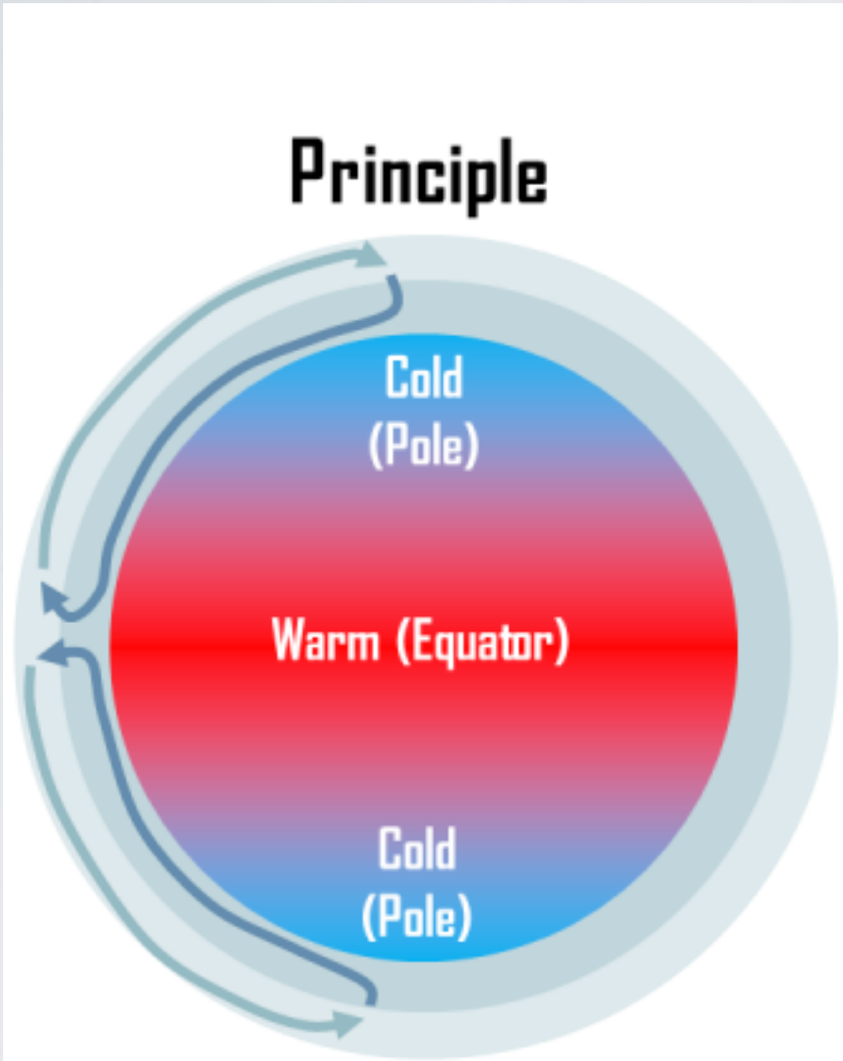
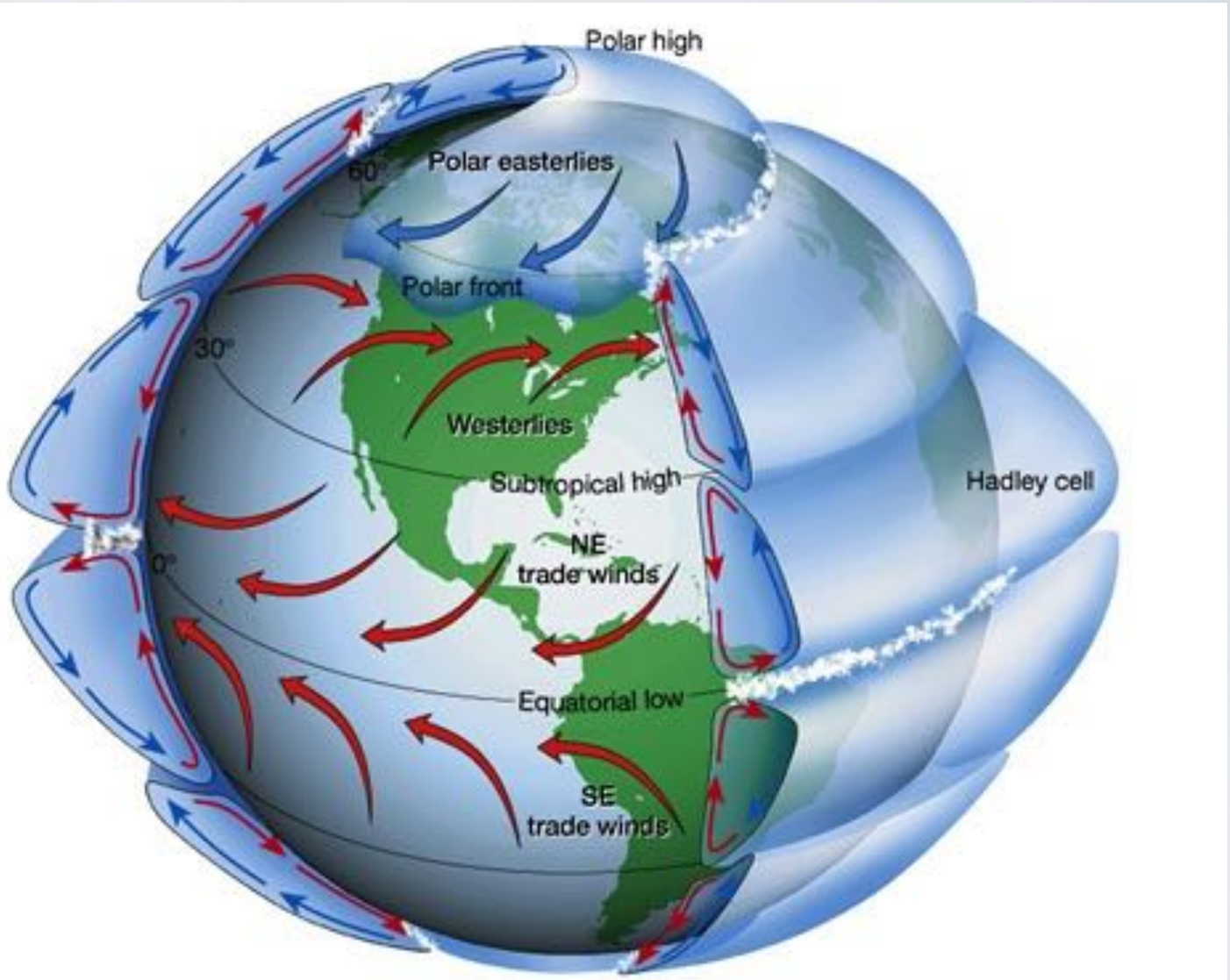
windpower

wind

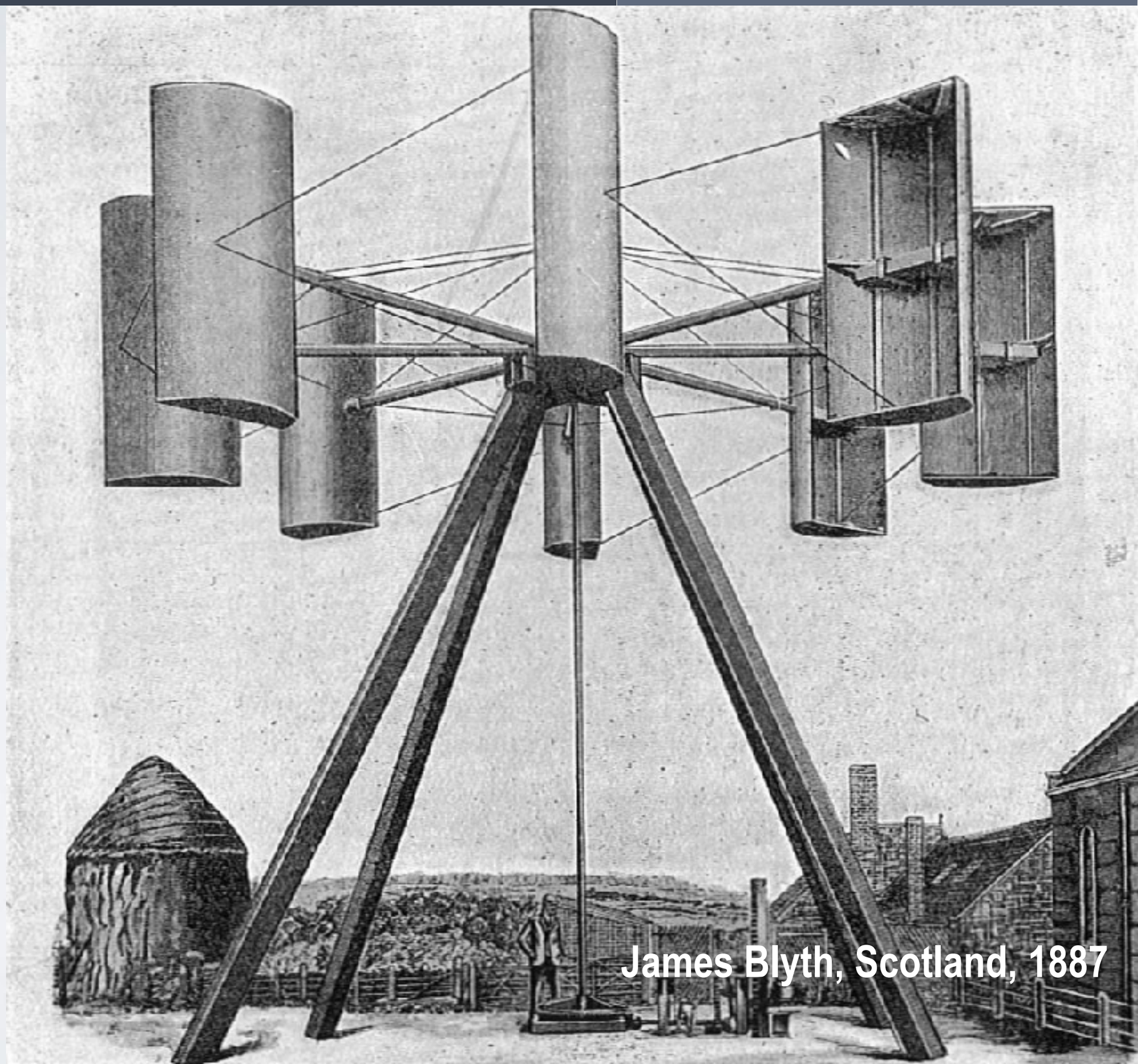




Ciências
ULisboa

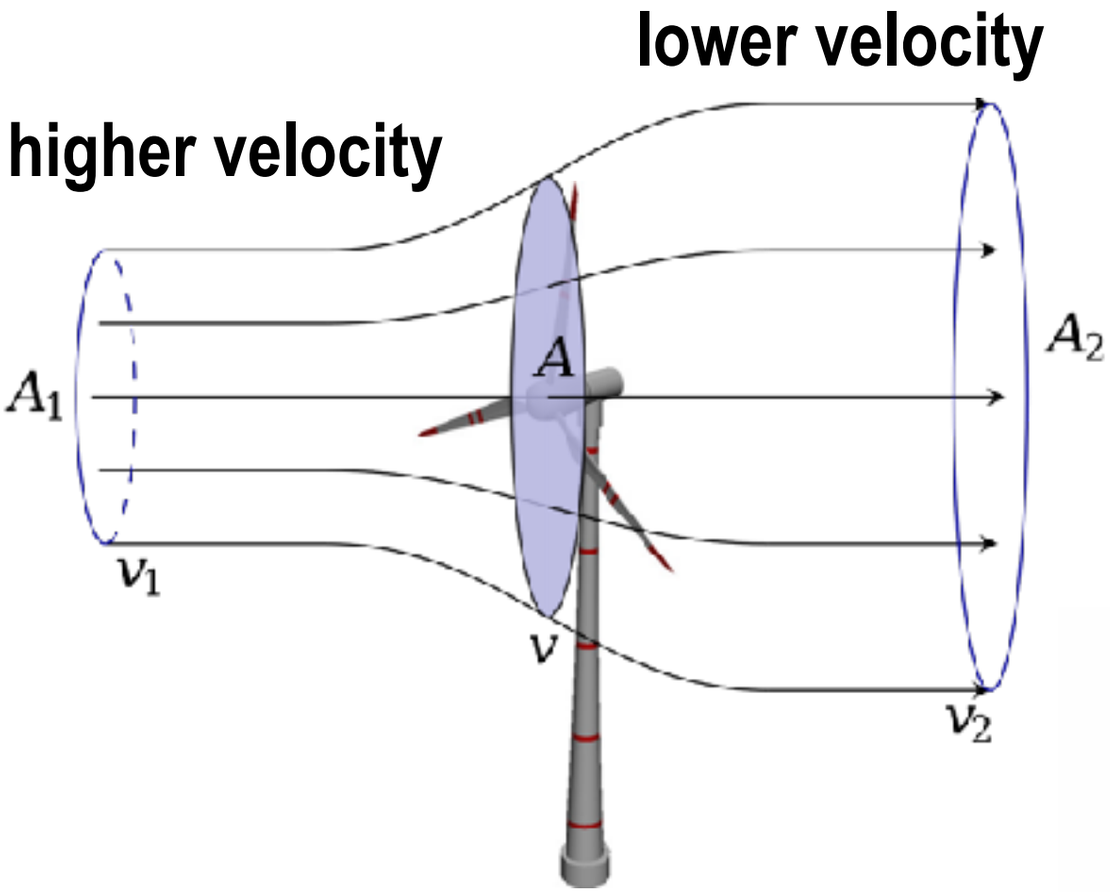
windmills

wind



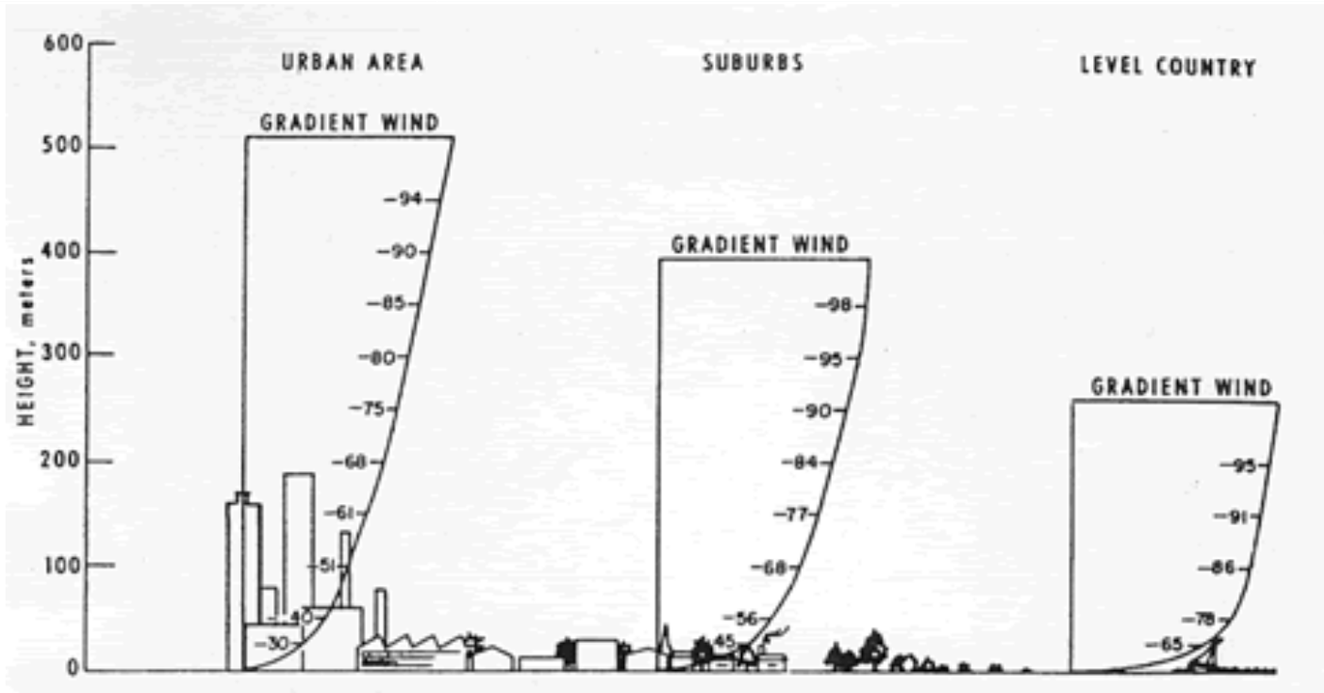
James Blyth, Scotland, 1887

Charles Brush, USA, 12kW, 1887

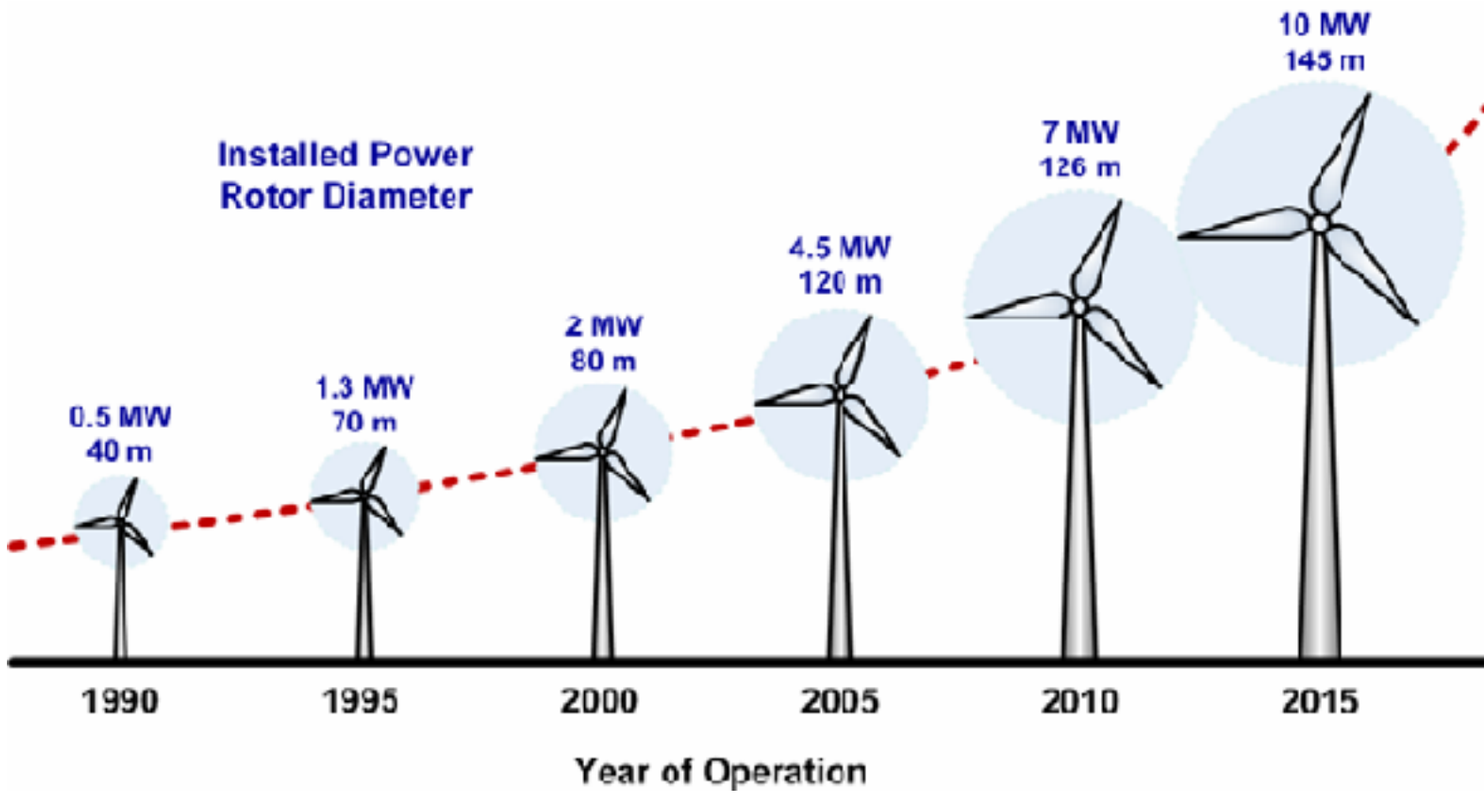


power ~ area x cube of wind speed

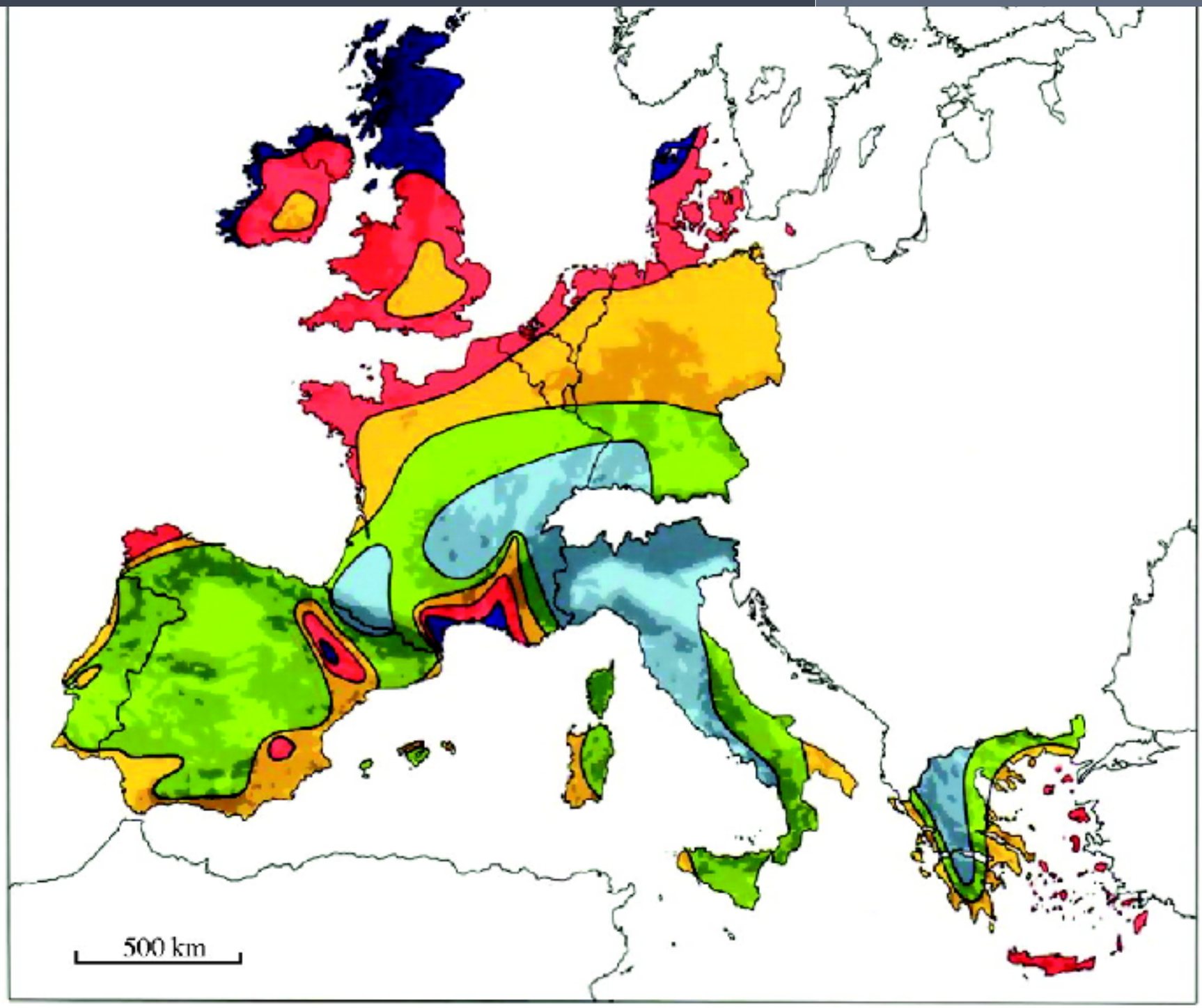
$$P = 0.5\rho A v_1^3$$



Prandtl law

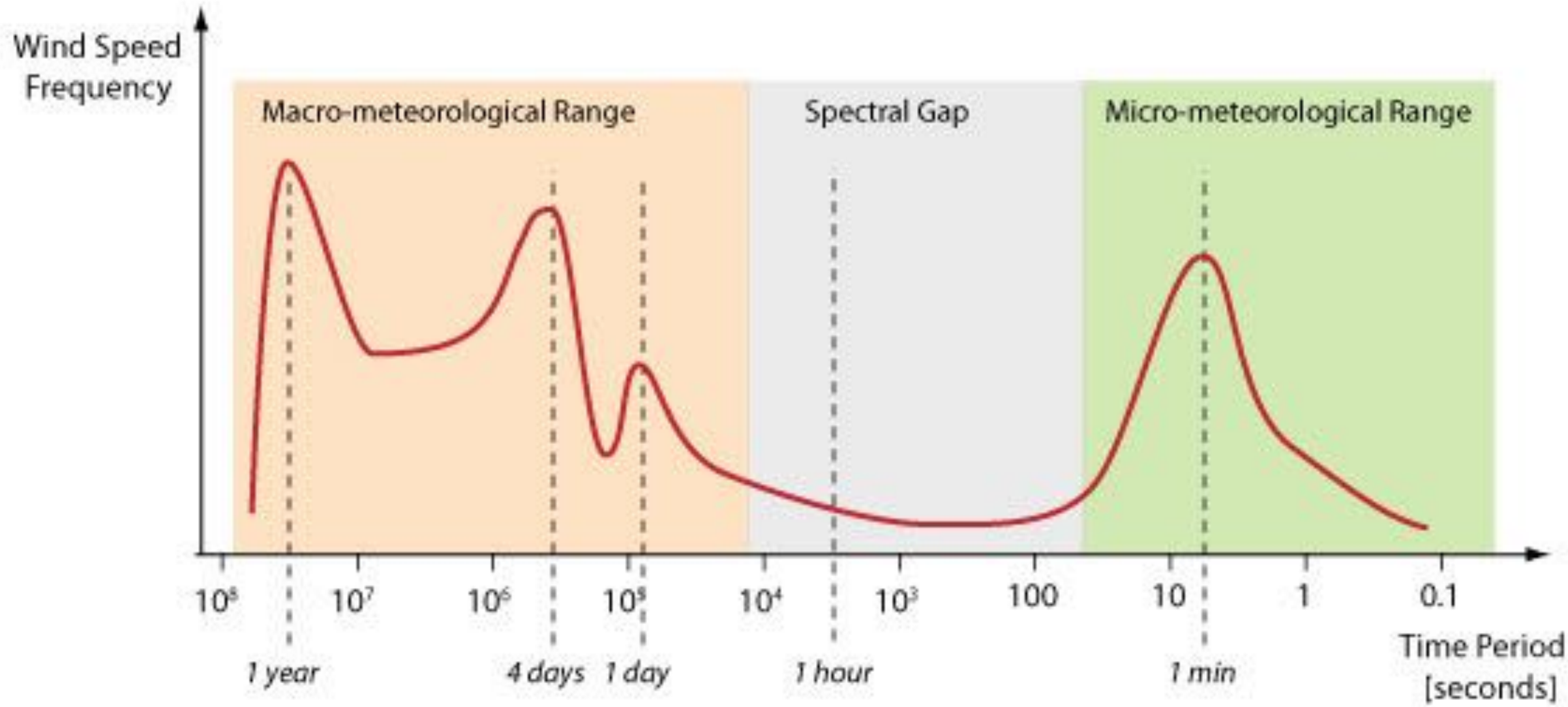


Ciências ULisboa



wind resources at 50 m above ground level for five different topographic conditions

	sheltered terrain		open plain		at a sea coast		open sea		hills and ridges	
	$m s^{-1}$	$W m^{-2}$	$m s^{-1}$	$W m^{-2}$	$m s^{-1}$	$W m^{-2}$	$m s^{-1}$	$W m^{-2}$	$m s^{-1}$	$W m^{-2}$
	>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



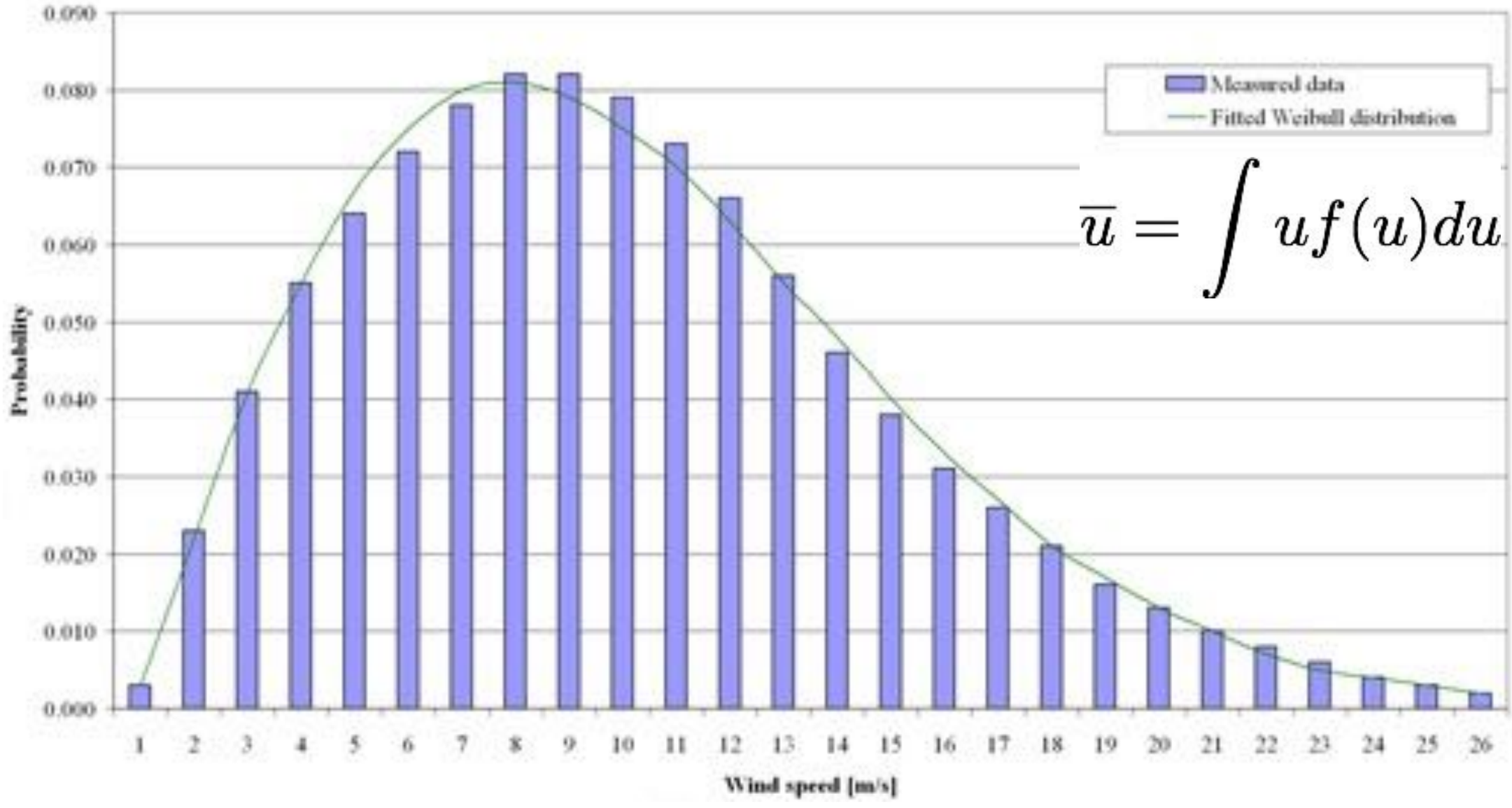
$$u(t) = \overline{u} + u'(t)$$

mean turbulence

steady-state

(average from 20 minutes to one hour)

Ciências ULisboa



$$\overline{u} = \int u f(u) du$$

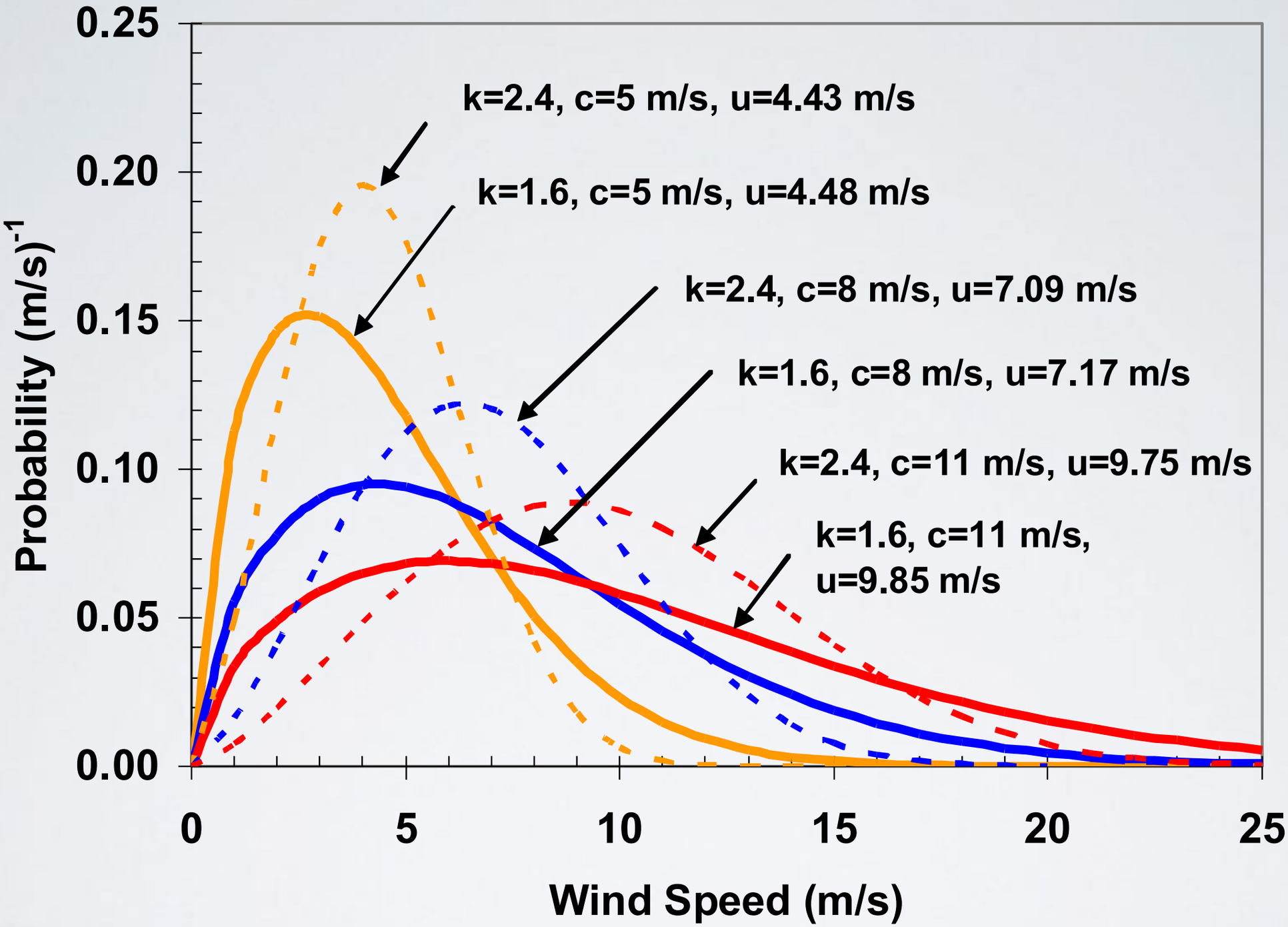
$$f(u) = \frac{k}{c}\left(\frac{u}{c}\right)^{k-1} \exp\left[-\left(\frac{u}{c}\right)^{k}\right]$$

Weibull distribution

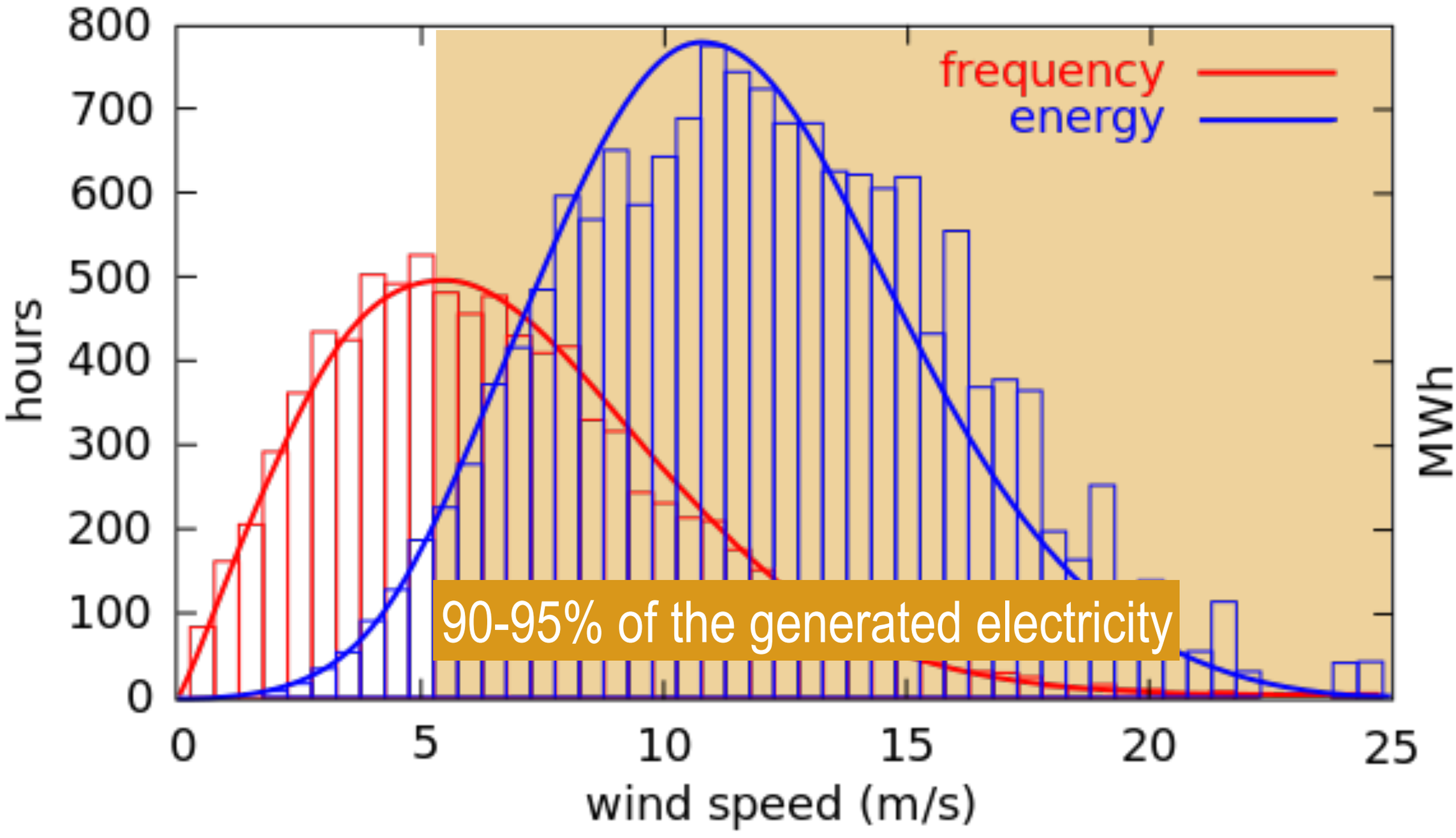
c - scale [m/s]

k - shape

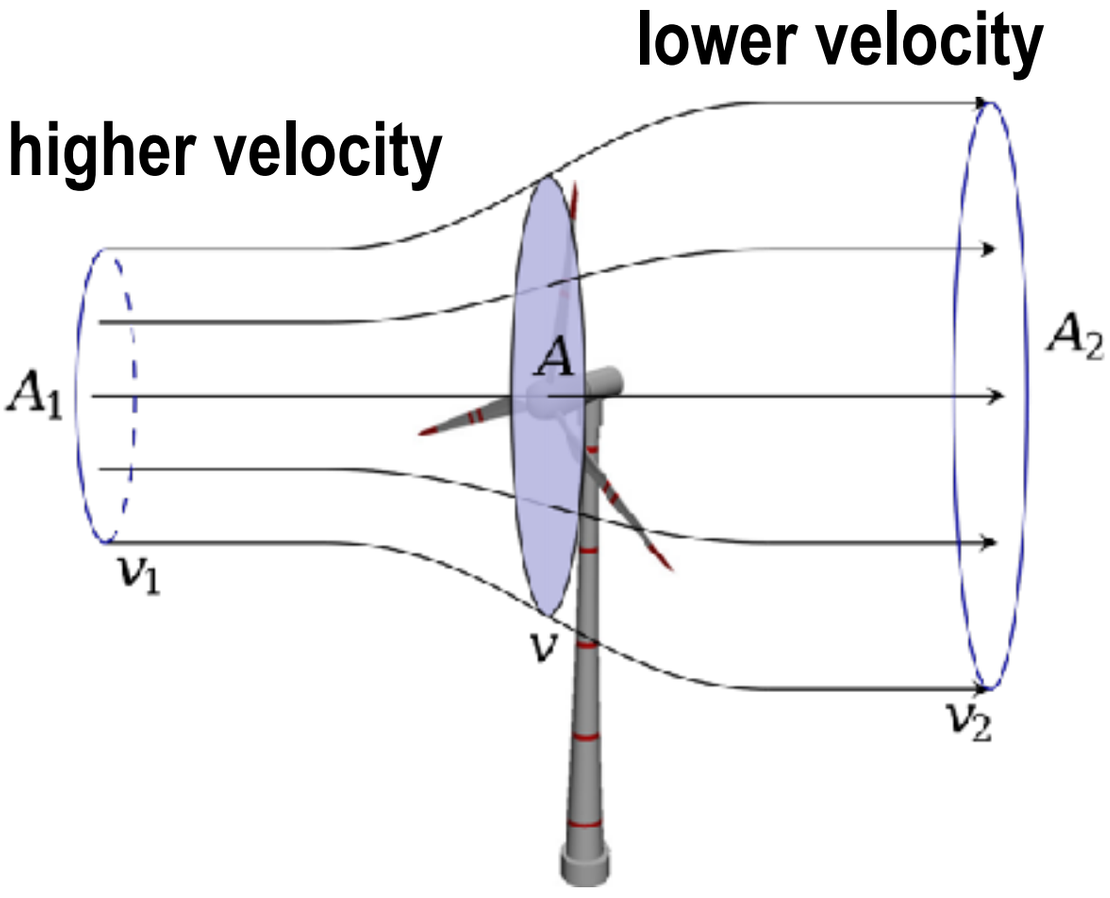
Ciências ULisboa

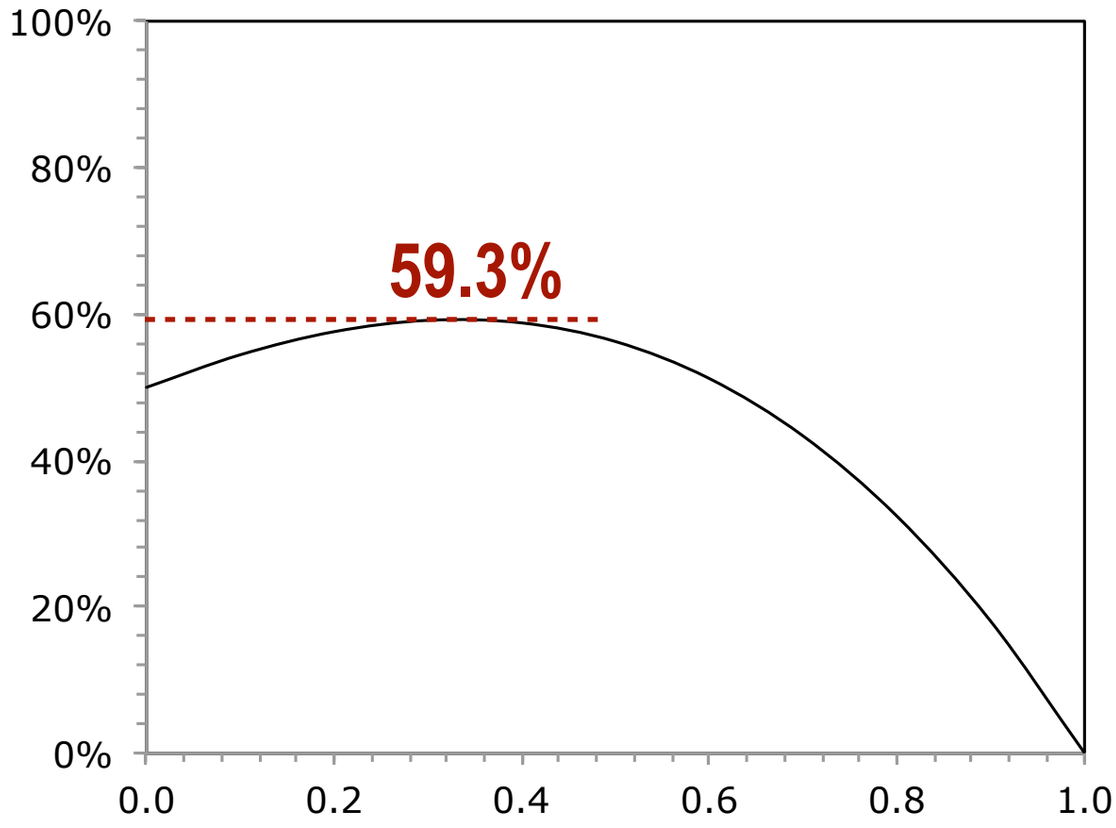


Ciências ULisboa



Ciências ULisboa





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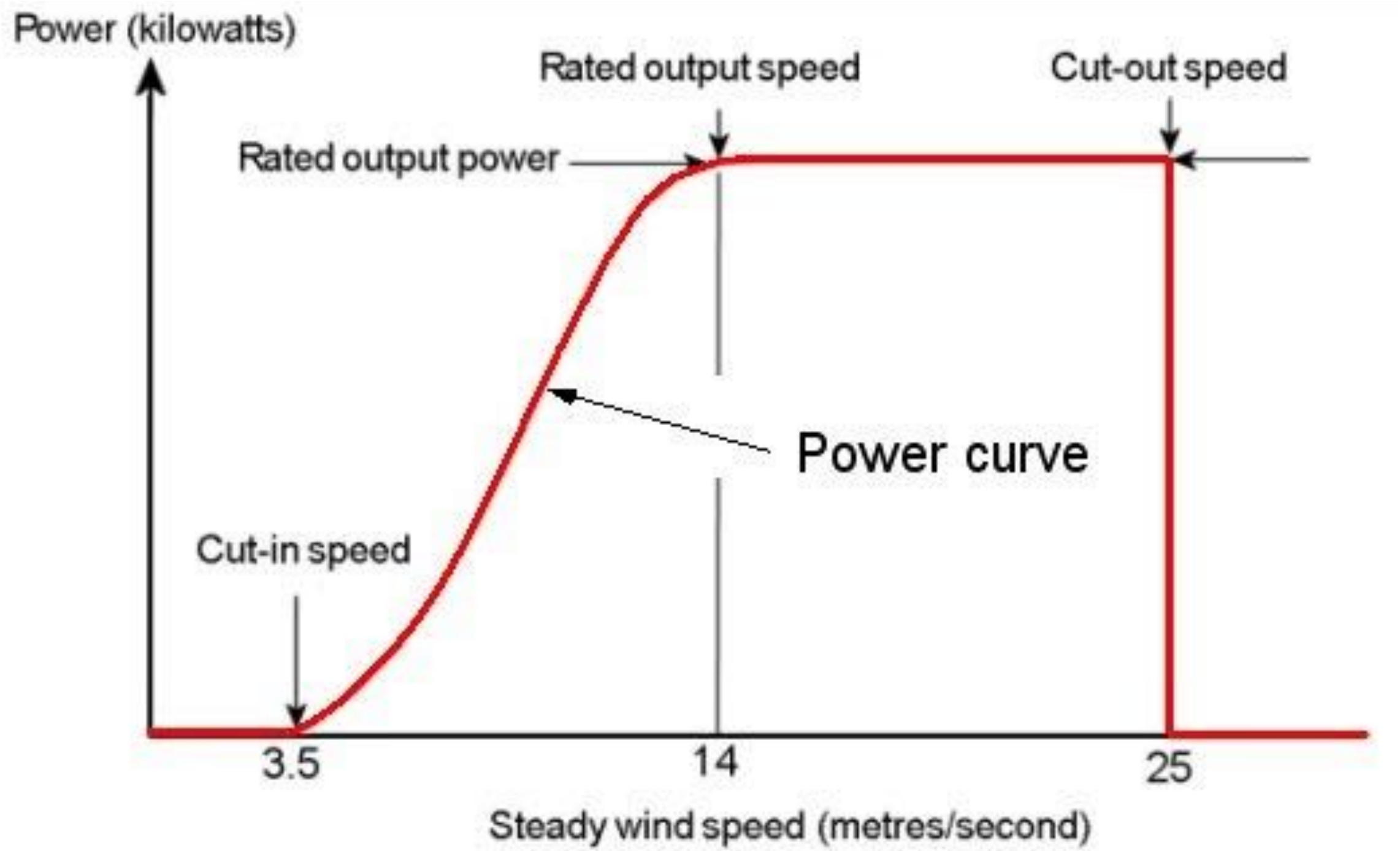
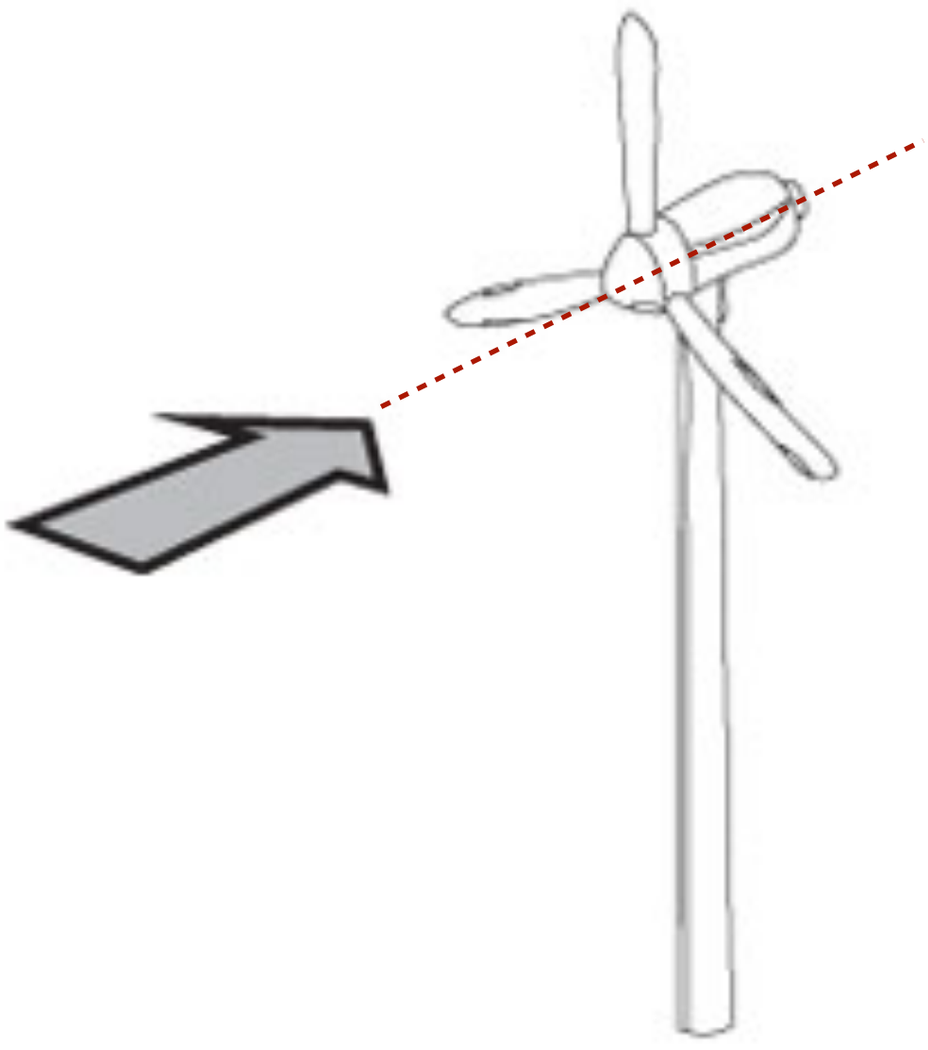


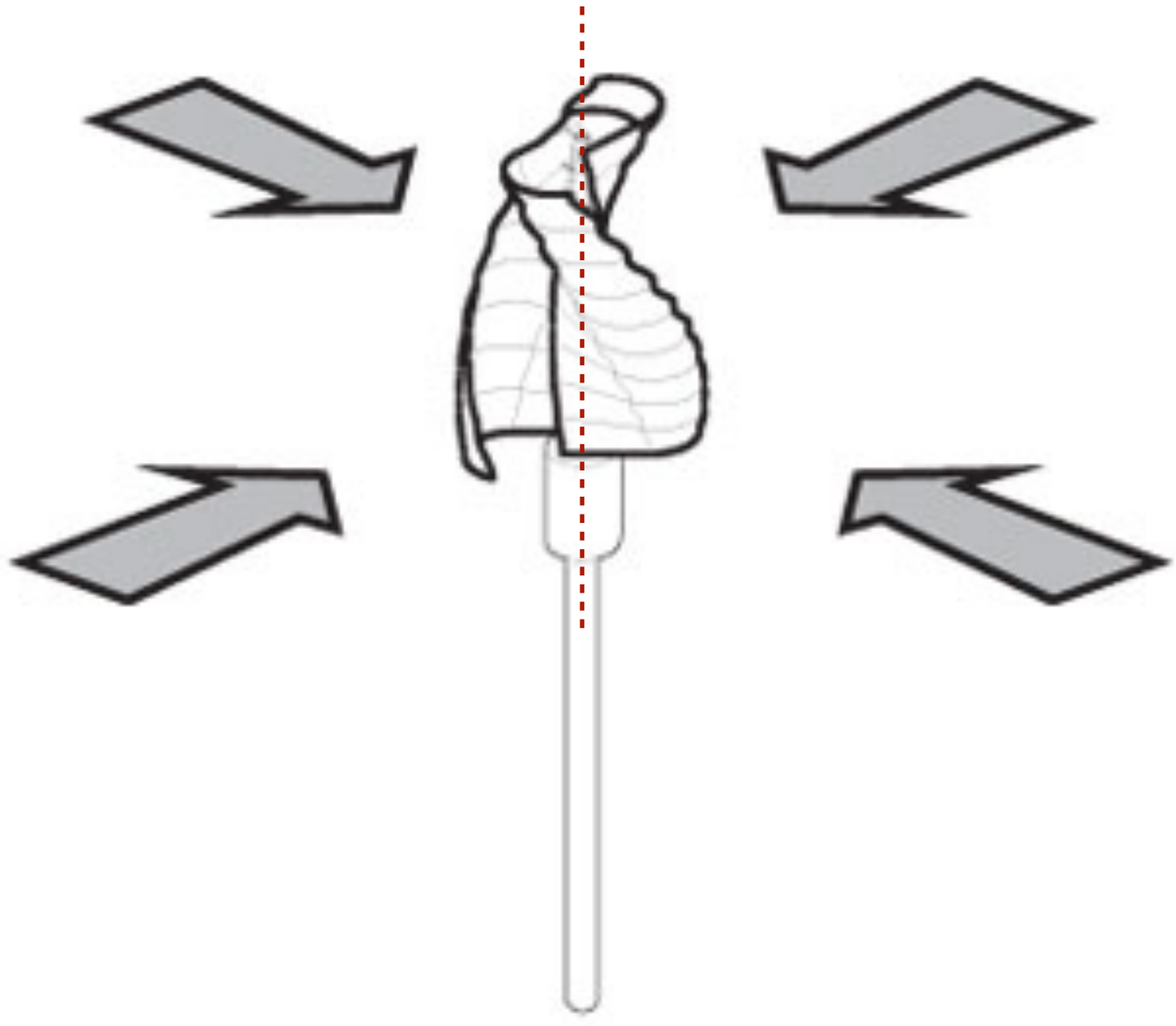
Ciências ULisboa

horizontal and vertical axis

wind



HAWT

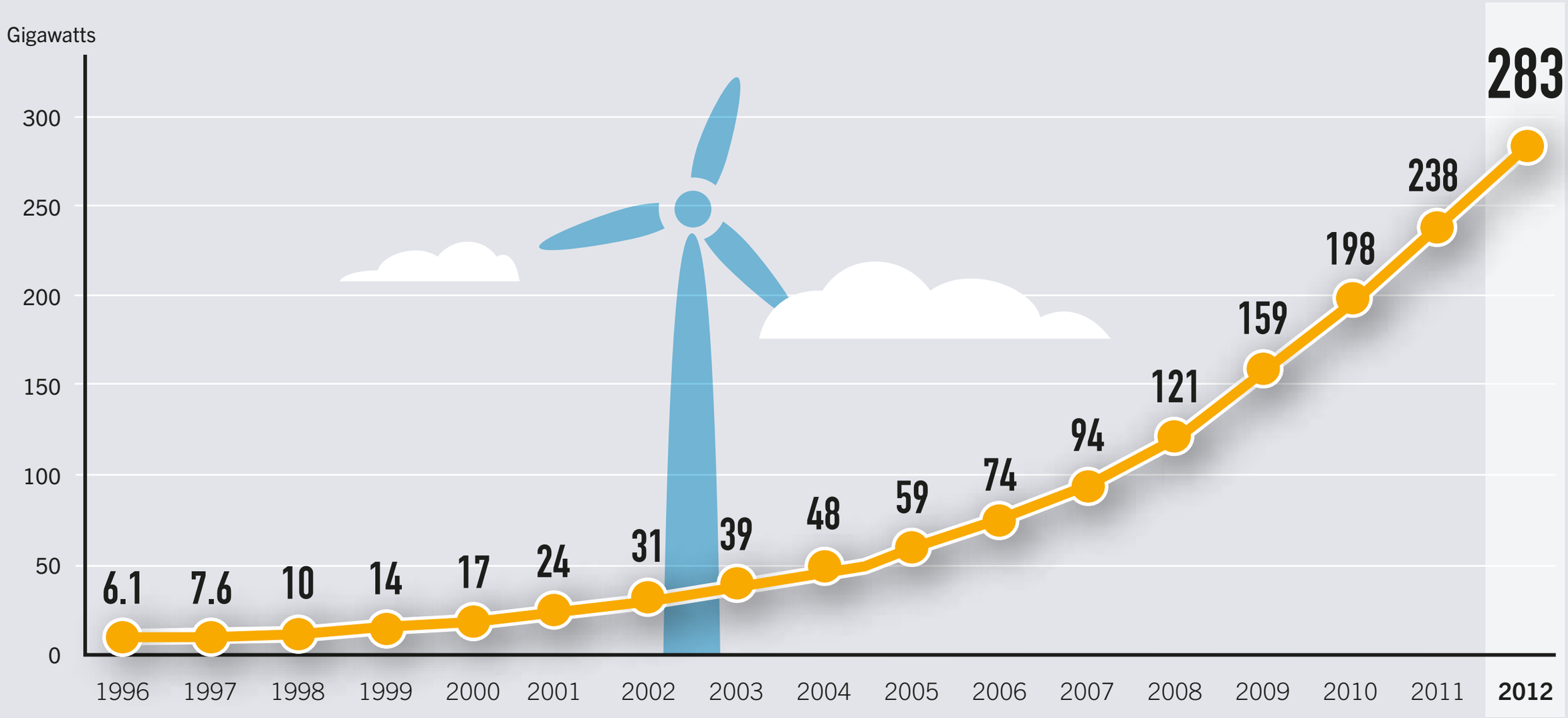


VAWT

Ciências ULisboa

wind power capacity

wind



Ciências ULisboa

Burgar Hill, Scotland, 3 MW, 1987
diameter 60 m, height 46 m


Vestas V164, 9.5 MW
diameter 164 m
height 220 m

VAWT

wind

Éole, 3.8 MW
height 110 m

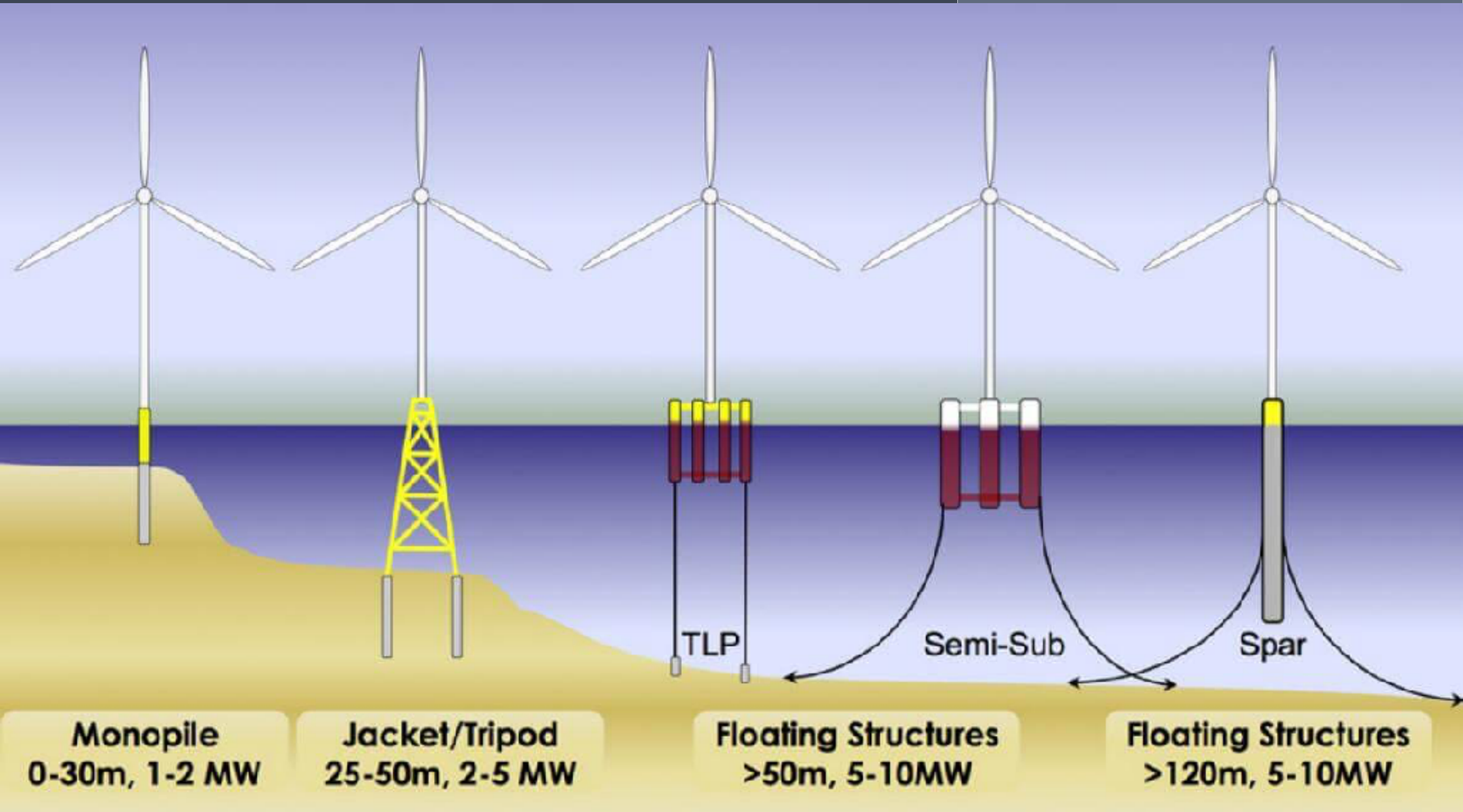
on-shore wind farm

wind

Ciências
ULisboa

off-shore wind farm

wind



Ciências ULisboa

- no emissions during running phase
- no fuel consumption
- low lcoe
- short time for installation
- no water need
- instability to electricity grid
- integration with other renewables for electricity storage

Ciências ULisboa

- mechanical and aerodynamic noise
- birds and bats mortality
- landscape visual impact
- land use

Ciências ULisboa

Comparison of everyday noises to utility-scale turbine sounds

Mechanical noise
Aerodynamic noise

Causes of bird fatalities

Number per 10,000 fatalities

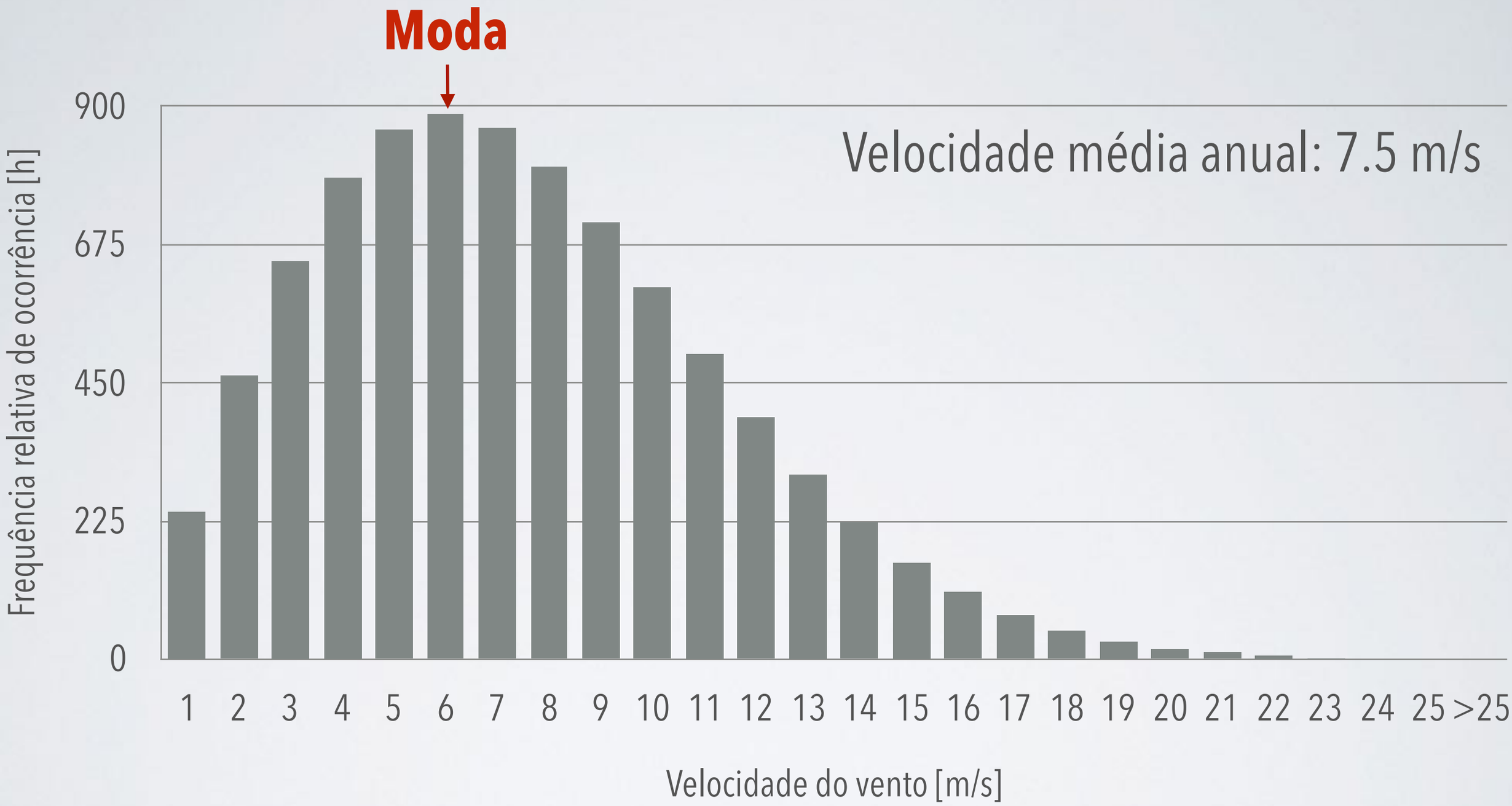
Source: Erickson et al. 2002, Summary of anthropogenic causes of bird mortality.

Technology	Typical Characteristics	Capital Costs (USD/kW)	Typical Energy Costs (LCOE – U.S. cents/kWh)
Power Generation			
Wind: Onshore	Turbine size: 1.5–3.5 MW Capacity factor: 25–40%	1,750–1,770 925–1,470 (China and India)	5–16 (OECD) 4–16 (non-OECD)
Wind: Offshore	Turbine size: 1.5–7.5 MW Capacity factor: 35–45%	3,000–4,500	15–23
Wind: Small-scale	Turbine size: up to 100 kW	3,000–6,000 (USA); 1,580 (China)	15–20 (USA)

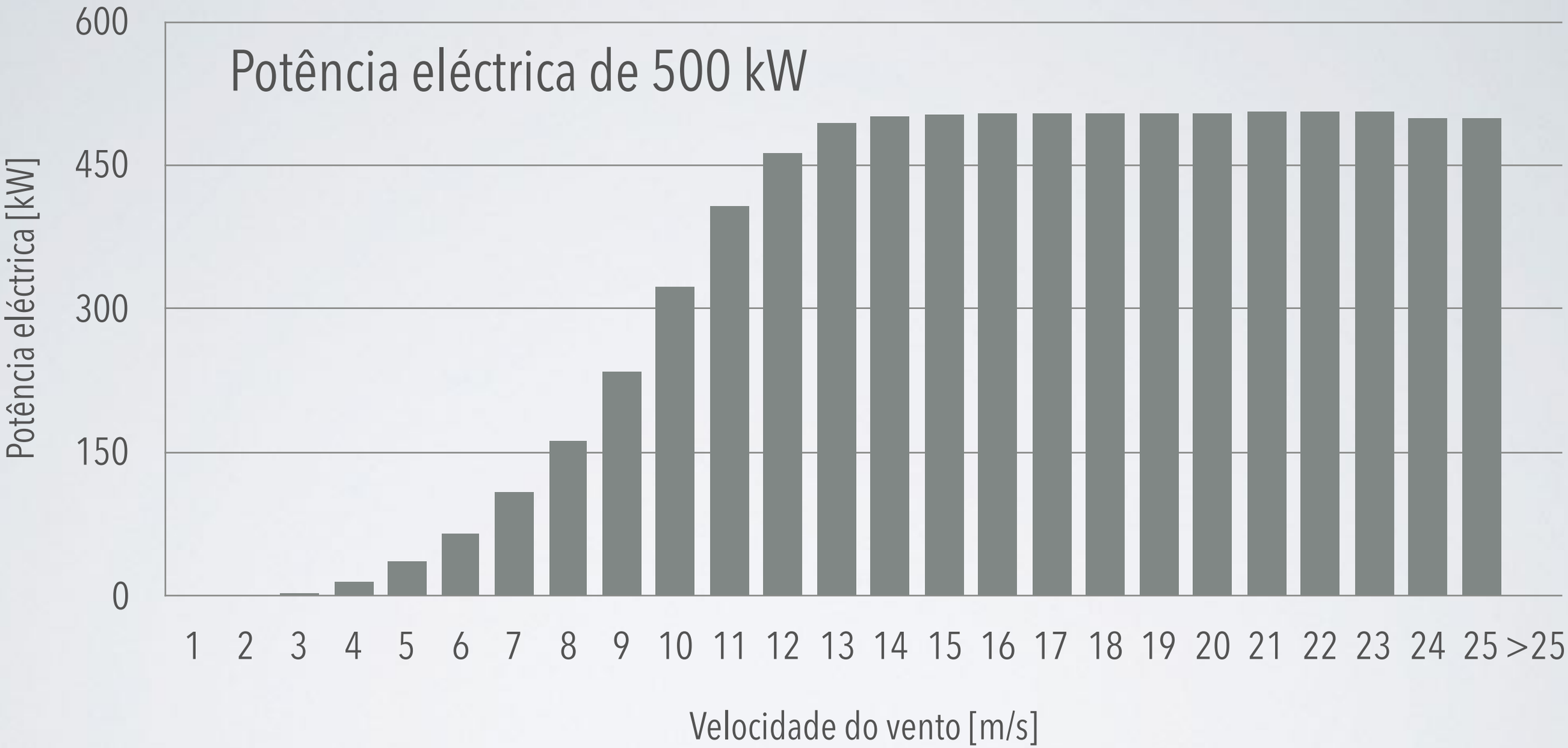
Off-shore compared to on-shore

	30km	50km	70km
Foundations	35-40%	45-50%	40-50%
Installation	9-13%	11-19%	10-23%
Grid connection	30-70%	44-83%	60-115%
Others	7-24%	7-24%	7-24%
	81-147%	**107-176%**	**117-212%**

Ciências ULisboa



Ciências ULisboa



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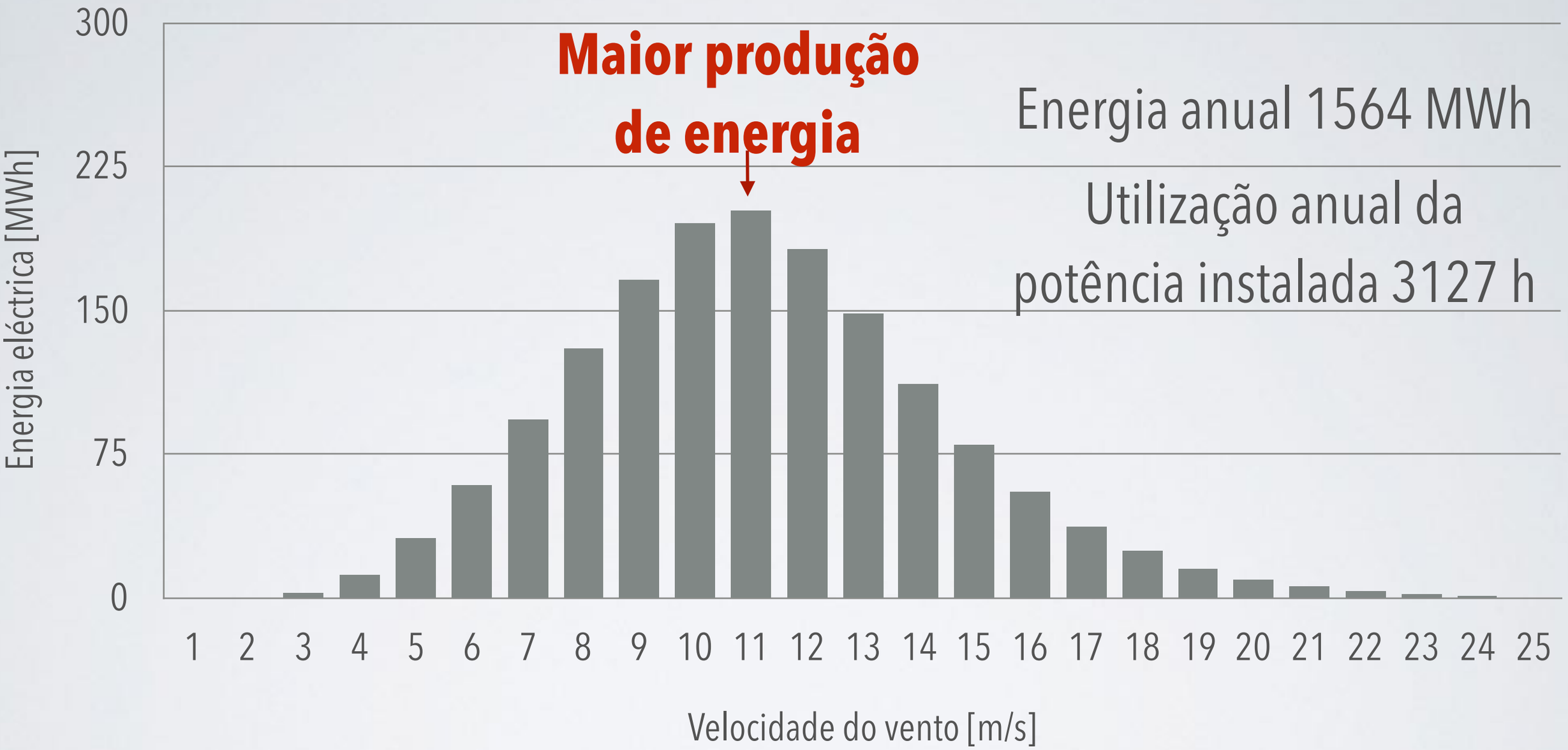

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Ciências ULisboa

O sistema solar fotovoltaico do *campus solar* tem uma potência nominal de 1,5 kW_p com uma eficiência média de 15,2%. O sistema está ligado à rede e beneficia de uma tarifa fixa de 0,38 €/kWh.

1. Considerando que a insolação média diária em Lisboa é 4,5 kWh/m^2, determinar a **produção média anual** do sistema. **(2 valores)**

2. Calcular o **fator de capacidade**. **(1 valor)**