



APPENDIX 10-1

**BALLIVOR WIND FARM
CARBON CALCULATIONS**

Ballivor Wind Farm: Carbon Balance Calculation

1. Technology Lifecycle Emissions

	Value	Unit
Turbine No.	26	
Turbine Size	4.5	MW
Capacity factor*	31.7	%
Curtailment	4	%
Operational life	30	years
Annual Output - no curt.	318,077	MWh/a
Annual Output - with curt.	305,354	MWh/a
Total Output	9,160,610	MWh
Wind lifecycle emissions	14.28	kg CO2/MWh

1. Total Technology Lifecycle emissions

Annual output	305,354	MWh
Lifespan	30	years
Lifecycle emissions	14.28	kg CO2/MWh
Total emissions	130,844	tonnes CO2

4. Carbon Balance

Windfarm Lifetime Emissions		
- technology	130,844	
- cycling	146,994	
- peat	7,553	
Total:	285,391	t CO2

2. Additional System Cycling Emissions

	Value	Unit
Carbon emissions from natural gas	56.9	kg CO2/GJ
CCGT emissions at 54% design efficiency	379.3	kg CO2/MWh
CCGT efficiency at Min Stable Generation	48.6	%
Demand Following: 18hrs@53%; 6 hrs@MSG		
Average efficiency from demand following	51.90	%
CCGT emissions at 51.9% efficiency	394.7	kg CO2/MWh
CCGT efficiency at low wind	46	%
CCGT emissions at 46% efficiency	448.9	kg CO2/MWh
CCGT efficiency at high wind	44	%
CCGT emissions at 44% efficiency	464.9	kg CO2/MWh
Additional emissions from wind cycling	16.05	kg CO2/MWh

2. Total Additional Cycling Emissions

Annual output	305,354	MWh
Lifespan	30	years
Cycling emissions	16.05	kg CO2/MWh
Total emissions	146,994	tonnes CO2

Windfarm Lifetime Savings	(t CO2)	Payback (yrs)
Against SEM mid-merit	6,820,074	1.26
Against EU FFC	6,035,010	1.42
Against 'Demand Following' CCGT	3,615,529	2.37

3. Additional Peatland Disturbance Emissions

	Value	Unit
Peat disturbed	11.97	ha
Net change in emissions	5.54	t CO2/ha/a

4. Fossil Fuel Emissions Displaced

SEM mid-merit emissions	744.5	kg CO2/MWh
EU Fossil Fuel Comparator	658.8	kg CO2/MWh
'Demand Following' CCGT unit	394.7	kg CO2/MWh

3. Total Additional Peatland Disturbance Emissions

Respread area	45.45	ha
Lifespan	30	years
Emissions increase	5.54	t CO2/ha/a
Total emissions	7,553	tonnes CO2

Ballivor Wind Farm: Carbon Balance Calculation

1. Technology Lifecycle Emissions

	Value	Unit
Turbine No.	26	
Turbine Size	6.5	MW
Capacity factor*	31.7	%
Curtailment	4	%
Operational life	30	years
Annual Output - no curt.	459,444	MWh/a
Annual Output - with curt.	441,066	MWh/a
Total Output	13,231,993	MWh
Wind lifecycle emissions	12.41	kg CO2/MWh

1. Total Technology Lifecycle emissions

Annual output	441,066	MWh
Lifespan	30	years
Lifecycle emissions	12.41	kg CO2/MWh
Total emissions	164,152	tonnes CO2

4. Carbon Balance

Windfarm Lifetime Emissions		
- technology	164,152	
- cycling	212,325	
- peat	7,553	
Total:	384,030	t CO2

2. Additional System Cycling Emissions

	Value	Unit
Carbon emissions from natural gas	56.9	kg CO2/GJ
CCGT emissions at 54% design efficiency	379.3	kg CO2/MWh
CCGT efficiency at Min Stable Generation	48.6	%
Demand Following: 18hrs@53%; 6 hrs@MSG		
Average efficiency from demand following	51.90	%
CCGT emissions at 51.9% efficiency	394.7	kg CO2/MWh
CCGT efficiency at low wind	46	%
CCGT emissions at 46% efficiency	448.9	kg CO2/MWh
CCGT efficiency at high wind	44	%
CCGT emissions at 44% efficiency	464.9	kg CO2/MWh
Additional emissions from wind cycling	16.05	kg CO2/MWh

2. Total Additional Cycling Emissions

Annual output	441,066	MWh
Lifespan	30	years
Cycling emissions	16.05	kg CO2/MWh
Total emissions	212,325	tonnes CO2

Windfarm Lifetime Savings	(t CO2)	Payback (yrs)
Against SEM mid-merit	9,851,219	1.17
Against EU FFC	8,717,237	1.32
Against 'Demand Following' CCGT	5,222,430	2.21

3. Additional Peatland Disturbance Emissions

	Value	Unit
Peat disturbed	11.97	ha
Net change in emissions	5.54	t CO2/ha/a

4. Fossil Fuel Emissions Displaced

SEM mid-merit emissions	744.5	kg CO2/MWh
EU Fossil Fuel Comparator	658.8	kg CO2/MWh
'Demand Following' CCGT unit	394.7	kg CO2/MWh

3. Total Additional Peatland Disturbance Emissions

Respread area	45.45	ha
Lifespan	30	years
Emissions increase	5.54	t CO2/ha/a
Total emissions	7,553	tonnes CO2

Assumptions Underlying the Analysis

Sources

Wind Farm Carbon Emissions

Wind turbine lifecycle emissions - includes turbine, transport, all civil works, operation and also decommissioning
LCA emissions are taken as an average of turbine supplier embodied carbon data: = 14.31 kg CO₂/MWh

System Cycling - additional emissions

Carbon emissions from natural gas - from 'Energy in Ireland 1990-2014' = 56.9 t CO₂/TJ

CCGT Design efficiency: 54%

Irish CCGT units on a system without intermittent wind would still operate in a 'load following' mode

Average emissions from load-following CCGTS at high wind: 464.92 kg CO₂/MWh; Average CCGT efficiency: 44%

Average emissions from load-following CCGTS at low wind: 448.87 kg CO₂/MWh; Average CCGT efficiency: 46%

Additional emissions from cycling: 16.05 kg CO₂/MWh

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Emissions from Peatland Disturbance

Total volume of peat excavated for roads, turbine bases, substation etc = 454,474m³

Excavated peat respread 1 m depth at all locations

Total area of respread peat = 45.45 ha

Assume that all areas excavated have a carbon emission factor of zero t CO₂/ha/a

Assume respread areas are recolonised with rushes & birch/willow scrub - with net emissions of 19.25 t CO₂/ha/a - and that no vegetation management is carried out.

CARBAL FINAL REPORT; industrial cutaway peatlands

Fossil Fuel Emissions Displaced

Wind displaces fossil electricity generated from thermal plants up to the system non-synchronous penetration limit

On the Irish Grid - taken as SEM Reference mid-merit plant (SEM/13/006) = 744.5 kg CO₂/MWh

In the EU Single Electricity Market - COM(2016)767 - the Fossil Fuel Comparator is 183 gCO₂/MJ = 658.8 kg CO₂/MWh

For a displaced 'Demand Following' CCGT unit = 379.3 kg CO₂/MWh

Recast of RED; See Annex VI