# Appendix 9-1

Carbon Calculation Worksheet

# Timahoe North Solar PV Farm: Carbon Balance Calculation

## 1. Technology Lifecycle Emissions

| | Value | Unit |
|---|---|---|
| Installed Capacity | 106 | MWdc |
| Global Irradiation | 1,028 | MWh/m2 |
| Curtailment | 4 | % |
| Degradation | 0.4 | % |
| Operational life | 35 | years |
| Total output over lifetime - no curt. | 2,904,699 | MWh/a |
| Total output over lifetime - incl. curt | 2,788,511 | MWh/a |
| Solar PV farm lifecycle emissions | 88.47 | kg CO2/MWh |

## 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 |

## 3. Additional Peatland Disturbance Emissions

| | Value | Unit |
|---|---|---|
| Peat disturbed | 63,400 | m3 |
| Oxidisation of Displaced Peat | 9,208 | t CO2 |
| Change in peatland classification - module area | 0 | t CO2 |
| Loss of Carbon Fixation by bog plants | 471 | t CO2 |
| Change in peatland classification - construction area | -3,204 | t CO2 |

## 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 |

## 1. Total Technology Lifecycle emissions

| | | |
|---|---|---|
| Lifespan | 35 | years |
| Annual output | 2,788,511 | MWh |
| Lifecycle emissions | 88.47 | kg CO2/MWh |
| Construction emissions | 8,643 | tCO2 |
| **Total emissions** | **255,350** | **tonnes CO2** |

## 2. Total Additional Cycling Emissions

| | | |
|---|---|---|
| Lifespan | 35 | years |
| Annual output | 2,788,511 | MWh |
| Cycling emissions | 16.05 | kg CO2/MWh |
| **Total emissions** | **44,745** | **tonnes CO2** |

## 3. Total Additional Peatland Disturbance Emissions

| | | |
|---|---|---|
| **Total emissions** | **6,475** | **tonnes CO2** |

## 4. Carbon Balance

| **Solar PV Farm Lifetime Emissions** | | |
|---|---|---|
| - technology | 255,350 | tCO2 |
| - cycling | 44,745 | tCO2 |
| - peat | 6,475 | tCO2 |
| **Total:** | **306,571** | **t CO2** |

| **Solar PV Farm Lifetime Savings** | **(t CO2)** | **Payback (yrs)** |
|---|---|---|
| Against SEM mid-merit | 2,076,046 | 5.17 |
| Against EU FFC | 1,837,071 | 5.84 |
| Against 'Demand Following' CCGT | 1,100,625 | 9.75 |

## Assumptions Underlying the Analysis

| | Sources |
|---|---|
| **Solar PV Farm Carbon Emissions** | |
| Solar PV farm infrastructure lifecycle emissions - includes PV modules, mounting structures, inverters, substation, transportation, all civil works, operation and maintenance and also decommissioning | |
| Lifecycle emissions are taken as an average of solar PV module supplier embodied carbon data: = 88.47 kg | |
| **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: | SEMO |
| Average emissions from load-following CCGTS at low wind: 448.87 kg CO2/MWh; Average CCGT efficiency: | SEMO |
| Additional emissions from cycling: 16.05 kg CO2/MWh | |
| **Emissions from Peatland Disturbance** | |
| Total volume of peat excavated for roads, inverters, substation etc = 63,400 m3 | |
| The excavated peat is stock-piled onsite | |
| Assume that all areas excavated and construction areas have a carbon emission factor of zero t CO2/ha/a | |
| Assume peat stockpile area has an emission factor of 39.43 tCO2/ha/a to account for increased oxidation of exposed peat. | CARBAL FINAL REPORT; industrial cutaway peatlands |
| Assume that vegetation management is carried out in the location of the solar PV modules to prevent shading | |
| **Fossil Fuel Emissions Displaced** | |
| 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 | Recast of RED; See Annex VI |
| For a displaced 'Demand Following' CCGT unit = 379.3 kg CO2/MWh | |