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Case: energy yield calculation

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Start with:

- Wind data (site specific, supplied)
- Turbine specifications

End with:

- Number of households that can be supplied with one turbine
- Return rate of wind turbine (years)

Important parameters

- Power equation: $$P = C_P \frac{1}{2} \rho U_\infty^3 \pi R^2$$

- Maximum power coefficient $C_{P,max}$:
$$C_P = \frac{P_{rotor}}{P_{wind}(A_{rotor})}$$

- Availability – which percent of the time is the turbine producing power

- Capacity factor – how much of the turbine power capacity is used

Instructions

ASSIGNMENT

1 Go to the Excel calculation sheet. Choose a wind turbine from the fact sheet and fill in the following parameters:

Turbine type	
Rated power	
Rotor diameter	
Cut-in wind speed	
Rated wind speed	
Cut-out wind speed	
Hub height above mean sea level	

2 Write down the equation for the wind turbine power curve:

3 In the wind profile section, a dropdown menu can be used to choose between two locations. What differences can be observed between the different wind profiles and what is the physical explanation for these differences?

4 Which wind speed yields the most electric energy and why is this the case? (Hint: Use table 1)

5 Which location has a more favorable wind profile for the offshore wind turbine that you selected?

6 What is the meaning of the term "capacity factor"?

7 Placing the largest wind turbine is not always the best option, why is this?

Excel sheet

Turbine specifications

Wind turbine (brand/type)			
Rated power	P_{rated}		[kW]
Rotor diameter	D_{rotor}		[m]
Cut-in wind speed	$v_{cut\ in}$		[m/s]
Rated wind speed	v_{rated}		[m/s]
Cut-out wind speed	$v_{cut\ out}$		[m/s]
Hub height	z_{hub}		[m]
Rotor area	A_{rotor}	0	[m^2]
Power coefficient	Cp_{max}	0,00	[-]

Wind profile

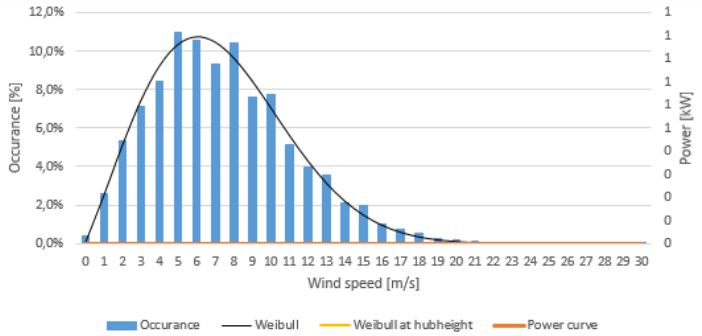
Location		K13	
Air density	ρ_{air}	1,225	[kg/m^3]
Weibull shape factor	k	2,10	[-]
Weibull scale factor	γ	0,90	[-]
Mean wind speed at 10m	$U_{mean,10}$	7,44	[m/s]
Mean wind speed at hub height	$U_{mean,hub}$	0,00	[m/s]

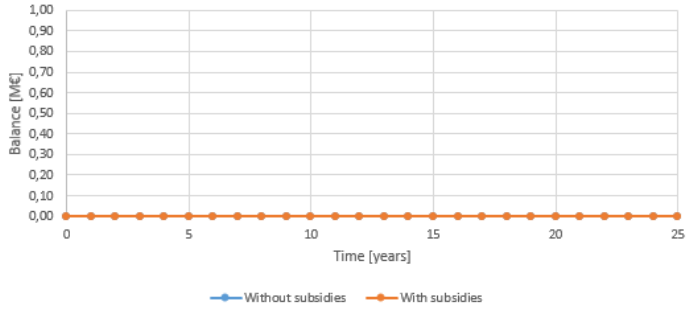
Energy yield

Annual energy consumption per household	E_{hh}	3340	[kWh]
Average availability	a_{avg}	95%	[%]
Time period of one year	T_{year}	8766	[h]
Total energy yield of one year	E_{annual}	-	[kWh]
Enough for households:	N_{hh}	0	[-]
Capacity factor	f_c	0%	[-]

Financial

Costs of installing an offshore wind turbine (CapEx)	2,50	[M€/MW]
Cost of operating an offshore wind turbine (OpEx)	25%	[% of CapEx]
Interest rate on initial investment	5%	[% of CapEx]
Installation cost of this offshore wind turbine	0,00	[M€]
Annual interest rate (over a 20 year period)	0,00	[M€]
Annual operating costs (over a 20 year period)	0,00	[M€]
Annual costs	0,00	[M€]
Long term estimated energy price	0,038	[€/kWh]
Subsidy for wind energy	0,130	[€/kWh]
Total energy price	0,168	[€/kWh]
Annual return on investment	0,00	[M€]
Internal rate of return	**0,0**	**[years]**





Excel sheet

Turbine specifications

Wind turbine (brand/type)			
Rated power	P_{rated}	4000	[kW]
Rotor diameter	D_{rotor}	110	[m]
Cut-in wind speed	$v_{cut\ in}$	2	[m/s]
Rated wind speed	v_{rated}	12	[m/s]
Cut-out wind speed	$v_{cut\ out}$	24	[m/s]
Hub height	z_{hub}	75	[m]
Rotor area	A_{rotor}	9503	[m^2]
Power coefficient	Cp_{max}	0,40	[-]

Wind profile

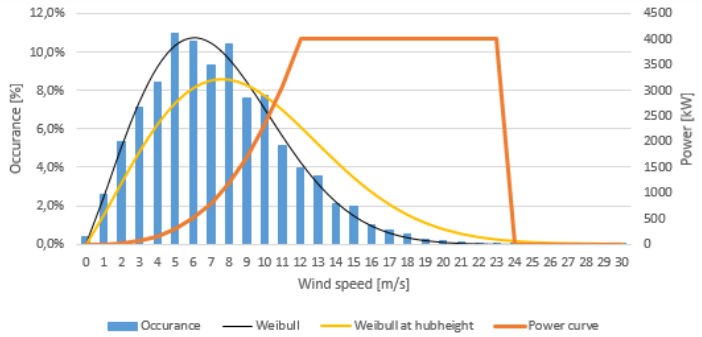
Location		K13	
Air density	ρ_{air}	1,225	[kg/m^3]
Weibull shape factor	k	2,10	[-]
Weibull scale factor	γ	0,90	[-]
Mean wind speed at 10m	$U_{mean,10}$	7,44	[m/s]
Mean wind speed at hub height	$U_{mean,hub}$	9,29	[m/s]

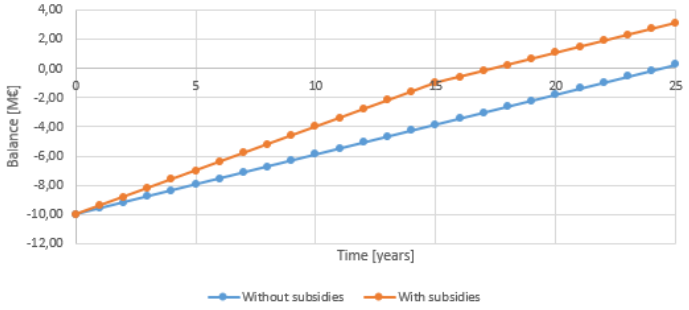
Energy yield

Annual energy consumption per household	E_{hh}	3340	[kWh]
Average availability	a_{avg}	95%	[%]
Time period of one year	T_{year}	8766	[h]
Total energy yield of one year	E_{annual}	15.830.143	[kWh]
Enough for households:	N_{hh}	4740	[-]
Capacity factor	f_c	45%	[-]

Financial

Costs of installing an offshore wind turbine (CapEx)	2,50	[M€/MW]
Cost of operating an offshore wind turbine (OpEx)	25%	[% of CapEx]
Interest rate on initial investment	5%	[% of CapEx]
Installation cost of this offshore wind turbine	10,00	[M€]
Annual interest rate (over a 20 year period)	0,03	[M€]
Annual operating costs (over a 20 year period)	0,17	[M€]
Annual costs	0,19	[M€]
Long term estimated energy price	0,038	[€/kWh]
Subsidy for wind energy	0,012	[€/kWh]
Total energy price	0,050	[€/kWh]
Annual return on investment	0,79	[M€]
Internal rate of return	**16,7**	**[years]**





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