calculation methods as basis
- adjust NOABL for terrain in each quarter [topography & roughness]
- adjust for height above / below mean over 3km²



Predicted Annual Mean Wind Speed

6.13 m/s



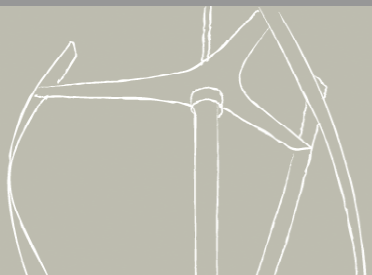
quietrevolution conclusions

NE 3km		N 3km		Nw 3km
106		86		78
	NE 1km	N 1km	Nw 1km	
	192	173	149	
E 3km	E 1km	SITE	W 1km	W 3km
159	188	179	137	102
	SW 1km	S 1km	SE 1km	
	164	166	166	
SW 3km		S 3km		SE 3km
169		200		200

153.8	MEAN ELEVATION OF LOCALITY
200.0	MAX ELEVATION IN LOCALITY
78.0	MIN ELEVATION IN LOCALITY
179	SITE ELEVATION
25.2	SITE ELEVATION ABOVE/ BELOW MEAN
12.6	SITE HEIGHT ABOVE OR BELOW LINE OF ACCELERATED WIND
8%	EACH 5% INC. HEIGHT ABOVE MEAN WIND LINE = 5% INC. EACH 5% DROP HEIGHT BELOW MEAN WIND LINE = 5% DROP
2%	PERCENTAGE INCREASE / DECREASE IN AMWS

Height adjusted
Predicted Annual Mean Wind Speed

6.25 m/s



Site : FIFE

Description

Turbines in grounds of store

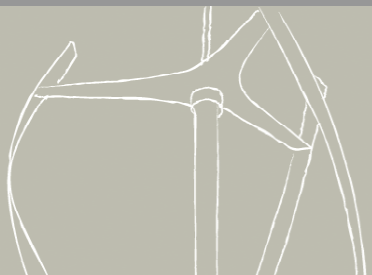
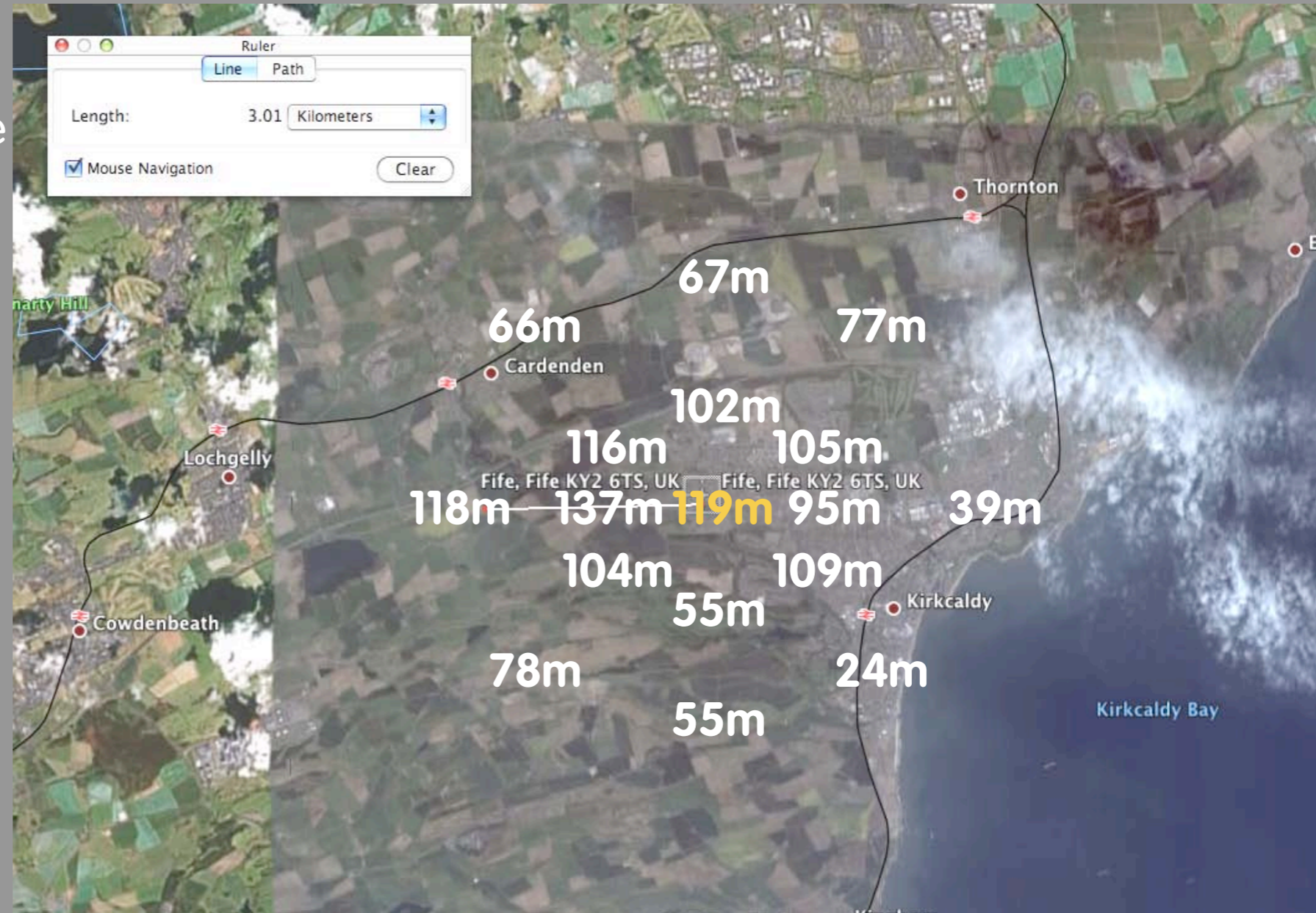
Location on relative high ground

Town to East and open country to South & West

Site Elevations

Falling in all directions except West

To West land rises approx. 20m and then falls.



Site Information

for the 1km grid square 325 693 (NT2593)

Wind speed at 45m agl (in m/s)

7.6	7.7	7.9
7.9	7.8	7.7
8	7.7	7.5

Wind speed at 25m agl (in m/s)

7	7.1	7.3
7.3	7.2	7.1
7.4	7.1	6.8

Wind speed at 10m agl (in m/s)

6.2	6.3	6.5
6.6	6.5	6.3
6.6	6.4	6

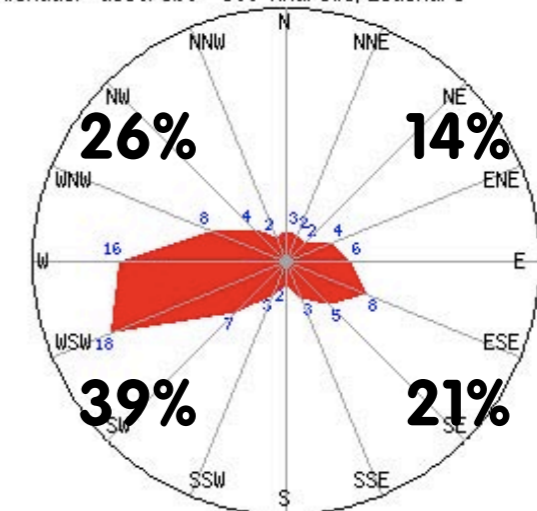
Grid Ref: NT252933
NOABL Database information
for 1km square at site

St. Andrews/Leuchars (LEUCHARS)

Stats based on observations taken between 11/2000 - 12/2008 daily from 7am to 7pm local time.

Month of year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SUM
	01	02	03	04	05	06	07	08	09	10	11	12	1-12
Dominant Wind Dir.	➤	➤	➤	➤	➤	➤	➤	➤	➤	➤	➤	➤	➤
Wind probability > = 4 Beaufort (%)	44	45	53	52	49	51	44	39	41	47	39	38	45
Average Wind Speed (kts)	11	11	12	12	11	11	11	10	10	11	10	10	10
Average Airtemp. (°C)	6	6	7	10	13	16	17	17	15	12	8	6	11
Select Month (Help)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year

Winddir distrib. St. Andrews/Leuchars



Wind direction Distribution (%)

Copyright www.windfinder.com

Wind rose
Percentages of resource by quarters

Site Information

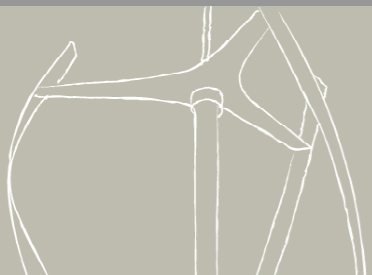
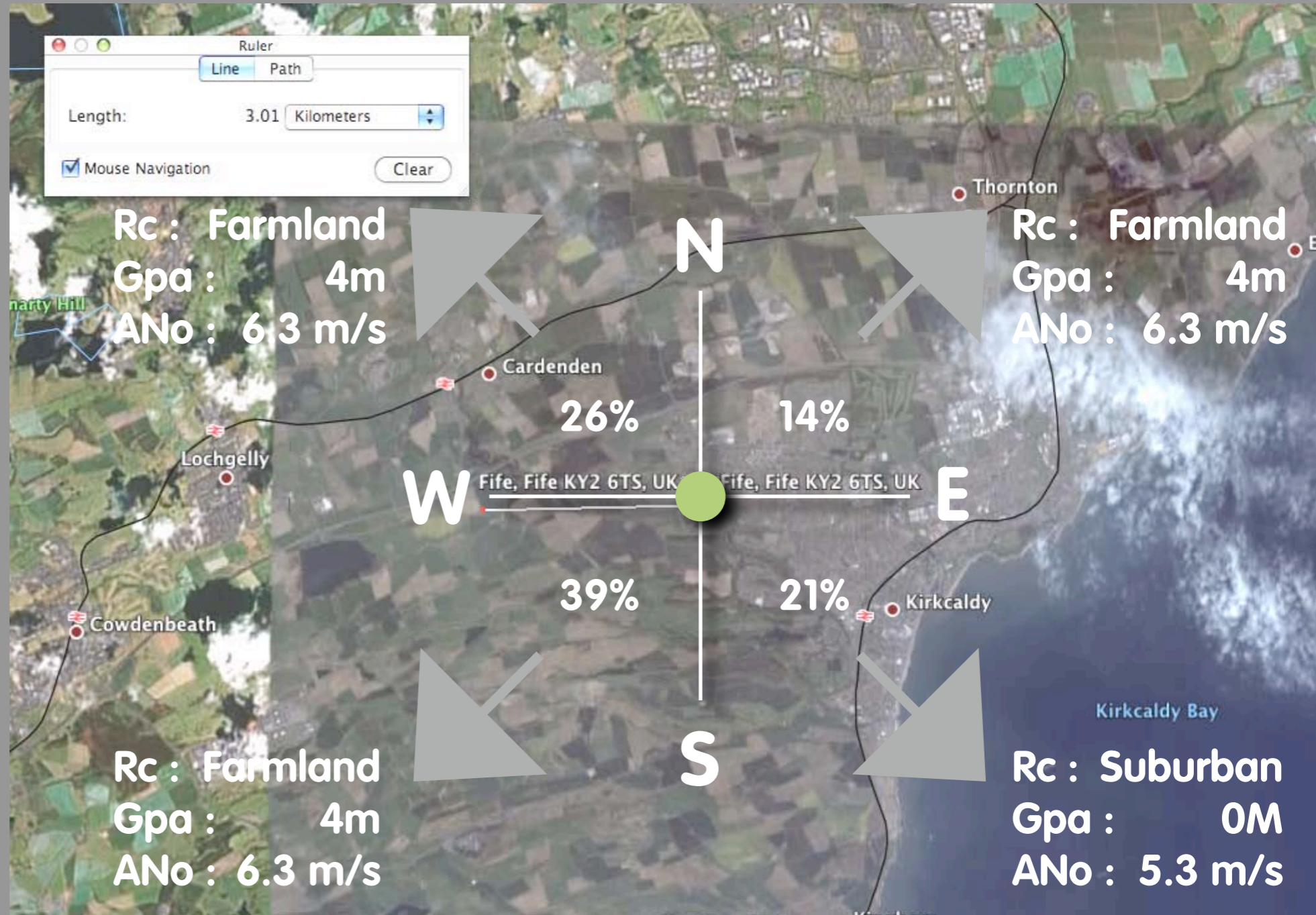
Calculations based on SAP

Centre of Rotor Height : 17.5m AGL

NOABL at CoR 6.8 m/s

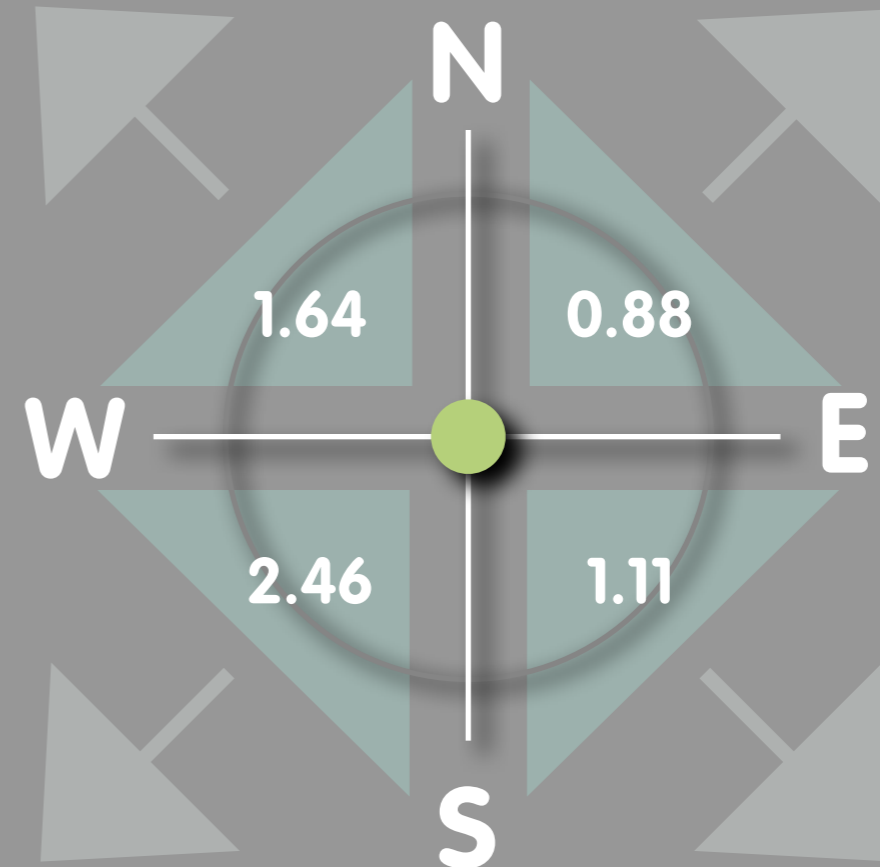
Key

- Rc Roughness Category
- Gpa Ground Plane Adjustment
- ANo Adjusted NOABL



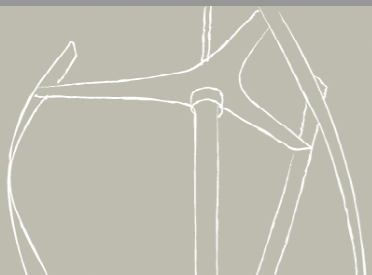
quietrevolution conclusions

- allocate percentage of wind from each quarter
- Use SAP calculation methods as basis
- adjust NOABL for terrain in each quarter [topography & roughness]
- adjust for height above / below mean over 3km²



Predicted Annual Mean Wind Speed

6.09 m/s



quietrevolution conclusions

NE 3km		N 3km		Nw 3km
66		67		77
	NE 1km	N 1km	Nw 1km	
	116	102	105	
E 3km	E 1km	SITE	W 1km	W 3km
118	137	119	95	39
	SW 1km	S 1km	SE 1km	
	104	99	109	
SW 3km		S 3km		SE 3km
78		55		24

88.8	MEAN ELEVATION OF LOCALITY
137.0	MAX ELEVATION IN LOCALITY
24.0	MIN ELEVATION IN LOCALITY
119	SITE ELEVATION
30.2	SITE ELEVATION ABOVE/ BELOW MEAN
15.1	SITE HEIGHT ABOVE OR BELOW LINE OF ACCELERATED WIND
17%	EACH 5% INC. HEIGHT ABOVE MEAN WIND LINE = 5% INC. EACH 5% DROP HEIGHT BELOW MEAN WIND LINE = 5% DROP
4%	PERCENTAGE INCREASE / DECREASE IN AMWS

Height adjusted
Predicted Annual Mean Wind Speed

6.33 m/s



quietrevolution

Tall Buildings

Prediction is not easy

Factors:

Absolute Height of Building

Height of Building above
general heights of
surrounding buildings

Orientation of Building
relative to more dominant
wind directions

Shape of Building

Number of Rotors on Roof

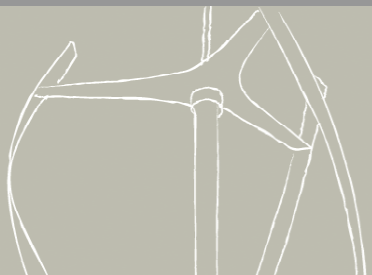
Depth of Building

Other Roof-top Structures

Underlying Topography

Location of Building Within
Overall Conurbation

Absolute Size of
Conurbation

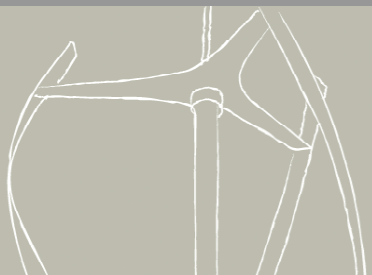


Tall Buildings

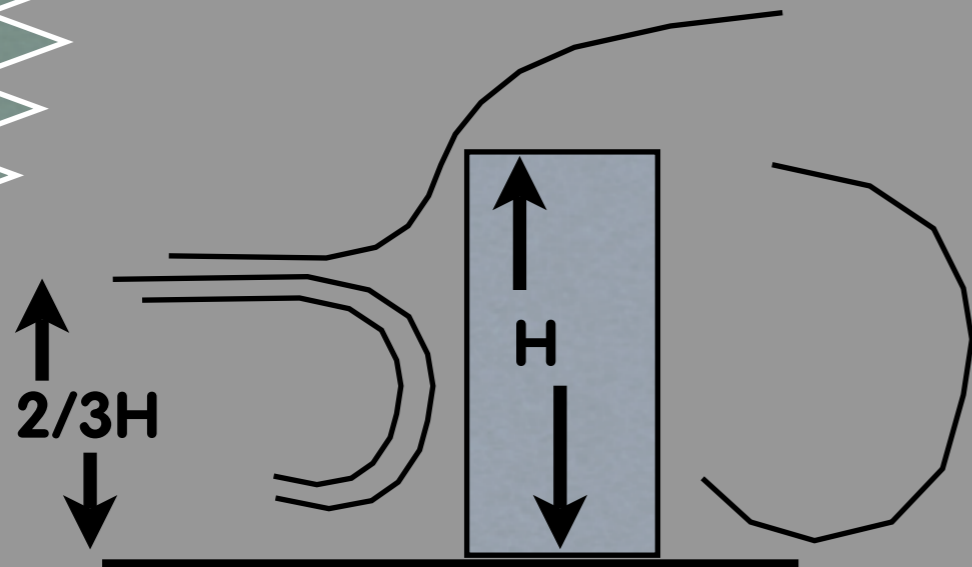
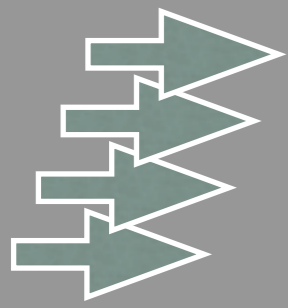
Remember:

Prediction is not easy

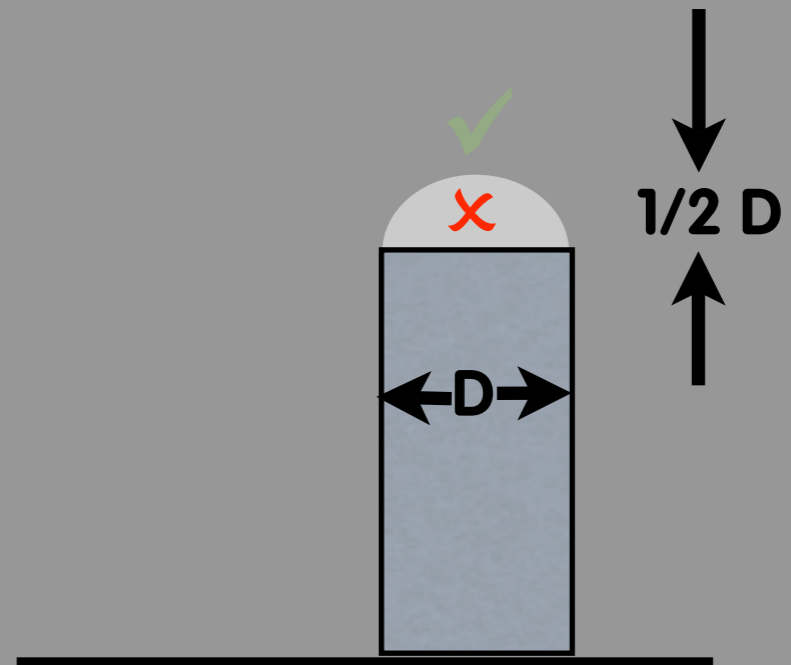
Wind comes from ALL directions



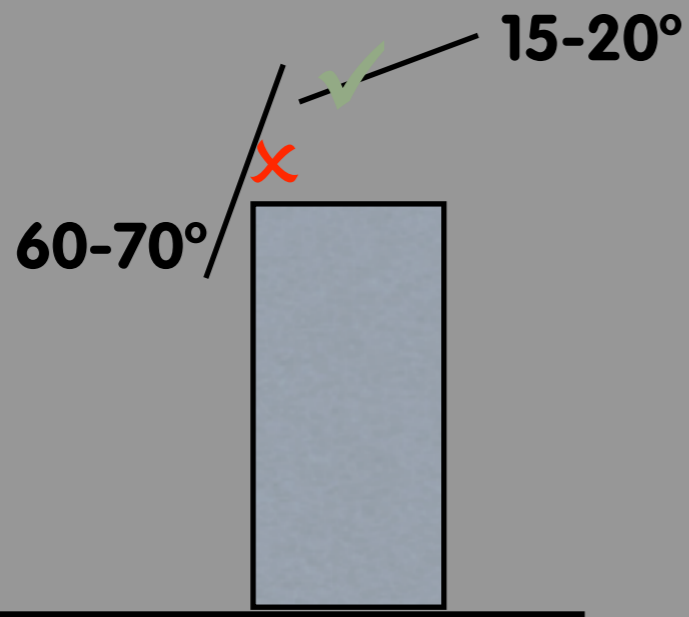
What happens to the wind



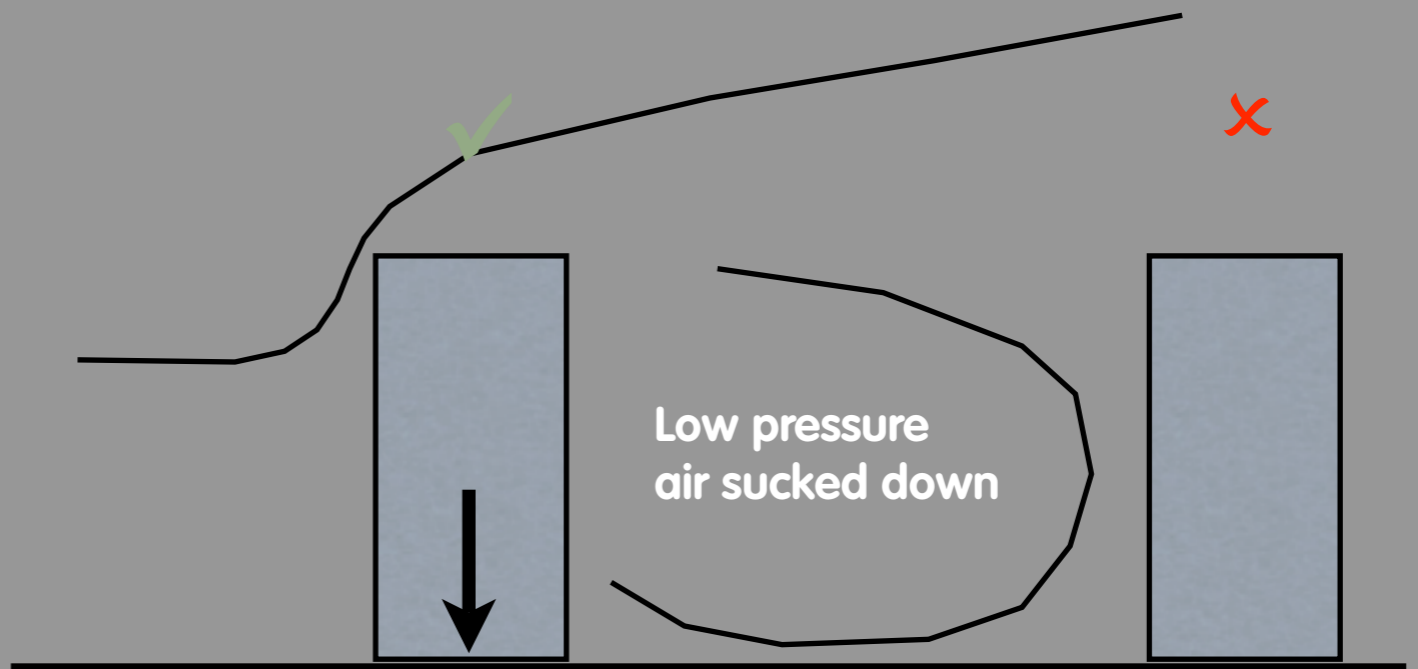
Section



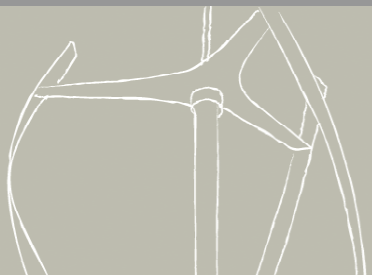
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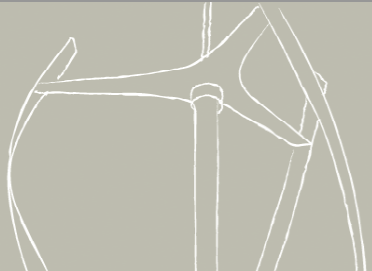
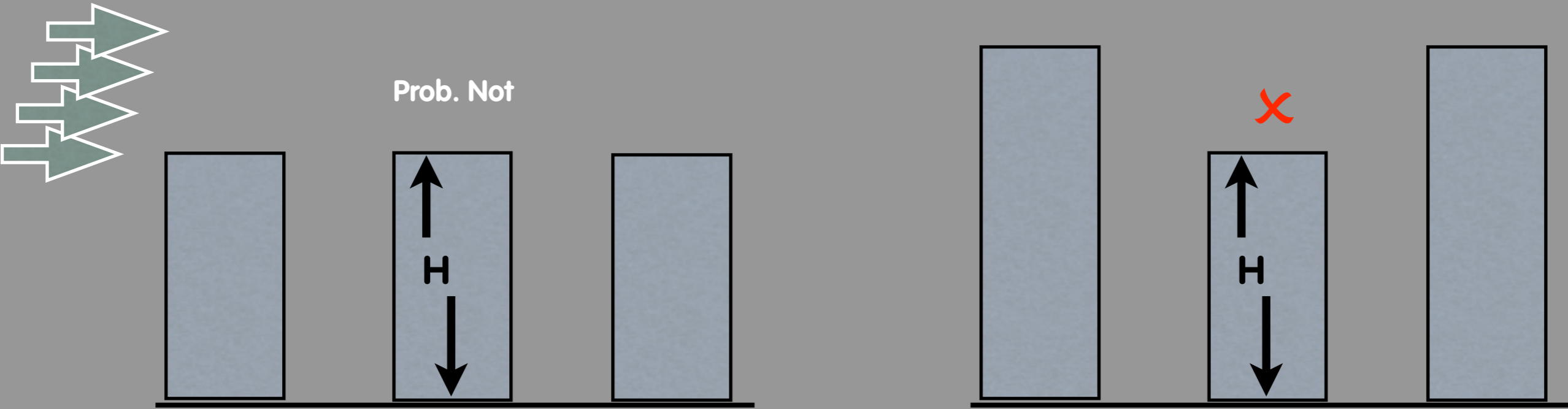
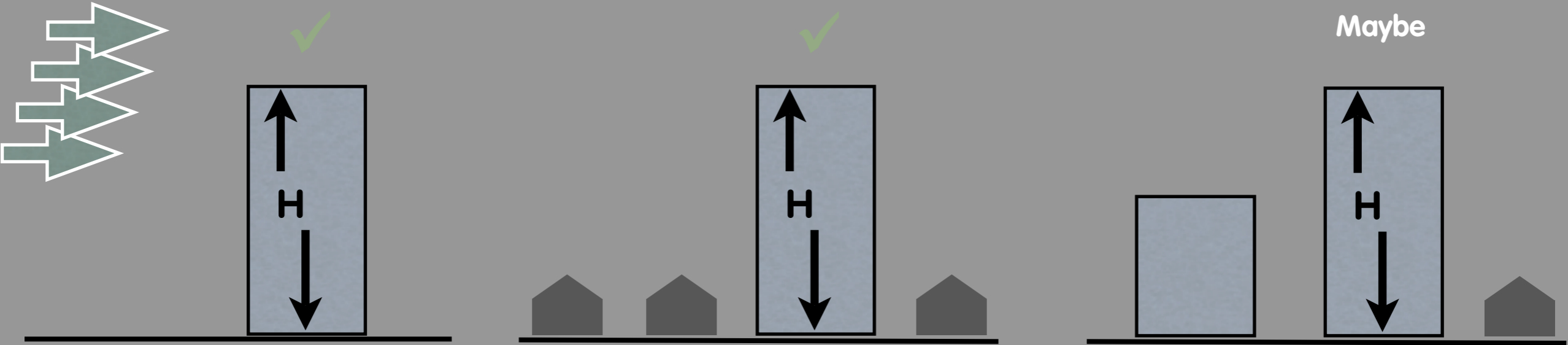
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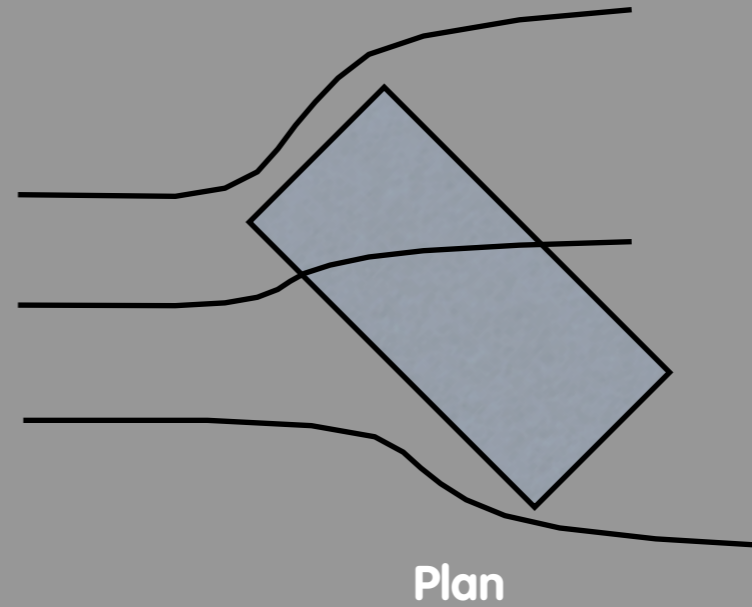
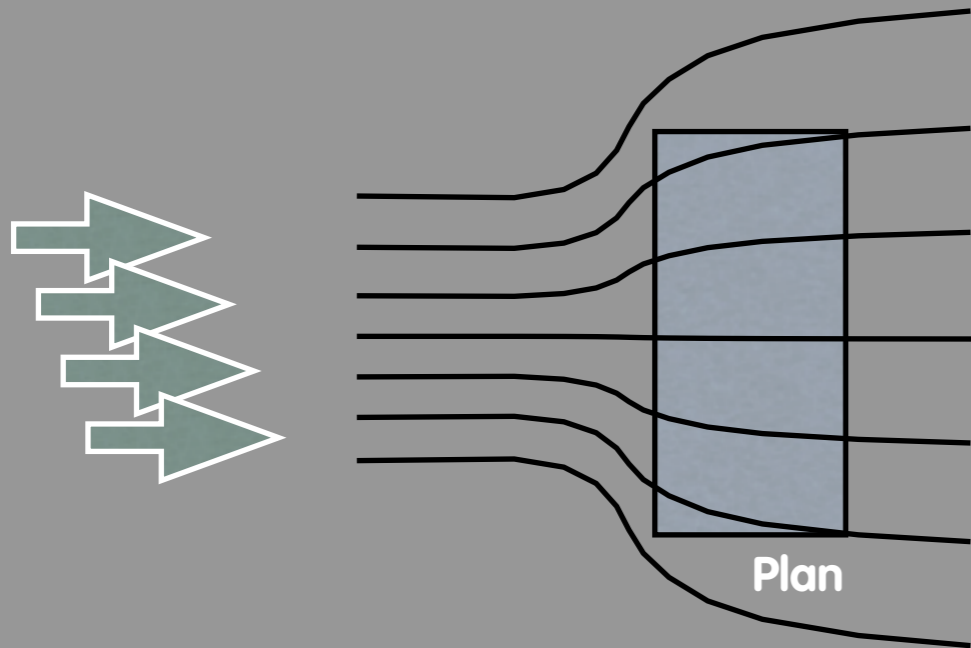
Section



Height of Building & Surrounding Buildings

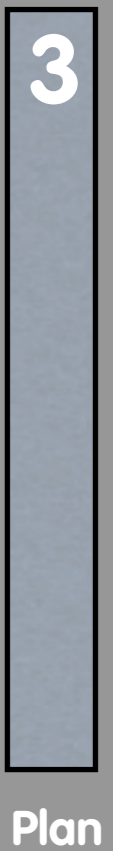


Orientation of Building

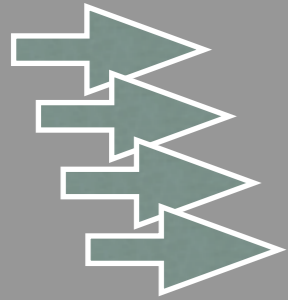


Shape of Building

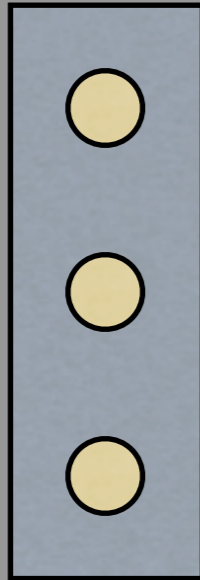
1. Size of roof
2. Ease for air to flow round
3. Overall blockage



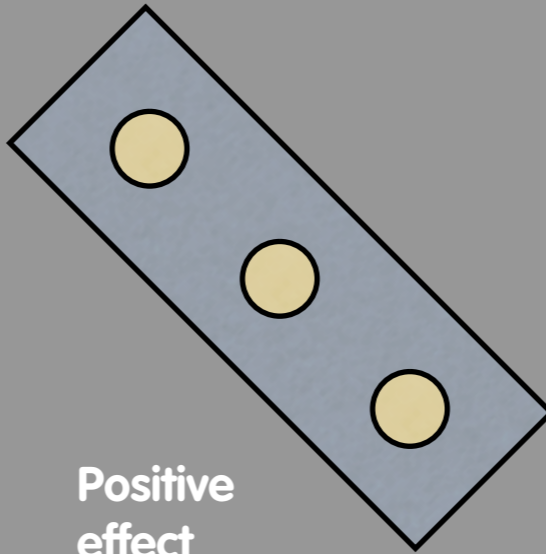
Number of Rotors on Roof



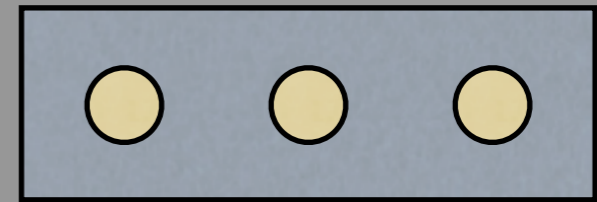
Positive effect



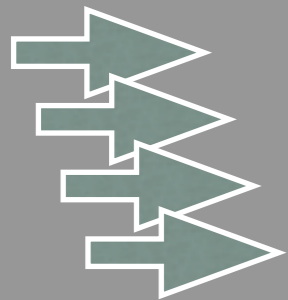
Positive effect



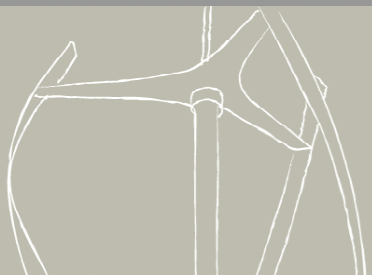
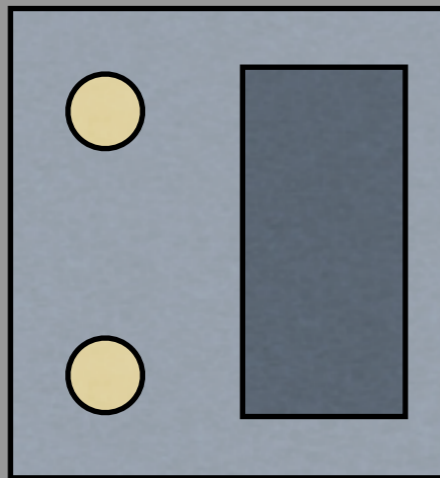
Negative effect



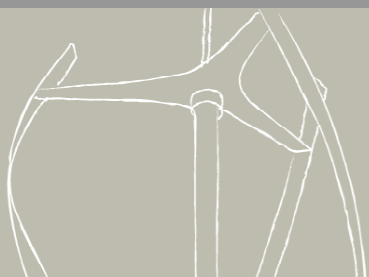
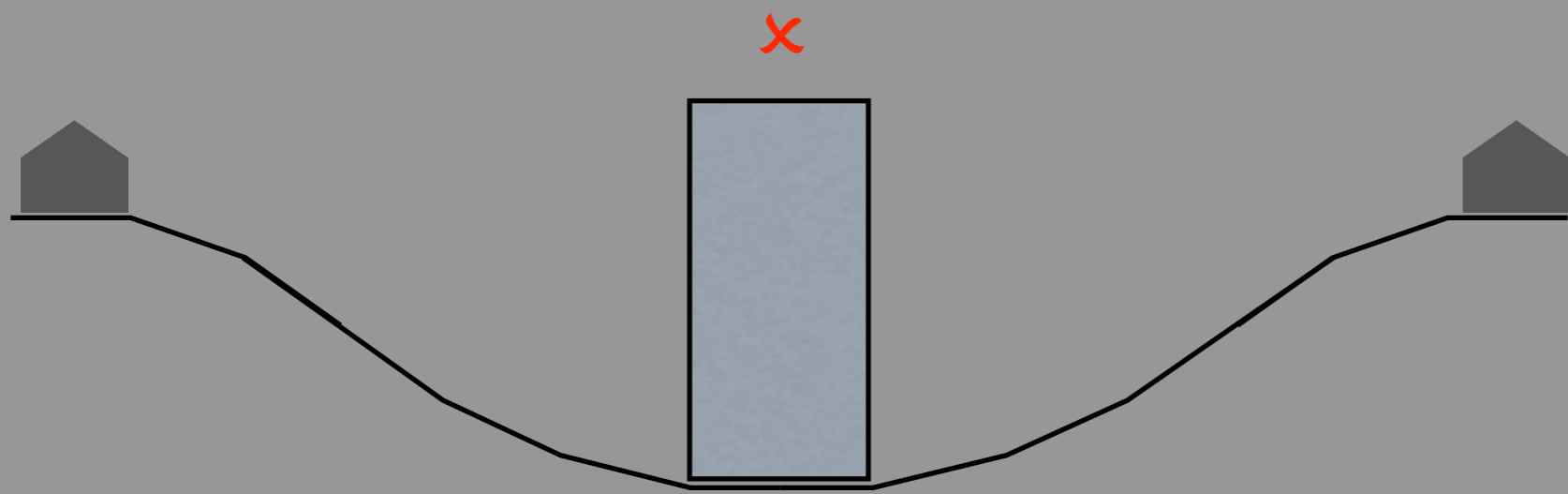
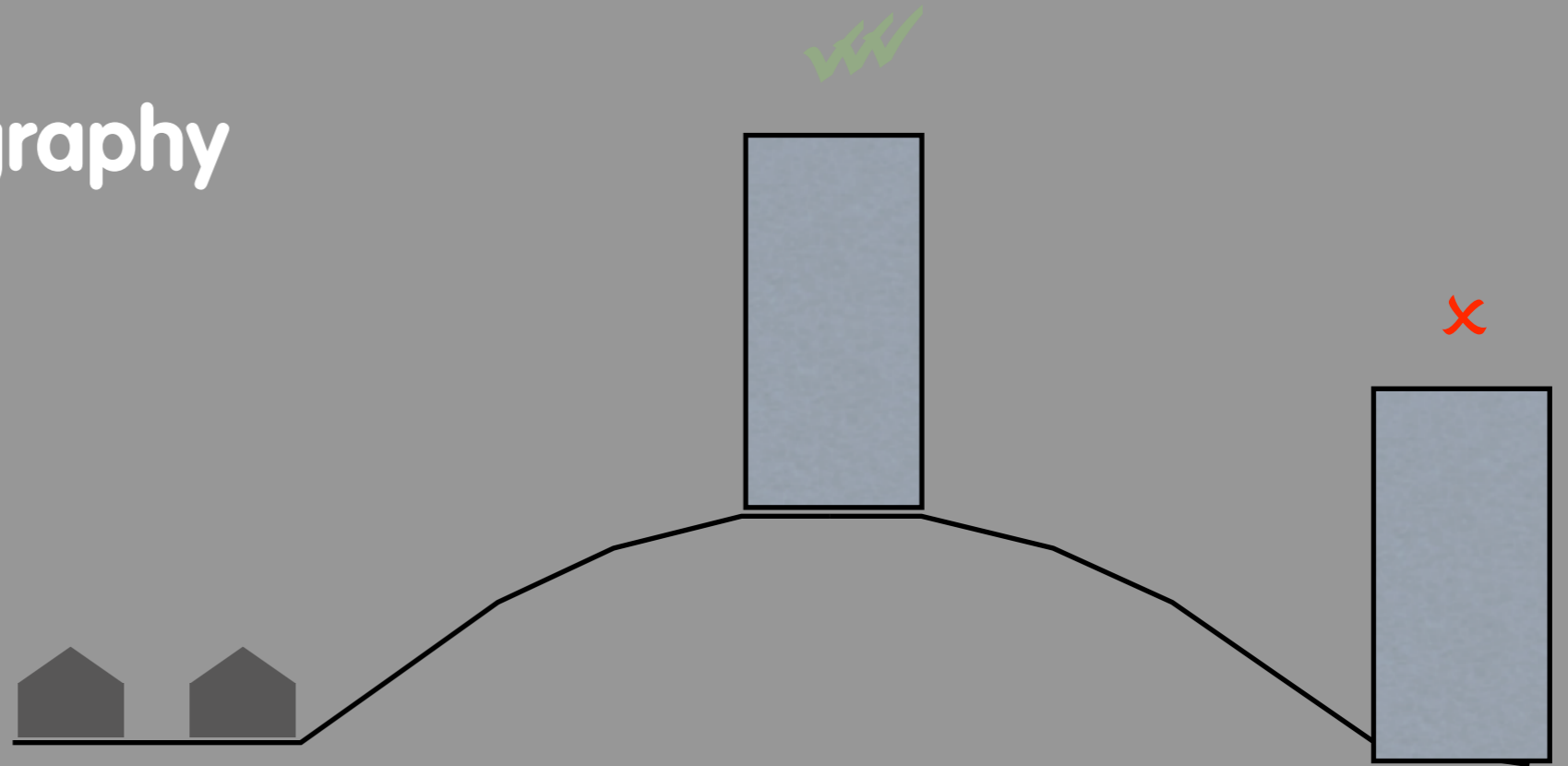
Other Roof-top Structures



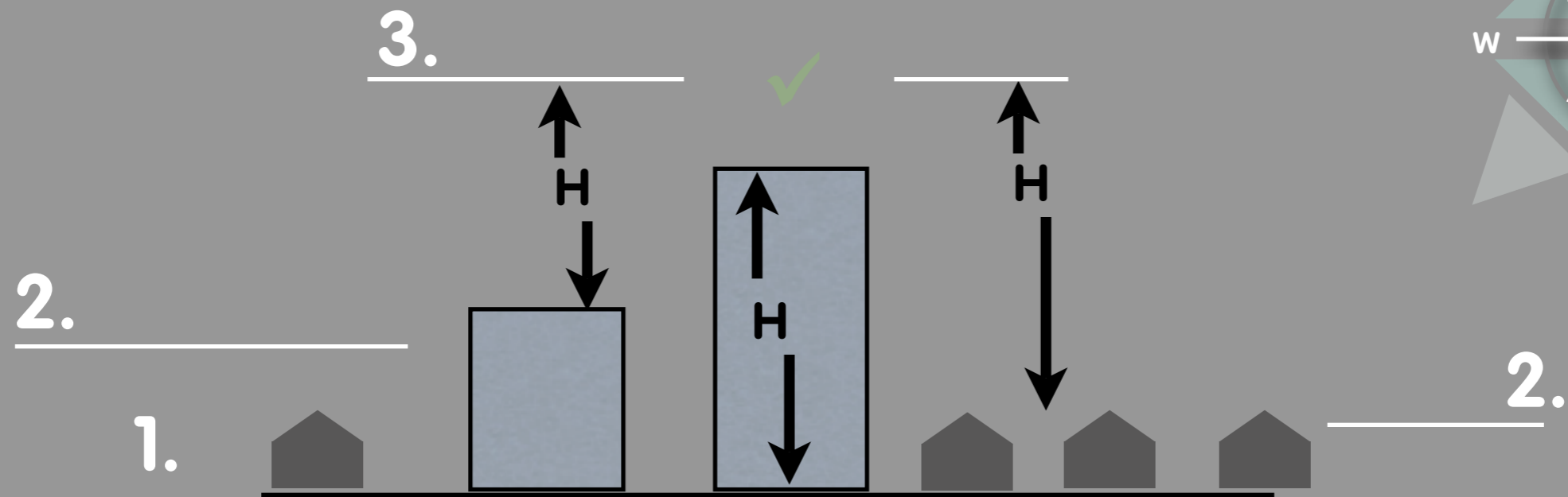
Negative effect



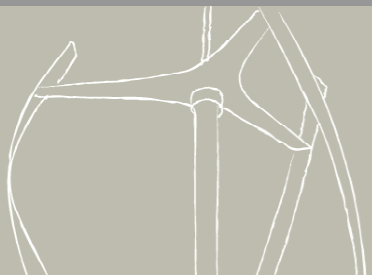
Underlying Topography



Conclusion for tall buildings

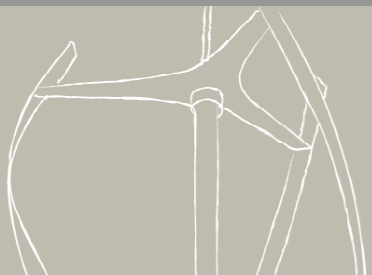


1. Assume Suburban Roughness Class in cities
2. Adjust ground plane, 2/3 height buildings
3. Assume additional height of building + rotor mast is effectively a tall mast.
4. Make sure there is 5.0m/s or greater



Evaluating Wind Resource

questions



quietrevolution