Forestry input data

ENTER DETAILS OF FORESTRY MANAGEMENT HERE!

Note: Data only needed if select to calculate capacity factor from forestry data (cell C15 in Core input data sheet), or to include detailed forestry management (cell C35 in Core input

(1) for estimating compensatory planting woodland carbon http://tinyurl.com/woodlandcarboncode

(2) for UK policy http://tinyurl.com/FCPolicy

(3) FC Scotland Control of Woodland Removal (including Compensatory Planting) http://tinyurl.com/FCScotlandCompPlant

No POC losses for bare soil included yet. If extensive areas of base soil is present at site need modified calculation.

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Input data	Expected values: Enter expected value here ▼	Record source of data	Possible range of values: Enter minimum value here ▼	Record source of data	Possible range of values: Enter maximum value here ▼	Record source of data
Windfarm characteristics						
Location						
Distance to nearest biofuel plant (km)						
Dimensions						
Total wind farm area (ha)						
Performance						
Height of turbines (m)						
Average site windspeed (m s^{-1})						
Estimated downtime for maintenance etc (%)						
Emissions due to forestry operations						
Emissions from felling (g CO_2 m^{-3})						
Emissions of CO_2 associated with transportation (g CO_2 km^{-1} t^{-1})						
Forestry Plantation Characteristics						
Note - total number of turbines already specified:						
AREA 1						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)	User-defined		User-defined		User-defined	
Major soil sub-group	Deep Peat		Deep Peat		Deep Peat	
Species	Scots pine		Scots pine		Scots pine	
Felled Forest Biomass used as biofuel?	No		No		No	
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t^{-1})						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						
AREA 2						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)						
Major soil sub-group						
Species						
Felled Forest Biomass used as biofuel?						
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t^{-1})						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						
AREA 3						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)						
Major soil sub-group						
Species						
Felled Forest Biomass used as biofuel?						
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t^{-1})						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						
AREA 4						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)						
Major soil sub-group						
Species						
Felled Forest Biomass used as biofuel?						
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t^{-1})						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						
AREA 5						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)						
Major soil sub-group						
Species						
Felled Forest Biomass used as biofuel?						
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t^{-1})						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						

Note: Estimated downtime. Estimated downtime for maintenance etc. Few reports on downtime of wind turbines are publically available. However, one review by Garrad Hassan (2011) suggests that the minimum downtime reported was 2% for the annual moving average for between 8 to 9 years of operation of new turbines, for a sample of 240 turbines. For a summary of findings see Garrad Hassan (2011).

Note: Emissions from felling and timber removal. Based on emissions factors from UK taken from Morison et al (2011), if clearfelling assumed to be performed by harvester and timber is assumed extracted with forwarder, the emissions are 6675

Note: Emissions associated with transportation. Assuming trasportation by trucks running on diesel and 20% of journey taken on forest roads, emissions factor obtained from Morison et al (2011) is 39.33 g CO_2 km^{-1} t^{-1} (range 38.5 – 40.15 g CO_2 km^{-1} t^{-1} - average = 39.33 g CO_2 km^{-1} t^{-1})

Note: Power curve
Based on Vestas 2.0MW Optispeed turbine with roughness class C2, modelled over wind speed of 5-10 m s^{-1}. To define a the power curve for a different turbine type, plot annual power output, *P* (MWh) against annual windspeed, W (m s^{-1}) and fit a linear regression to obtain slope, *a*, and intercept, *b*:

$$P = aW + b$$

Note: Soil sub-group
Used in determination of forestry characteristic.
Peaty gley = Peaty Soils (5-50cm) e.g. peaty gley, peaty podsol
Deep peat = Deep Peat (>50cm) e.g. basin and blanket bogs

Note: Species
So far only Scots pine and Sitka spruce included.

Note: Value of felled forestry Values available in Mason et al., 2009.

Note: Carbon : Biomass ratio of felled forestry Wood biomass can be converted to dry weight using wood density based values from Lavers (1983) with a subsequent assumption that C:dry matter ratio is 50% (Matthews 1993). For simplicity an integrated factor, the 'wood density to biomass factor' taken from Mason et al (2009) can be used.
Value = 0.5

Forestry input data

ENTER DETAILS OF FORESTRY MANAGEMENT HERE!

Note: Data only needed if select to calculate capacity factor from forestry data (cell C15 in Core input data sheet), or to include detailed forestry management (cell C35 in Core input data sheet)

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Input data	Expected values: Enter expected value here	Record source of data	Possible range of values: Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Construction design						
Note - total number of turbines already specified:	**15**		**15**		**15**	
AREA 1						
Number of turbines in this area	15		15		15	
Turbine foundations						
Average depth of peat removed when constructing foundations (m)	0.35		0.35		0.35	
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular		Rectangular	
Length at surface (m)	30		30		30	
Width at surface (m)	25		25		25	
Length at bottom (m)	30		30		30	
Width at bottom (m)	25		25		25	
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)	0.35		0.35		0.35	
Approximate geometric shape of whole dug when constructing hardstanding	Rectangular		Rectangular		Rectangular	
Length at surface (m)	97		97		97	
Width at surface (m)	30		30		30	
Length at bottom (m)	97		97		97	
Width at bottom (m)	30		30		30	
Piling						
Is piling used?	No		No		No	
Volume of Concrete						
Volume of concrete used (m^3)	17250		17250		17250	

Windfarm CO_2 emission saving

Note: The total emission savings are given by estimating the total possible electrical output of the windfarm multiplied by the emission factor for the counterfactual case (coal-fire generation and electricity from grid)

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Values taken from input sheet	Total Exp	Total Min	Total Max	Forestry Area 1 Exp	Forestry Area 1 Min	Forestry Area 1 Max	Forestry Area 2 Exp	Forestry Area 2 Min	Forestry Area 2 Max	Forestry Area 3 Exp	Forestry Area 3 Min	Forestry Area 3 Max	Forestry Area 4 Exp	Forestry Area 4 Min	Forestry Area 4 Max	Forestry Area 5 Exp	Forestry Area 5 Min	Forestry Area 5 Max
Power Generation Characteristics																		
No. of turbines	15	15	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Power rating of turbines (turbine capacity) (MW)	5.6	5.5	6.6	5.6	5.5	6.6	5.6	5.5	6.6	5.6	5.5	6.6	5.6	5.5	6.6	5.6	5.5	6.6
Power of windfarm (MW)	84	82.5	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estimated downtime for maintenance etc (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Counterfactual emission factors																		
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945
Grid-mix emission factor (t CO_2 MWh^{-1})	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707	0.20707
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424

Calculation of capacity factor	1	Direct input of capacity factor		
		Exp	Min	Max
Entered capacity factor (%)		26.62	23.96	29.28

Parameters	*Slope (a)*			*Intercept (b)*		
Partial power curves for different turbines	Exp	Min	Max	Exp	Min	Max
User-defined	0.0	0.0	0.0	0.0	0.0	0.0
Vestas 2.0 MW Optispeed C2	1392.5	1392.5	1392.5	-4291.9	-4291.9	-4291.9

Calculation of capacity factor from forestry management	Total Exp	Total Min	Total Max	Forestry Area 1 Exp	Forestry Area 1 Min	Forestry Area 1 Max	Forestry Area 2 Exp	Forestry Area 2 Min	Forestry Area 2 Max	Forestry Area 3 Exp	Forestry Area 3 Min	Forestry Area 3 Max	Forestry Area 4 Exp	Forestry Area 4 Min	Forestry Area 4 Max	Forestry Area 5 Exp	Forestry Area 5 Min	Forestry Area 5 Max
Wind speed ratio calculated in 7d				#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Average site windspeed (m s^{-1})	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual theoretical energy output from turbine (MW $turbine^{-1}$ yr^{-1})	49056	48180	57816	49056	48180	57816	49056	48180	57816	49056	48180	57816	49056	48180	57816	49056	48180	57816
Power curve				User-defined	User-defined	User-defined	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines
(Power curve code)				1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Slope (a)				0	0	0	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Intercept (b)				0	0	0	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Annual power output from an individual turbine (MW $turbine^{-1}$ yr^{-1})				#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Calculated capacity factor (%)				#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######

Calculation of annual energy output from wind farm	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
Direct input of capacity factor Capacity factor(%)	27	24	29	27	24	29	27	24	29	27	24	29	27	24	29	27	24	29
Annual energy output from windfarm (MW yr^{-1})	**195881**	**173159**	**253928**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

RESULTS	**Total**			**Area 1**			**Area 2**			**Area 3**			**Area 4**			**Area 5**		
Windfarm CO_2 emission saving over…																		
…coal-fired electricity generation (tCO_2 yr^{-1})	**185107**	**163635**	**239962**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
…grid-mix of electricity generation (tCO_2 yr^{-1})	**40561**	**35856**	**52580.8**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
…fossil fuel - mix of electricity generation (tCO_2 yr^{-1})	**83053**	**73419.4**	**107665**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

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Windfarm CO_2 emission saving

Note: The total emission savings are given by estimating the total possible electrical output of the windfarm multiplied by the emission factor for the counterfactual case (coal-fire generation and electricity from grid)

Emissions due to turbine life

Note: The carbon payback time of the windfarm due to turbine life (eg. manufacture, construction, decomissioning) is calculated by comparing the emissions due to turbine life with carbon-savings achieved by the windfarm while displacing electricity generated from coal-fired capacity or grid-mix.

Method used to estimate CO_2 emissions from turbine life (eg. manufacture, construction, decommissioning)?	Calculate wrt installed capacity

	Exp	Min	Max
Direct input of emissions due to turbine life (t CO_2 windfarm^{-1})	0	0	0
Calculation of emissions due to turbine life from energy output			
CO_2 emissions due to turbine life (tCO_2 turbine^{-1})	4765	4671	5699
No. of turbines	15	15	15
Total calculated CO_2 emission of the wind farm due to turbine life (t CO_2 windfarm^{-1})	71472	70071	85487

	Total			Construction Area 1			Construction Area 2			Construction Area 3			Construction Area 4			Construction Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Calculation of emissions due to cement used in construction																		
Volume of cement used (m^3)	17250	17250	17250	17250	17250	17250	0	0	0	0	0	0	0	0	0	0	0	0
CO_2 emission rate (t CO_2 m^{-3} cement)	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316
Total CO_2 emissions due to cement used in construction	5451	5451	5451	5451	5451	5451	0	0	0	0	0	0	0	0	0	0	0	0

RESULTS **Losses due to turbine life (eg.**	76923	75522	90938
Additional CO_2 payback time of windfarm due to turbine life (eg. manufacture, contruction, decomissioning)			
…coal-fired electricity generation (months)	5	6	5
…grid-mix of electricity generation (months)	23	25	21
…fossil fuel - mix of electricity generation (months)	11	12	10

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Emissions due to turbine life

Note: The carbon payback time of the windfarm due to turbine life (eg. manufacture, construction, decomissioning) is calculated by comparing the emissions due to turbine life with carbon-savings achieved by the windfarm while displacing electricity generated from coal-fired capacity or grid-mix.

http://www.concretecentre.com/PDF/SCF_Table%207%20Embodied%20CO2_April%202013.pdf

mpa The Concrete Centre

Embodied carbon dioxide (CO_2e) of concretes used in buildings

CONCRETE APPLICATION	Concrete designation	CO_2e (kgCO_2e/m^3)[1]			CO_2e (kgCO_2e/tonne)[1]		
		CEM I concrete	30% fly ash concrete	50% ggbs concrete	CEM I concrete	30% fly ash concrete	50% ggbs concrete
Blinding, mass fill, strip footings, mass foundations, trench foundations [2]	GEN1	177	128	101	77	55	44
Reinforced Foundations [2]	RC25/30**	316	263	197	133	111	83
Ground floors [2]	RC28/35 *	316	261	186	134	110	79
Structural: in situ floors, superstructure, walls, basements [2]	RC32/40 **	369	313	231	154	131	96
High strength concrete [2]	RC40/50 **	432	351	269	178	146	111
		CO_2e (kgCO_2e/m^3)			CO_2e (kgCO_2e/tonne)		
Unreinforced Precast flooring[3]		-			165		
Reinforced precast flooring[3]		-			171		
Average Generic Concrete Block[4]		-			84		

* *includes 30kg/m^3 steel reinforcement*

** *includes 100kg/m^3 steel reinforcement*

<u>Emissions due to backup power generation</u>

Note: CO_2 loss due to back up is calculated from the extra capacity required for backup of the windfarm given in the input data.

Note: Wind generated electricity is inherently variable, providing unique challenges to the electricity generating industry for provision of a supply to meet consumer demand (Netz, 2004). Backup power is required to accompany wind generation to stabilise the supply to the consumer. This backup power will usually be obtained from a fossil fuel source. At a high level of wind power penetration in the overall generating mix, and with current grid management techniques, the capacity for fossil fuel backup may become strained because it is being used to balance the fluctuating consumer demand with a variable and highly unpredictable output from wind turbines (White, 2007). The Carbon Trust (Carbon Trust/DTI, 2004) concluded that increasing levels of intermittent generation do not present major technical issues at the percentages of renewables expected by 2010 and 2020, but the UK renewables target at the time of that report was only 20%. When national reliance on wind power is low (less than ~20%), the additional fossil fuel generated power requirement can be considered to be insignificant and may be obtained from within the spare generating capacity of other power sectors (Dale et al, 2004). However, as the national supply from wind power increases above 20%, without improvements in grid management techniques, emissions due to backup power generation may become more significant. The extra capacity needed for backup power generation is currently estimated to be 5% of the rated capacity of the wind plant if wind power contributes more than 20% to the national grid (Dale et al 2004). Moving towards the SG target of 50% electricity generation from renewable sources, more short-term capacity may be required in terms of pumped-storage hydro-generated power, or a better mix of offshore and onshore wind generating capacity. Grid management techniques are anticipated to reduce this extra capacity, with improved demand side management, smart meters, grid reinforcement and other developments. However, given current grid management techniques, it is suggested that 5% extra capacity should be assumed for backup power generation if wind power contributes more than 20% to the national grid. At lower contributions, the extra capacity required for backup should be assumed to be zero. These assumptions should be revisited as technology improves.

	Expected	**Minimum**	**Maximum**
Reserve capacity required for backup			
No. of turbines	15	15	15
Power rating of turbines (turbine capacity) (MW)	5.6	5.5	6.6
Power of wind farm (MW h^{-1})	84	82.5	99
Rated capacity (MW yr^{-1})	735840	722700	867240
Extra capacity required for backup (%)	5	5	5
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10
Reserve capacity (MWh yr^{-1})	3679	3614	4336

Carbon dioxide emissions due to backup power generation			
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.945	0.945	0.945
Grid-mix emission factor (t CO_2 MWh^{-1})	0.20707	0.20707	0.20707
Fossil fuel- mix emission factor (t CO_2 MWh^{-1})	0.424	0.424	0.424
Lifetime of windfarm (years)	50	50	50
Annual emissions due to backup from…			
…coal-fired electricity generation (tCO_2 yr^{-1})	3477	3415	4098
…grid-mix of electricity generation (tCO_2 yr^{-1})	762	748	898
…fossil fuel - mix of electricity generation (tCO_2 yr^{-1})	1560	1532	1839

RESULTS			
Total emissions due to backup from…			
…coal-fired electricity generation (tCO_2)	173842	170738	204885
…grid-mix of electricity generation (tCO_2)	38093	37412	44895
…fossil fuel - mix of electricity generation (tCO_2)	**77999**	**76606**	**91927**
Additional CO_2 payback time of windfarm due to backup			
…coal-fired electricity generation (months)	11	13	10
…grid-mix of electricity generation (months)	11	13	10
…fossil fuel - mix of electricity generation (months)	11	13	10

Assumption: Backup assumed to be by fossil-fuel-mix of electricity generation. Note that hydroelectricity may also be used for backup, so this assumption may make the value for backup generation too high. These assumptions should be revisited as technology develops.

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<u>Emissions due to backup power generation</u>

Note: CO_2 loss due to back up is calculated from the extra capacity required for backup of the windfarm given in the input data.