Airborne Wind Energy :

Taking Wind Energy to the next level

Carbon Tracking Ltd.

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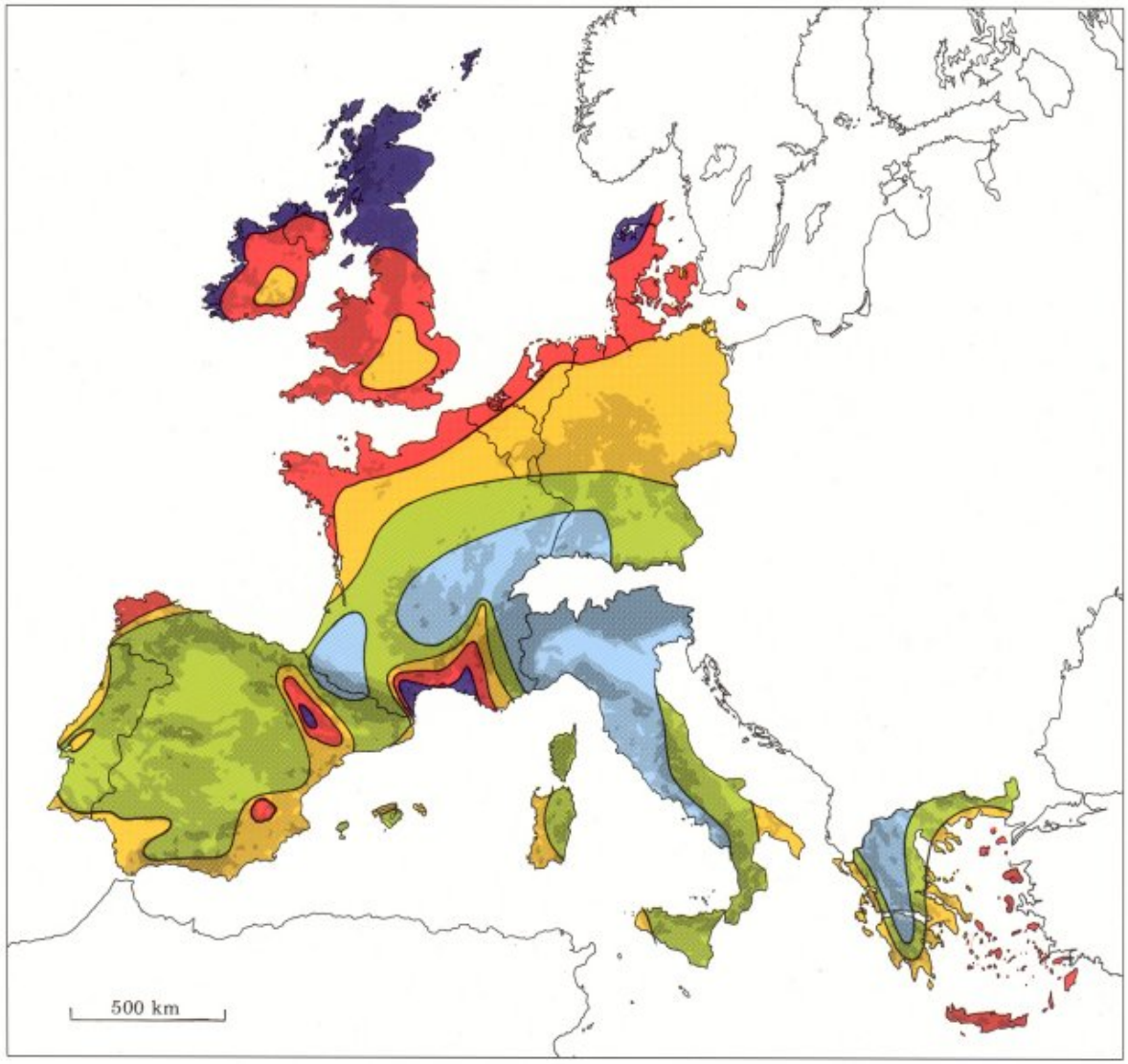
Issues for the Wind Industry

- Running out of good sites
- Increased capital costs for larger turbines
- Low capacity factor

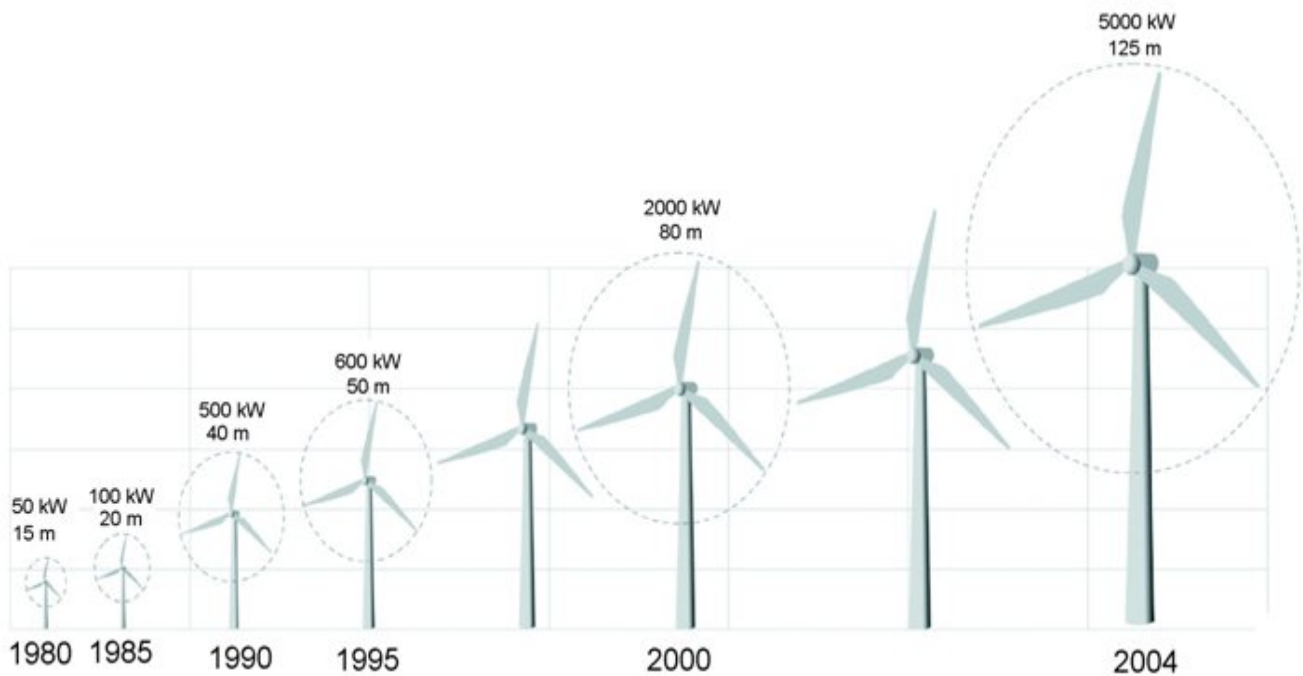


Wind resources[1] at 50 metres above ground level for five different topographic conditions

	Sheltered terrain[2]		Open plain[3]		At a sea coast[4]		Open sea[5]		Hills and ridges[6]	
	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}
	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0- 8.5	400- 700
	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

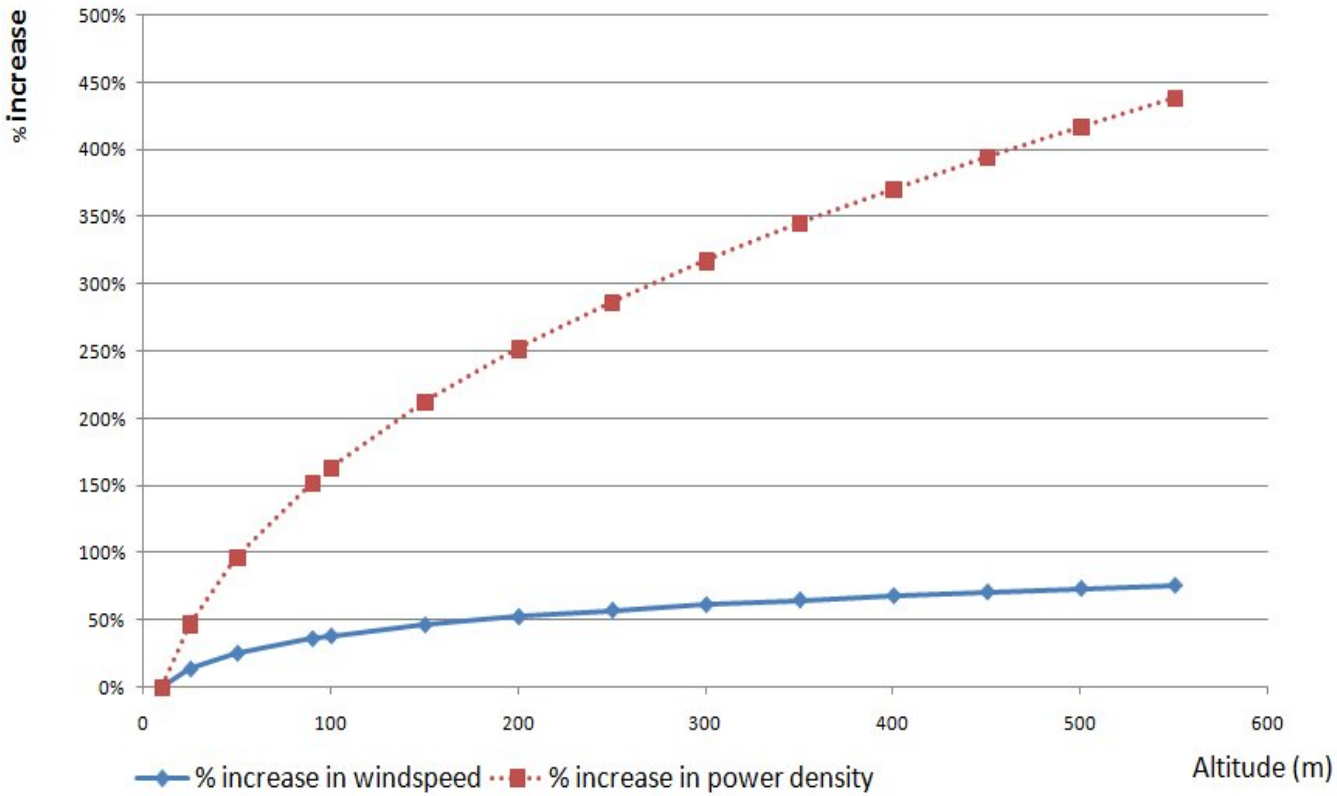
Current Wind Turbine technology

- Rapid growth in turbine size in last 10 years
- Onshore turbines have reached optimal size (2~3MW)
- These turbines only exploit the wind energy up to 150m
- Above this, costs increase faster than energy yield
  - i.e. Tower/blade configuration creates limits

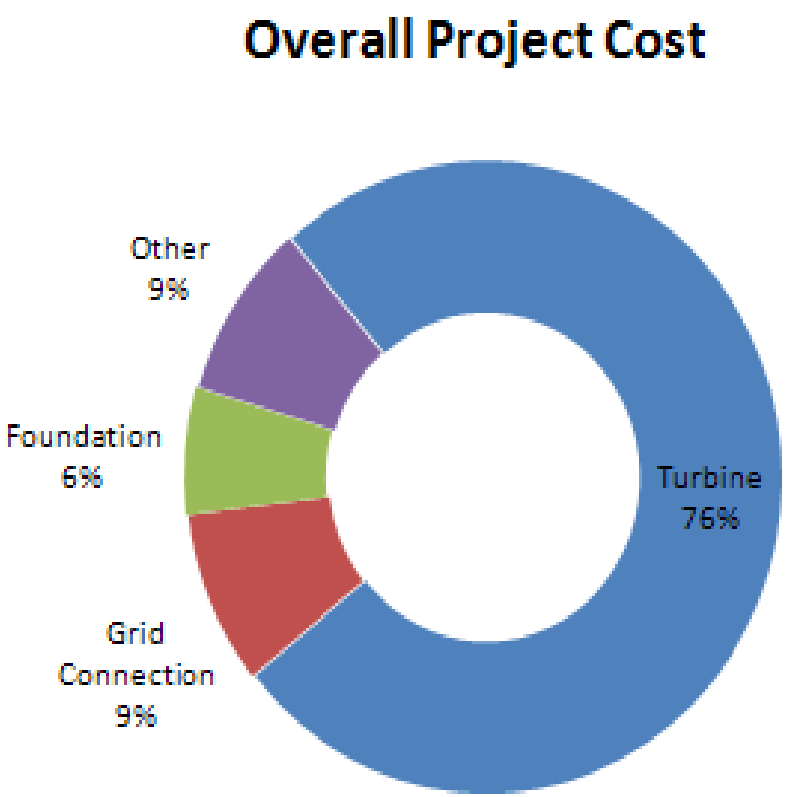


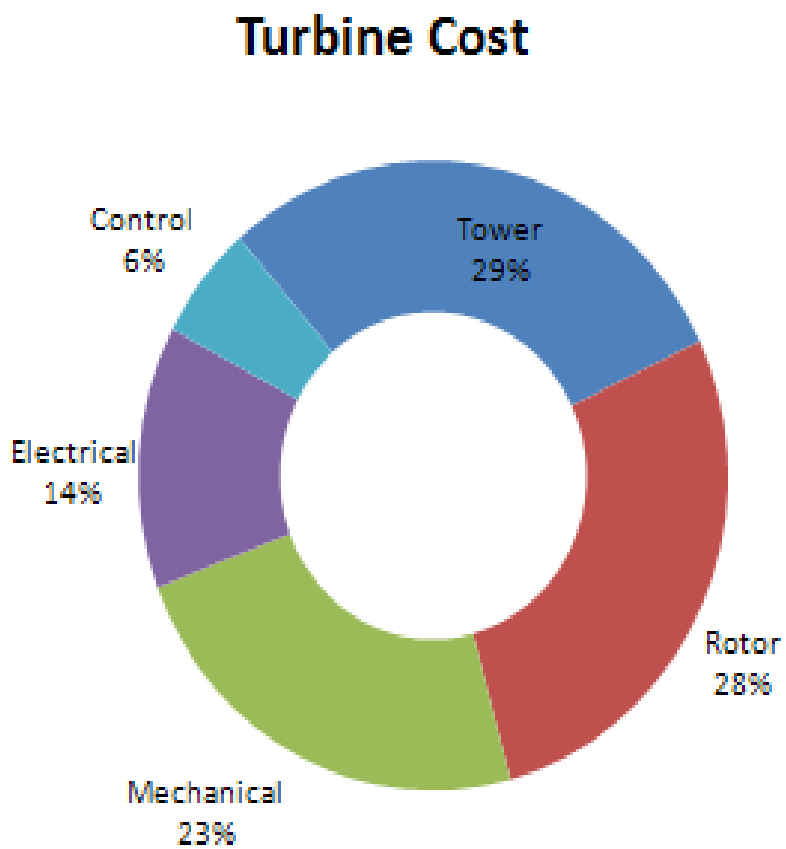
The Wind Resource

- Wind speed/stability increases with altitude
- Power density increases with the cube of wind speed.
- From 100m to 500m, wind speed increases by 23% but power density increases by 88%,
- i.e. Class 2 sites become Class 4 sites.

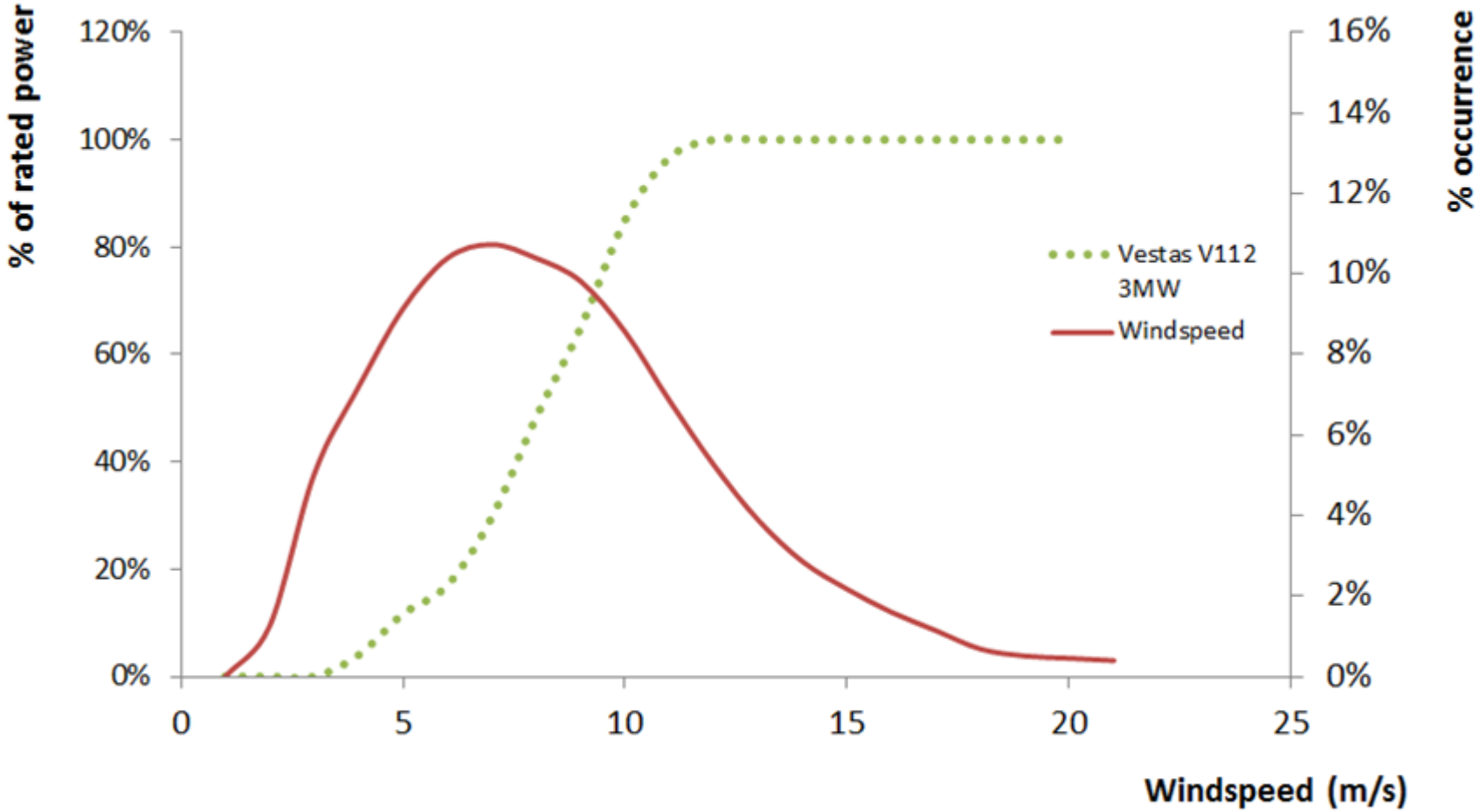


Current Wind Turbine technology





Capacity Factor : How much wind can you catch ?



Capacity factor is stable around 30~35%.

The Good News ?

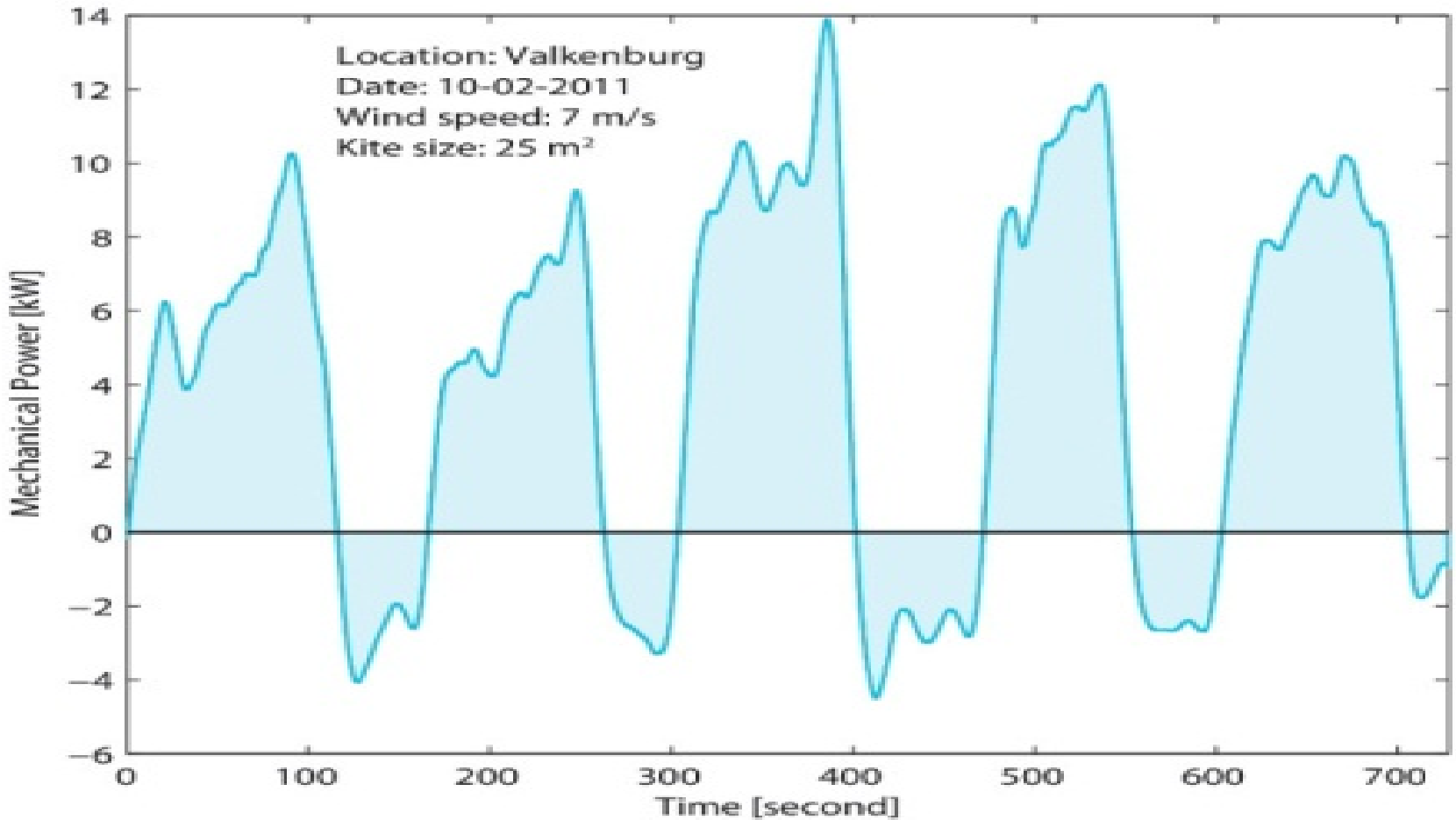
- Airborne Wind Energy technologies promise to address the three issues with traditional wind energy
- The energy harvesting part is airborne
  - glider / kite / balloon
- Tethered to the ground

Tu Delft : 01

Tu Delft : 02

Tu Delft : 03

TU Delft : 04

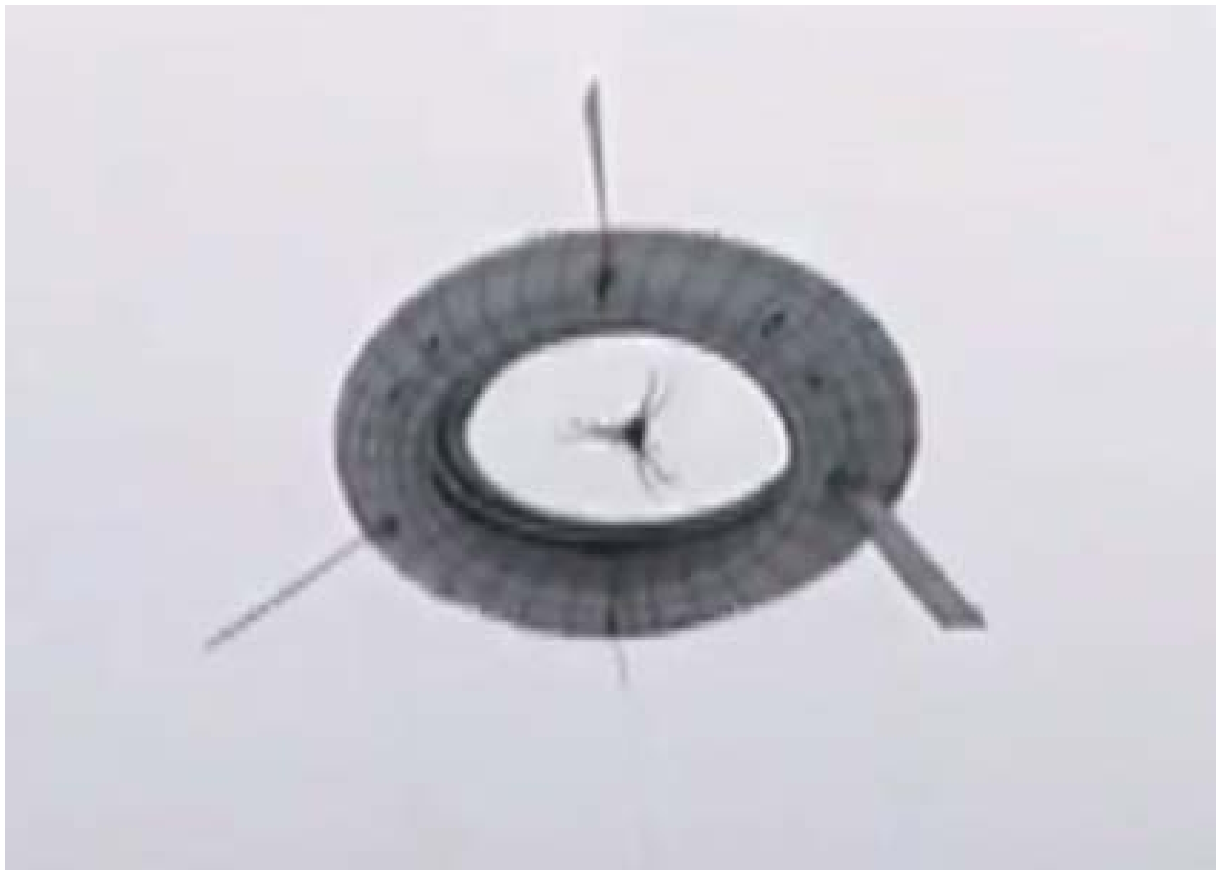

Location: Valkenburg
Date: 10-02-2011
Wind speed: 7 m/s
Kite size: 25 m²
Mechanical Power [kW]
Time [second]
14
12
10
8
6
4
2
0
−2
−4
−6
0
100
200
300
400
500
600
700

Makani 01

Makani 02

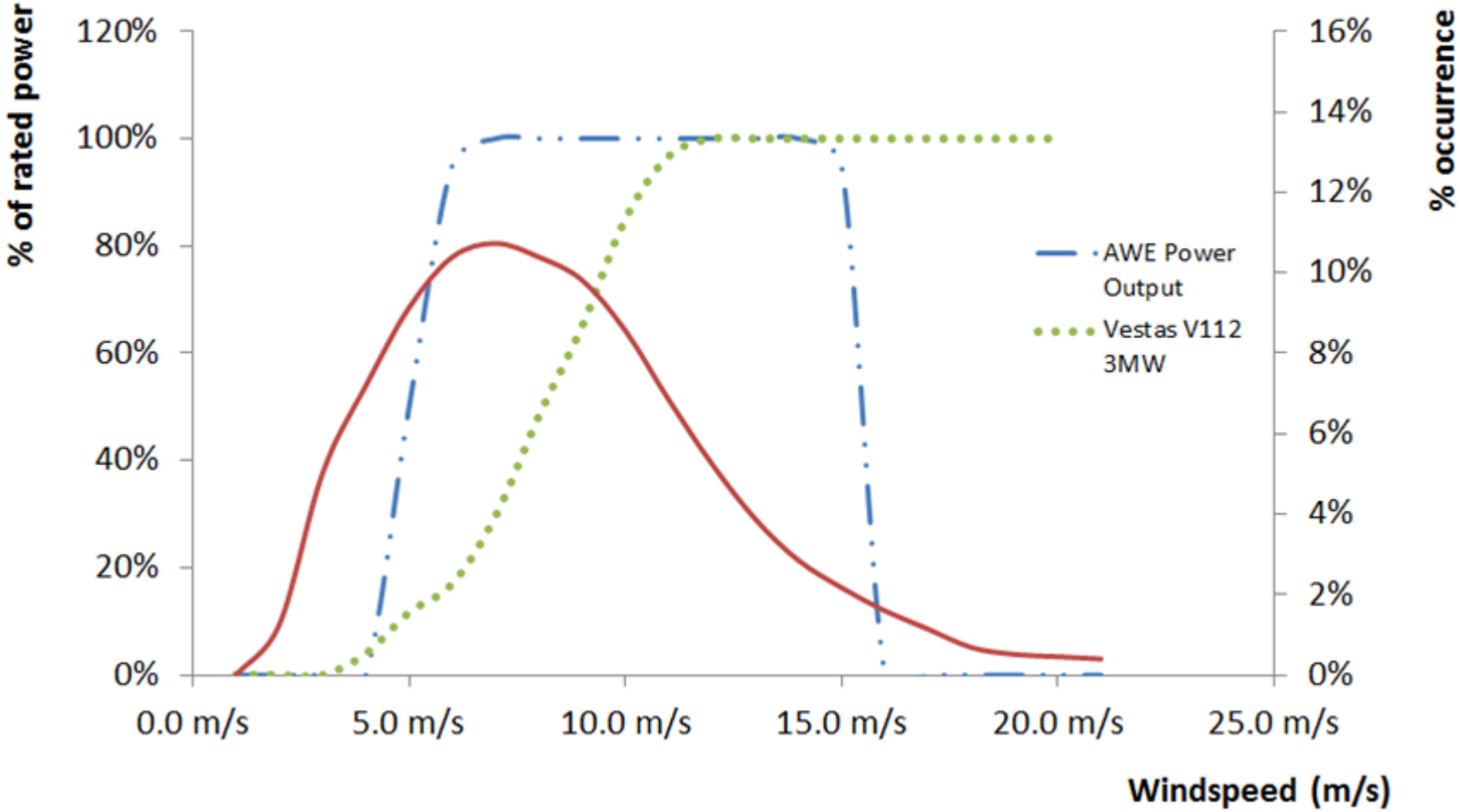
Makani 03

Altaeros 01



Altaeros 02

The promise of AWE



AWE : The Wider Industry

Commercial		Academic	
Aeroix	DE	CSU Chico	US
Ampyx Power	NL	KU Leuven	BL
Baseload Energy	US	Rowan University	US
CMNA Power	US	Swiss Kite Power /FNHW	CH
Highest Wind	US	TU Delft	NL
Joby Energy	US	U Limerick	IE
Kite Gen Research	IT	U Sussex	UK
Kite NRG	IT	Politecnico of Turin	IT
KiteMill	NO		
KiteTech	UK		
Magenn Power Inc.	US		
Makani Power Inc.	US		
NTS Energiesyteme	DE		
Sequoia	IT		
Sky Sails Gmbh	DE		
Sky Windpower Corporation	US		
Skymill Energy	US		
Twind	IT		
Windlift LLC	US		