Appendix 16.3

Green House Gas Calculations

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HERBATA DATA CENTRE, NAAS

EIAR: Appendix 16.3 - GHG Calculations

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1 GHG CALCULATIONS

1.1.1 This appendix includes further technical detail regarding the methodology and calculations outlined within Chapter 16: Climate Change. For ease of understanding, the headings used within this appendix follow those used within the EIAR chapter.

1.2 Characteristics of the Project

1.2.1 The overall development comprises two main elements:

- The Data Centre Application – comprising 6 no. two storey data centre buildings, an administration/management building, car parking, landscaping, energy infrastructure and other associated works. These elements are the subject of the planning application submitted to Kildare County Council (KCC).
- The Substation Application – comprising a grid substation and 110 kV transmission connection. These elements are subject of the Strategic Infrastructure Development (SID) application to An Bord Pleanála.

1.2.2 The Data Centre Application and the Substation Application together constitute the “Project” for the purposes of this assessment.

1.2.3 The characteristics of the Project of relevance to the GHG calculations are detailed below.

Buildings

1.2.4 The Project comprises the following buildings:

- 6 no. Data Centre Buildings, each with a total internal area and height as follows:
  - Total gross internal area (GIA) – 27,261 m^2
  - Height to parapet – 18 m
  - Height to flue – 19 m
- Admin workshop and Water Treatment Plant (WTP) GIA – 818.9 m^2;
- Site security hut GIA – 42.1 m^2;
- District Heating (DH) building GIA - 340.5 m^2;
- Total of 210 no. car parking spaces comprising of 63 electric car charging spaces and 14 no. disabled car parking spaces;
- Total number of 52 no. bicycle spaces (8 per Data Centre building and 4 for the administration workshop);
- Demolition of 5 no. agricultural buildings to the centre of the site; and
- Demolition of 3 no. dwellings along the northern boundary of the site, fronting onto R409 road.

1.2.5 Whilst subject to internal layout requirements of end users, each Data Centre building will consist of the main data hall block with an external plant gantry and an enclosed yard to the rear encompassing the building energy infrastructure. The front of each Data Centre building will comprise of end-user client administration/office areas, plus storage areas and the loading/receiving docks.

1.2.6 The buildings will be steel-framed with insulated metal faced cladding panels to the façade. The rear external yard will also be also enclosed with a metal louvre system to align with the main building form and the building entrance area will have large, glazed windows.

1.2.7 The following measures are committed to within the design of the buildings:

- The design team will seek to source goods, services, or works with a reduced environmental impact throughout their lifecycle. In this regard, tender requests will set out the policies and targets as set in the Resource and Waste Management Plan (RWMP) (HDR, 2023) which must be achieved. Tenders will be assessed and include scoring for proposals demonstrating how compliance will be achieved with the policies and targets of the RWMP (e.g. proposals for use of recycled materials rather than virgin materials, identification of resource efficient options, collaboration with supply chains).
- Materials will aim to reflect local sustainable manufacturing sources and support low carbon green initiatives:
  - All timber and wood-based products will be responsibly sourced (e.g. FSC or PEFC);
  - Insulation materials and building services will be specified with low embodied environmental impact;
  - Locally sourced construction materials will be preferentially used, with priority to the use of prefabricated elements where possible to reduce construction-phase transport emissions;
  - Specification of recycled and reused materials will be a main design consideration where feasible;
  - The buildings will be ‘designed for robustness’ to ensure that damage to the building due to wear and tear, for example in areas of heavy usage, are minimised and can be repaired with minimal environmental or cost impact;
  - Construction of components off-site and use of pre-fabricated elements where feasible;
  - Concrete for certain types of foundations and preparatory foundations works can be specified with recycled aggregates where feasible; and
  - Where available, reinforcement for concrete is to be specified with 95% recycled content. Similarly, steelwork will be specified with a 95% recycled content where available.
- Energy efficiency measures to reduce energy demand, in line with national data centre guidance and policy requirements:
  - The data halls will be primarily cooled using external air, utilising Ireland’s cooler climate. Further cooling required i.e. during higher summer temperatures, will be provided through adiabatic cooling systems;
  - Heat pumps to be installed to serve the data centres’ office areas;
  - Admin areas housing office spaces and reception areas to face north-west and north-east to minimise solar gains and reduce cooling demand within such areas;
  - Fabric performance of the buildings to be maximised to reduce the space heating loads in winter and cooling loads in the summer; and
  - Highly efficient LED lighting to be specified to all data halls and office areas. Lighting to all other areas of the buildings to be highly efficient and incorporate occupancy sensors where applicable.
- 30% of the total energy demand will be met by renewable sources, in line with local policy requirements. This will comprise:
  - Solar photovoltaic (PV) arrays located on the roof of each of the six Data Centre buildings; and
  - Corporate Power Purchase Agreements (CPPA) will be used to procure renewable energy from wind / solar farms. In addition to providing energy for the Project, CPPAs will

fund the construction of wind and solar farms. The Applicant has had discussions with various solar and wind renewable energy suppliers with a view to supplying energy through CPPAs, identifying sufficient capacity available from suppliers to meet the 30% operational renewable energy target. CPPAs will be finalised following a grant of permission, along with a connection agreement with Eirgrid, and will be entered into prior to operational requirements. The process and technical aspects of CPPAs are considered fully in Volume II, Appendix 1.3.

Gas Turbines

1.2.8 Mains (Gas Networks Ireland [GNI]) connected, on-site natural gas turbines are the proposed primary energy source for the Project. Generation of electricity is proposed using gas turbines, located within a dedicated, adjoined plant area, to the rear of each Data Centre building. Each Data Centre building will comprise of 8 no. turbines.

Battery Energy Storage Systems

1.2.9 For the purpose of providing uninterrupted and conditioned power, each Data Centre building will have a dedicated battery energy storage system (BESS) located within the adjoined plant area, to the rear of each Data Centre building. The BESS will consist of rack mounted lithium iron phosphate battery modules.

1.2.10 The storage capacity provides a back-up energy source and in addition adds resilience to the wider network, having the capacity to provide immediate export of energy to the national grid, or the capacity to store excess electricity generated externally, if required.

Substation

1.2.11 A 110 kV GIS is proposed to be located to the north west corner of the subject site and will provide the grid connection on site. The provision of the substation and grid connection will enable the export of energy generated onsite to the wider network. The substation will also enable the energy storage facility to be connected to the national grid and add greater capacity and resilience to the national electric energy generation capacity and the national electric grid.

1.3 Construction Effects

1.3.1 The manufacturing of associated materials and construction of the Project would result in both direct and indirect GHG emissions.

1.3.2 The majority of the construction-stage impacts are ‘Scope 3’ (supply chain) emissions resulting from the extraction of raw materials and manufacturing of construction materials, alongside the emissions associated with their transportation to site.

1.3.3 The following sections detail the methodology undertaken to calculate GHG emissions associated with the Project, accounting for the Project elements as described within section 1.2.

Data centre buildings

1.3.4 At this stage in the design of the Project, material estimates have some uncertainty in terms of their quantities. As such, published benchmarks (RICS, 2012) have been used to inform the calculation of embodied carbon associated with the building structures, excluding the server fit out (addressed within paragraphs 1.3.25 to 1.3.28). The benchmark data is expressed in $kgCO_2e/m^2$ of floorspace as an intensity, which has then been scaled by the total applicable floor area for each building.

1.3.5 No benchmark data is yet available specifically for data centre buildings. As such, appropriate alternative building types have been selected and scaled by the relevant floor areas for each area of the data centre buildings (i.e. admin areas, data halls, and external plant yard). Table 1-1 lists each benchmark used, and the floor area by which it has been scaled.

Table 1-1: Data centre building embodied carbon

Data centre area use	Benchmark building type	Embodied carbon intensity ($kgCO_2e/m^2$)	Floor area per data centre (m^2)
Data halls	Other industrial/utilities/specialist uses	545	24,756
Admin area	Low rise offices (1-4 storey building)	925	2,505
External plant yard	Utilities compound	395	6,164

1.3.6 Total embodied carbon associated with all data centre buildings was calculated to total 109,464 tCO_2e.

Admin workshop and water treatment building, site security building, and district heating building

1.3.7 At this stage of design, material estimates have some uncertainty in terms of their quantities and specific products to be used in the final design. As such, a published benchmarks (RICS, 2012) have also been used to estimate possible emissions from the admin workshop and water treatment plant building, site security hut, and district heating building.

1.3.8 Table 1-2 lists each benchmark used, and the floor area by which it has been scaled.

Table 1-2: Admin workshop and water treatment building, site security building, and district heating building embodied carbon

Building	Benchmark building type	Embodied carbon intensity ($kgCO_2e/m^2$)	Floor area (m^2)
Admin workshop and water treatment building	Low rise offices (1-4 storey building)	925	819
Site security hut	Low rise offices (1-4 storey building)	925	42
District heating building	Other industrial/utilities/specialist uses	545	341

1.3.9 Total embodied carbon associated with all buildings was calculated to total 982 tCO_2e.

Gas turbines

1.3.10 There is limited design data and few published LCAs from which to calculate the embodied emissions associated with the gas turbines and associated plant. Data from an environmental product declaration (EPD) for a 5,125 kVA generator (ABB, n.d.) has therefore been used to provide an approximation of the potential order of magnitude of emissions.

1.3.11 The EPD listed a manufacturing GWP of 23.20 $kgCO_2e$ per kVA, which was scaled by the Project's maximum electricity demand of 240 MW to give an estimated embodied emission value of 5,568 tCO_2e.

1.3.12 The turbines are likely to be refurbished every two years. However, given this will not result in the installation of new turbines, just the repair and servicing of the existing turbines, resultant emissions are likely to be immaterial and as such have not been considered further. Additionally, given national decarbonisation requirements, it is likely that any repair work is likely to decarbonise over the Project's lifetime.

BESS

1.3.13 Owing to their charge capability, energy density, round-trip efficiency and falling costs, lithium-ion batteries (LIB) are the most commonly employed battery technology for stationary applications. At this stage in the Project's design, batteries with lithium iron phosphate (LFP) cathode material have been specified. It is the carbon intensity of these materials – and the carbon intensity of the associated manufacturing processes – that have been considered in this assessment.

1.3.14 There are several carbon-intensive processes that take place in the manufacturing of a lithium iron phosphate batteries, that make up the majority of their associated embodied carbon emissions. These processes are as follows.

- The mining and refining of raw materials: the energy intensity varies greatly depending on the type of mine and type of ore being mined.
- Electrode manufacturing, especially the evaporation of solvent used when coating the electrode. Such evaporating process is energy intensive because of the air flow needed to maintain a safe concentration of flammable solvent (Porzio and Scown, 2021).
- Anode production: anodes are composed of graphite and a polyvinylidene difluoride binder; to ensure the absence of any oxygen impurity in the graphite, it is baked at 1100 °C in an inert or reducing atmosphere (Accardo et. al., 2021).
- Dry room: because moisture is detrimental to the electrochemical performance of LIBs, the cell assembly process needs to occur in a dry room with strictly controlled humidity levels. Dry room operation has been identified as a predominant driver of energy use for cell production (Dai et al, 2019).
- Production of non-cell materials: this involves the production of cell containers, separator, battery management system (BMS), cooling system, and final packaging.

1.3.15 The carbon intensity of the production of LFP LIBs used for the purposes of this assessment has been informed by a range of LCAs reported within selected literature. Such findings are summarised within Table 1-3, below. This GHG values account for the emissions associated with the upstream supply of raw materials, battery cell production and battery pack assembly.

Table 1-3: Summary of literature research findings.

Reference	GHG emission (kgCO_2e/kWh)
Hao et al. 2017	109.3
Yudhistira, 2021	169
Pell and Lindsay, 2022	52.0 to 106.7 (reported range when applying uncertainty analysis)
Landi et al. 2022	556.9

1.3.16 Studies by Hao et al. (2017) and Pell and Lindsay (2022) consider batteries for use in electric vehicles, while Yudhistira (2021) and Landi et al. (2022) consider batteries for use in grid electricity storage applications. The latter appears to result in greater emissions than the results associated with electric vehicle (EV) batteries. However, the disparity between values reported for batteries used in grid electricity storage applications are significant, with those reported by Landi et al. (2022) 230% greater than those reported by Yudhistira (2021) and not within the bounds of emissions intensities reported for use in EVs. As such, the use of GHG emissions intensities reported by Landi et al. (2022) have not been used to inform the assessment of embodied carbon associated with the proposed BESS.

1.3.17 A further study analysing the most up-to-date published data regarding the energy use associated with the production of LIBs, using published heat and electricity consumption data for the various processes involved in LIB manufacturing, has also been used to contextualise the above emissions intensities (Emilsson and Dahllöf, 2019). While this study focuses on nickel manganese cobalt oxide (NMC) LIB, it has been reported that the magnitude of emissions associated with the production of NMC LIB and LFP LIB are comparable (Hao et al. 2017).

1.3.18 In order to account for potential uncertainty in estimating NMC LIB production GHG emissions due to the variability of emissions intensities associated with the energy supply mix (both electricity and heat), a range of GHG intensities have been used. When also accounting for further emissions of 59 kgCO_2e/kWh battery capacity owing the sourcing of upstream materials (taken from Dai et al, 2019), a range of 61 – 106 kgCO_2e/kWh battery capacity can be stated.

1.3.19 This range of calculated intensities aligns with those given in Table 1-3, and provides some additional confidence in the values used.

1.3.20 The proposed BESS capacity will match the load of the data centres to provide backup electricity supply with a duration of between 4 and 20 minutes (decreased duration with battery age). To provide a conservative estimate, the total output capacity of 240 MW was scaled by 20 minutes (or 0.33 hours) to give total storage capacity of 79.2 MWh.

1.3.21 The lifetime of the battery packs is dependent on the average depth of discharge (DoD); while in reality this may vary depending on the state of the electricity market at any given moment, the current assumed average DoD for the Project is 80%. Based on published literature values, a DoD of 80% would result in an expected lifetime of 5,000 cycles (IEA, 2020b). Therefore, over the forecasted 50 year assessment period and assuming one full cycle per day, the battery packs would have to be replaced circa four times. This has been accounted for in the embodied carbon values in summarised below. To be conservative, present-day values are used for the carbon intensity of battery pack production even for future replacements.

1.3.22 Accounting for the range of carbon intensities reported within the literature, GHG emission intensities from 52.0 kgCO_2e/kWh to 169 kgCO_2e/kWh were scaled by the storage capacity of the proposed BESS (59.4 MWh) and replacement rate over the lifetime of the Project. This gives a range of 16,474 tCO_2e to 53,539 tCO_2e. The greater value has been assessed in order to provide a more conservative worst-case approach.

Substation (including transformers, busbars and other equipment)

1.3.23 There is limited design data and few published LCAs from which to calculate the embodied emissions associated with the substation, busbars and BoS components, alongside housing structures for the BESS. Data from an EPD for a 16 kVA – 1000 MVA transformer (ABB, 2003) has therefore been used to provide an approximation of the potential order of magnitude of emissions, as transformers are among the major substation plant components and have a relatively high materials and carbon intensity, including the copper or aluminium winding.

1.3.24 The LCA listed a manufacturing GWP of 2,190 kgCO_2e per MVA. This was scaled by the Project's proposed transformer rating (150 MVA) and the maximum number of transformers (4 no.) to give an estimated embodied emission value of 1,314 tCO_2e. This value includes lifecycle stages A1-A3.

Server fit out

1.3.25 The impact of embodied carbon associated with the servers has been estimated using product LCAs for servers appropriate for data centre use. Given the specific servers to be installed within the proposed data centres will be subject to tenant specification, not yet known at this stage in the project design, a range of 1U and 2U servers were considered with power ratings (at 100% load) between 244.2 W and 449.8 W. Associated embodied carbon intensity values reported are between 1,370 kgCO_2e per unit, and 1,770 kgCO_2e per unit (Sphera, 2021).

1.3.26 The total number of servers to be installed across the 6 no. proposed data centres was estimated by scaling each individual server power rating by the total proposed IT load associated with the data centres (180 MW), resulting in an estimated total number of servers of between 400,178 and 737,101.

1.3.27 The lifetime of each server unit was taken into account within the calculations and was assumed to be 4 years as specified by the product LCA. As such, when scaled by the Project's 50 year lifetime, a replacement rate of 13 was estimated. This replacement rate was scaled by the total server number to estimate the number of servers required over the Project's lifetime. This total lifetime server number was then scaled by each embodied carbon factor as appropriate to give an estimate of total embodied carbon. The above is summarised within Table 1-4, below.

Table 1-4: Server embodied carbon.

Server Type	Power rating (at 100% load)	No. units required	Replacement Rate	GWP ($kgCO_2e$ per unit)	Lifetime embodied carbon
1U	244.2	737,101	13	1,375	13,177,597
2U	281.5	639,432	13	1,370	11,385,790
1U	449.8	400,178	13	1,770	9,209,656
2U	389	462,725	13	1,768	10,637,678

1.3.28 Given the specific server type is not currently known, the assessment of embodied carbon has been informed by the greatest estimate of embodied carbon associated with the servers, in order to present the most conservative, worst-case scenario.

Construction transport emissions

1.3.29 Emissions associated with HGV movements and personnel vehicle movements during the construction of the Project have been estimated.

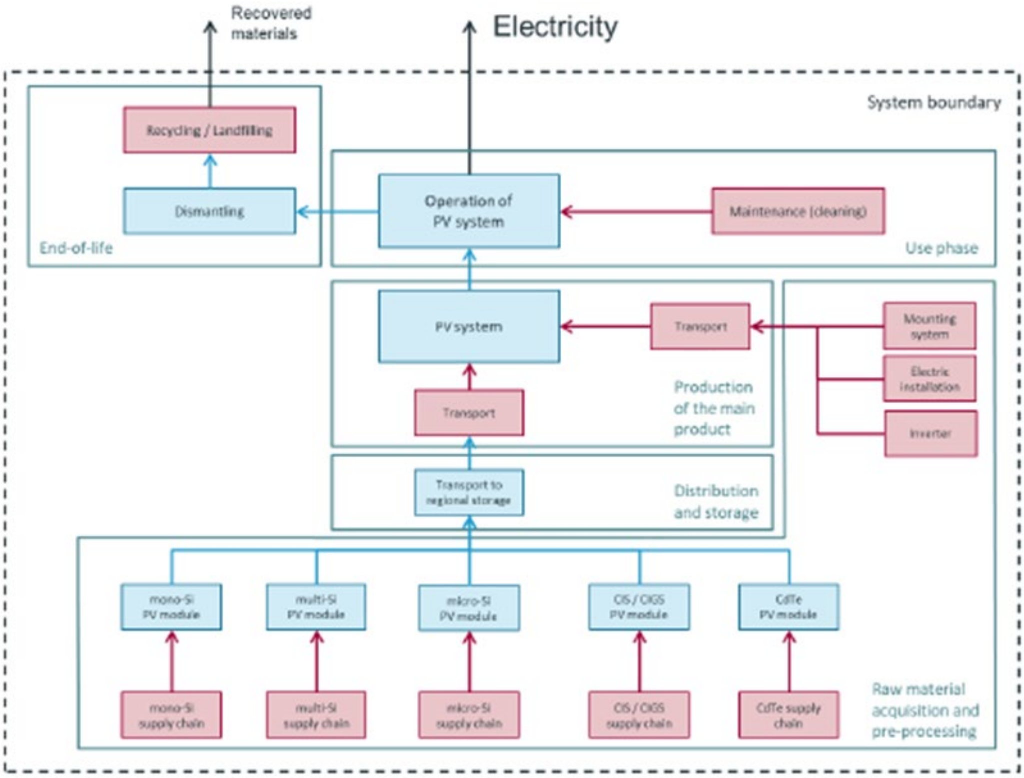
1.3.30 An average of 425 construction staff trips per day, and 47 HGV trips per day (a conservative estimate given this is the likely peak number of trips) were scaled by the number of construction days over the 8 year and 8 month construction period, assumed average distance of travel (50 km, to account for local construction staff and local material sourcing, in addition to internationally procured products which may be delivered by HGV from Dublin Port), and emissions factor for fully laden diesel HGVs (0.98496 $kgCO_2e$/km) and medium petrol car (0.17819 kgCO2e/km) (DESNZ, 2023).

1.3.31 Total emissions associated with construction stage transport movements totals 33,312 tCO_2e.

Solar PV

1.3.32 The quantification of the emissions resulting from these activities requires a GHG Lifecycle Assessment (LCA). Figure 1-1 below displays the system boundaries considered in a typical GHG LCA for a PV development of this nature.

Figure 1-1: System boundaries for a solar PV development (IEA, 2020a)



1.3.33 Currently, 95% of total global PV production is accounted for by crystalline silicon (c-Si) panel technology (84% of which is accounted for by mono-crystalline (mono c-Si) and 16% by multi-crystalline (multi c-Si)) (ISE, 2023).

1.3.34 Emerging technologies for high efficiency c-Si panel types such as passivated emitter and rear contact (PERC), heterojunction (HJT), and interdigitated back contact (IBC) technology, so-called ‘third generation’ technologies, are becoming more readily available on the market, with PERC designs now the dominant PV technology (IEA, 2022). LCA information on these technologies is beginning to become available (reviewed in Muteri and Curto, 2020), with some evidence to suggest that there are reductions in GHG emissions during the manufacturing process, but the authors of the review highlighted that many construction and end-of-life aspects of third-generation technologies are yet to be evaluated. This limits the conclusions that can be drawn from any attempted LCA for these technologies, and this assessment has therefore considered only established first generation c-Si panel technologies in the assessment of GHG effects, likely to be conservative estimates of the true GHG effect of PV systems manufactured in the present day.

1.3.35 The key GHG emitting process involved in the manufacturing of c-Si panels and associated BoS components are as follows:

- The extraction of quartz, from which metallurgical-grade silicon is extracted. This silicon is then further purified into solar-grade silicon, typically via the energy intensive Siemens reactor method.
- The forming of silicon ingots: an electricity-intensive process requiring 32 kWh per kg of mono-Si ingot (via the Czochralski process), or 7 kWh per kg of multi-Si ingot (IEA, 2020a).
- The extraction of raw materials for and manufacturing of BoS components, e.g. silica for glass, copper ore for cables, iron and zinc ore extraction and refinement for mounting structures and bauxite extraction and refinement for module framing (c-Si modules require circa 2.1 kg of aluminium per m^2 of module) (IEA, 2015).

1.3.36 The emissions resulting from the processes described above, as well as the emissions occurring due to the transportation of materials to site and onsite emissions occurring during the assembly of the Project, account for circa 70% of total lifecycle GHG emissions (not including the avoided emissions resulting from the displacement of more carbon intensive electricity generation) (NREL, 2012).

1.3.37 Solar PV LCAs are a complex process, given the large number of materials and processes involved in the production of PV modules and BoS components. Furthermore, the associated GHG emissions are dependent on the location (and associated energy mix) of where these processes are occurring. As such – and in the absence of greater detail regarding panel types and manufacturer specifications etc – a detailed LCA is beyond the scope of this assessment. Instead, a robust approach has been formulated by considering meta analyses of published solar PV LCAs, thereby accounting for the likely range of magnitude of the Project's construction-stage GHG emissions.

Emissions factors and data sources

1.3.38 The current literature surrounding PV system LCAs is characterised by a high degree of variability in its published GHG figures, and therefore a degree of uncertainty occurs in selecting any one of these figures as a means of analysing the embodied GHGs in constructing a solar array. As a means of dealing with this uncertainty, the primary source of emissions factors used in assessing the embodied carbon effects of the Project was NREL's (2012) 'Life Cycle Greenhouse Gas Emissions of Crystalline Silicon Photovoltaic Electricity Generation'. The study constituted a meta-analysis of over 397 LCAs regarding C-SI PV systems, all of which were subject to a screening process, and for those which passed the screening process, a subsequent harmonisation process. Using the NREL study as a means of acquiring GHG factors for construction-stage[1] GHG emissions partially eliminated the large degree of variability and uncertainty in the published literature surrounding PV LCAs, and ensured the range of construction-stage GHG emissions stated in this chapter represent the most realistic and accurate effects.

1.3.39 The screening process removed the majority of the considered studies, so that the meta-analyses considered in detail only 13 studies (containing a total of 42 lifecycle GHG factors). The screening process ensured that minimum standards for the following criteria were met:

- Quality: the study used an accepted LCA methodology (e.g. ISO 14040 (ISO, 2006));
- Transparency: the study described its methods, sources and values of input data; and
- Relevance: relevant, up-to-date technology was analysed.

1.3.40 As well as the lifecycle GHG implications of PV systems being sensitive to the energy input/mix required for their manufacturing and production, they are also sensitive to other input parameters including module efficiency, solar insolation, system lifetime and performance ratio[2] (Pacca et al, 2007). As a means of accounting for potential variability due to these factors, the LCA studies in NREL's meta study were subject to a harmonisation process. The process involved correcting the considered LCA results following the normalisation of the aforementioned input parameters. Table 1-5 states the input parameters used in the harmonisation process and subsequent generation of improved lifecycle GHG factors for PV systems.

[1] Construction-stage – in this sense – also refers to the emissions associated with maintenance and any EoL treatment-related emissions. It excluded the GHG implication of exporting low carbon power onto the grid.

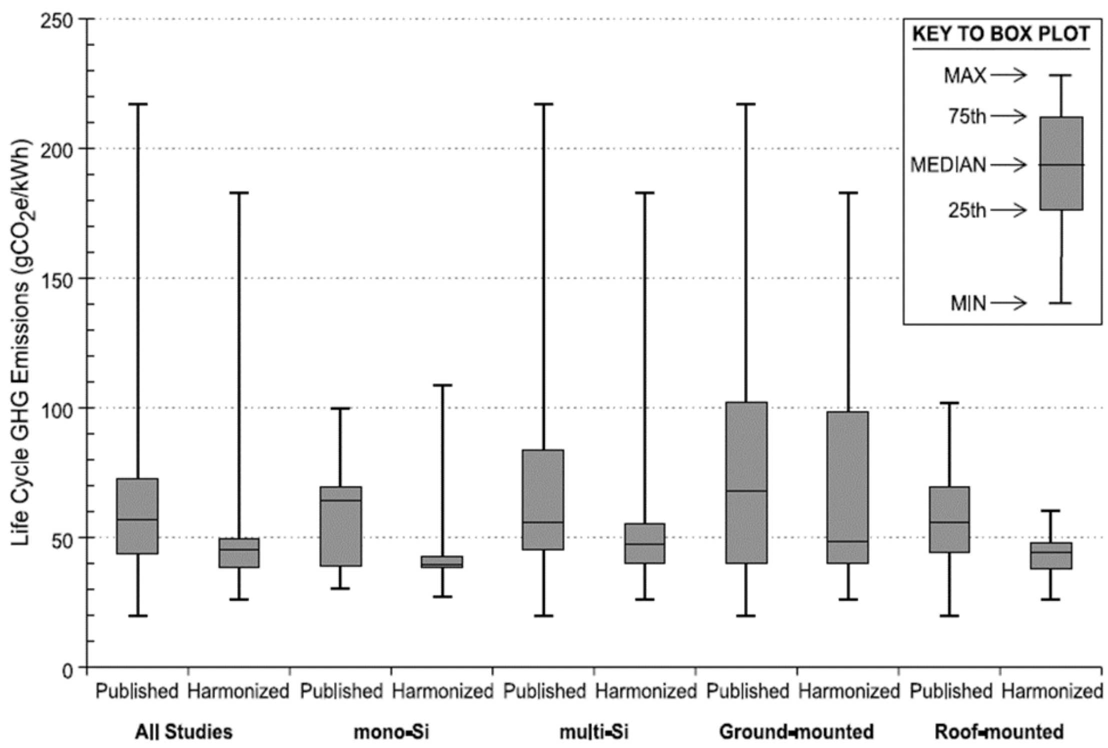
[2] Performance ratio refers to the difference in potential energy output (for a given module efficiency and annual solar insolation value), and actual energy output. The performance ratio is determined by BoS efficiency losses (namely inverter and cabling losses), cell mismatch, elevated PV module temperature, reflection from the module front surface, soiling, shading, and component failures.

Table 1-5: NREL harmonised input parameters

Solar insolation ($kWh/m^2/yr$)	System lifetime (years)	c-Si module efficiency (%)		Performance ratio	
		Mono	Multi	Ground-Mounted	Rooftop
1,700	30	14	13.2	0.8	0.75

1.3.41 Based on the input parameters in Table 1-5, the NREL study generated a range of harmonised GHG impacts. These are displayed in Figure 1-2.

Figure 1-2: NREL lifecycle GHG emissions factors (NREL, 2012)



1.3.42 Based on Figure 1-2, it was decided that the range of emissions factors that would most closely represent the possible range of construction-stage GHG emissions for both possible technology types for the Project would be the lower quartile range (LQR) and upper quartile range (UQR) values for all LCAs considered in the meta-analysis. These have represented the upper and lower limits of the range presented in this assessment. Therefore, the initial range of values being considered were 39 to 49 gCO_2e/kWh (with a median value of 44 gCO_2e/kWh).

1.3.43 The lifetime GHG emissions factor – when expressed in terms of the system's lifetime energy output (i.e in terms of kWh) – is sensitive to the annual insolation value used in the calculation. The harmonized insolation value of 1,700 $kWh/m^2/yr$ used in the NREL study is representative of the meteorological conditions of southern Europe.

1.3.44 The IEA's 'Life Cycle Inventories and Life Cycle Assessments of Photovoltaic Systems' report (IEA, 2020a) contains country specific annual average solar energy yields, whereby average annual energy outputs from PV systems in various countries are expressed in terms of the peak capacity of the system. An average annual energy yield (in terms of annual kWh/kW_p[3]) for a solar array in southern Europe was obtained by averaging the same values for Spain, Portugal, Italy and Greece. This value was then used to factor out the annual energy output for the lifetime GHG

[3] 'W_p' refers to the nominal power of a solar array, i.e. its peak generation capacity.

emissions factor, so that the emissions factor could be expressed in terms of gCO_2e/MW (i.e. in terms of installed capacity rather than lifetime energy generation), and therefore representative of the likely range of construction-stage GHG effects of the Ireland-based Project. The lifetime GHG factors, expressed as gCO_2e/MW could then be multiplied by the 3.72 MW generating capacity of the PV to be installed at the Project (120 kWp per data centre to support the admin areas, 500 kWp per data centre to support remaining demand) in order to calculate the construction-stage GHG impacts in tCO_2e. Table 1-6 display these construction-stage GHG intensities and impacts of the Project, as well as the possible upper and lower limits.

Table 1-6: Construction stage GHG emissions factors and impacts of solar array

	Lower limit	Median	Upper limit
Literature Lifecycle GHG intensity (gCO_2e/kWh)	39	44	49
Literature Average annual energy yield[4] (kWh/kW_p)	1,419	1,419	1,419
Literature Operating lifetime (yrs)	30	30	30
Literature Total GHG (gCO_2e/kW_p)	1,659,645	1,914,975	2,085,198
Literature Total GHG (tCO_2e/MW_p)	1,660	1,915	2,085
Development annual energy yield (MW_p)	3.72	3.72	3.72
Total Development GHG (tCO_2e)	**6,174**	**7,124**	**7,757**

1.3.45 A potential limitation of this assessment is the age of the meta-analysis study that has used to inform the potential construction-stage GHG emissions. So as to provide further confidence in the results expressed in Table 1-6, a recent study by Milousi et al (2019) was also considered. This study calculated the lifecycle GHG implications of 3 kW PV systems of varying panel technology in Crete, which were therefore under similar irradiance conditions to the harmonized irradiance value expressed in the NREL study. The Milousi et al (2019) study concluded that mono-Si systems have a lifecycle GHG impact of 52.4 gCO_2e/kWh, whilst multi-Si systems have a lifecycle GHG impact of 44.3 gCO_2e/kWh. These results provide further confidence that the results expressed in Table 1-6 are in the correct order of magnitude.

1.4 Operational Effects

1.4.1 The use of the Project post-completion would result in indirect GHG emissions due to the use of electricity (sourced from natural gas) within the buildings. The operational energy demand has been split into regulated and unregulated energy.

1.4.2 Regulated energy consumption results from the specification of controlled fixed building services and fittings, such as space heating and cooling, hot water, ventilation, and lighting. It is these regulated loads that are able to be reduced through embedded design measures.

1.4.3 Unregulated energy consumption is associated with systems or processes that are not controlled and do not have regulations imposed on them. Unregulated energy consumption within the Project is largely resultant from the data hall demand, where any energy efficiency and carbon reduction measures will be within the control of the tenant.

1.4.4 The methodology undertaken to calculate emissions associated with each is detailed below.

Energy Sources

1.4.5 The energy demand associated with the Project is to be met by the onsite generation of electricity using gas turbines. This strategy is in line with recent EU and Irish Government direction on the use of gas for generation as a transition fuel, with gas being sourced from the Gas Networks

[4] For a solar array in southern Europe

Ireland (GNI) gas network. As such, all operational emissions associated with electricity consumption at the Project have been calculated by scaling relevant energy demands, by the SEAI current natural gas emissions factor of 204 gCO_2e/kWh.

1.4.6 The resultant calculated lifetime emissions are conservative, as they do not account for the planned decarbonisation of the gas network by GNI by 2050. Adoption of such a gas supply will greatly reduce the operational emissions associated with the power generated on site.

1.4.7 The following measures have been proposed by GNI to enable decarbonisation of gas networks:

- Introduction of bio-methane from agricultural sources;
- Introduction of hydrogen in lieu of methane by up to 20% by volume. This will gradually increase over time; and
- Use of carbon capture and storage to reduce carbon emissions. Although this technique is unlikely to be applied directly to this site, it will allow GNI to capture the CO_2 produced by power generation.

1.4.8 Further, to support Net Zero strategy, the Applicant will be a strong supporter of Biomethane production from offsite Anaerobic Digestion (AD) facilities. GNI forecasts in biomethane production show significant growth in AD facilities forecasted between now and 2030. These fuels will likely provide the renewable form of feedstock for operating onsite generation. Additional information with regards to the Project’s energy supply strategy is provided within Volume II, Appendix 1.3.

Regulated Energy Consumption

1.4.9 Emissions associated with the regulated energy consumption have been informed by consumption figures reported within the Energy Efficiency and Climate Change Adaptation Design Statement (HDR, 2024) prepared in support of this application. This Statement reports energy intensities for energy consumption associated with the offices, reception, WC, circulation areas, and security rooms. The energy consumption associated with the heating, ventilation and air conditioning (HVAC) used to condition the data storage halls and switchroom areas, and the server energy demand, were not taken into account.

1.4.10 Operational energy reductions have been embedded within the building design through the integration of energy efficiency measures (as detailed within paragraph 1.2.7). The statement details a reduction of 22% from 96.1 kWh/m^2 per annum to 75.1 kWh/m^2 per annum. When the as built energy intensity (75.1 kWh/m^2 per annum) is scaled by the total GIA for the Project, an annual energy consumption of 12,374,039 kWh per annum is estimated. This offers an annual reduction of 3,460,118 kWh due to the embedded efficient design.

Solar PV

1.4.11 The annual energy output of the proposed solar PV array has been calculated assuming a load factor of 10.77%, as calculated from the Digest of UK Energy Statistics (DUKES) 6.3 data set, using the average load factors for solar PV generation from 2011/12 to 2020/21 (BEIS, 2022). The annual load factor of solar PV associated with the admin areas relates to the total number of hours at which the array is generating electricity at its rated capacity (i.e. 120 kW per data centre, total of 720 kW) over the total number of hours in a year. A PV array’s load factor is determined by irradiance conditions, performance ratio and orientation and tilt of the panels. Total annual energy output from the proposed solar PV array has been estimated at 679 MWh in the first year of operation. A degradation factor of 0.7% (IEA, 2021) has been applied to all subsequent years, with the lifetime energy output from the solar PV array totalling 28,741 MWh.

1.4.12 It has been assumed that electricity generated by the solar PV array displaces electricity that would otherwise have been generated by the onsite gas generators. As such, avoided emissions have been calculated by scaling the electricity generated by the solar PV by the current natural gas emissions intensity factor (204 $kgCO_2e/kWh$).

CPPA

1.4.13 As detailed within the Energy Efficiency and Climate Change Adaptation Design Statement (HDR, 2024), 30% of the energy demand remaining following energy efficiency reduction measures will be met by renewable sources. Approximately 5% of such energy demand has been calculated to be met by the onsite generation by solar PV in the first year of operation, the remainder will be met by purchased electricity via Commercial Power Purchase Agreements (CPPA).

1.4.14 Annual energy output from the solar PV (accounting for annual degradation of the panels) was subtracted from 30% of the annual estimated regulated energy demand (following energy efficiency reductions) to give the remainder of the regulated energy consumption to be met by CPPA. In the first year of operation this totals 3,033 MWh, and 156,869 MWh over the Project's lifetime.

1.4.15 The commitment to a CPPA enables the Project to avoid 1,007 tCO_2e per annum, or 52,081 tCO_2e over the Project lifetime. This has been calculated by scaling the above energy consumption to be met by CPPA by the current electricity intensity factor (332 gCO_2e/kWh) and does not account for targeted decarbonisation of the electricity network.

Summary

1.4.16 Energy demand and emissions associated with the regulated energy demand have been summarised within Table 1-7, below, detailing the reductions enabled by the designed-in energy efficiency and renewable energy measures. In combination, such measures (including the use of gas generators in place of total energy demand sourced solely from grid electricity) results in an emissions reduction of 66%.

Table 1-7: Regulated energy demand mitigation measures.

	Annual Energy Demand (kWh)	Annual Emissions (tCO_2e)
No mitigation		
Total	**15,834,157**	**5,257**[2]
Embedded emissions reduction measures		
Energy Efficiency measures	-3,460,118	
Solar PV[1]	-679,285	
CPPA[1]	-3,032,926	
Total	**8,661,827**	**1,767**[3]
Total percentage reduction	**-45%**	**-66%**

[1]Accounting for the first year of operation only. Over the lifetime of the solar PV array panel degradation will result in reduced output. Given 30% of energy demand must be met by renewable sources, this will result in an uplift throughout the Project's lifetime in the energy demand to be met within the CPPA.

[2]Emissions have been scaled by SEAI emissions factors for electricity (332 gCO_2e/kWh)

[3]Emissions accounting for embedded emissions reduction measures have been scaled by SEAI emissions factors for natural gas (204 gCO_2e/kWh) to account for the use of gas generators in the onsite provision of electricity.

Unregulated Energy Consumption

1.4.17 Emissions associated with the unregulated energy consumption has been informed by the project design – 6 no. data centre buildings, each comprising of eight data halls with an electrical capacity to support up to 30 MW of IT equipment load in each building. In addition, further demand arises from building services and regulated energy demand (as detailed above) adding a total of 10 MW additional energy demand per data centre building, resulting in total building consumption of 40 MW, and a total Project demand of 240 MW, or 2,103,840 MWh per annum.

1.4.18 Total unregulated energy consumption has been calculated by subtracting the calculated regulated demand (as detailed above) from the total Project energy demand. To provide a conservative emissions estimate, it was assumed that the data centres would run 24 hours a day, 365.25 days a year, resulting in the consumption of 2,091,466 MWh per year.

Solar PV

1.4.19 The annual energy output of the proposed solar PV array has been calculated assuming a load factor of 10.77%, as calculated from the Digest of UK Energy Statistics (DUKES) 6.3 data set, using the average load factors for solar PV generation from 2011/12 to 2020/21 (BEIS, 2022). The annual load factor of solar PV associated with the data halls relates to the total number of hours at which the array is generating electricity at its rated capacity (i.e. 500 kW per data centre, total of 3,000 kW) over the total number of hours in a year. A PV array's load factor is determined by irradiance conditions, performance ratio and orientation and tilt of the panels. Total annual energy output from the proposed solar PV array has been estimated at 2,830 MWh in the first year of operation. A degradation factor of 0.7% (IEA, 2021) has been applied to all subsequent years, with the lifetime energy output from the solar PV array totalling 119,756 MWh.

1.4.20 It has been assumed that electricity generated by the solar PV array displaces electricity that would otherwise have been generated by the onsite gas generators. As such, avoided emissions have been calculated by scaling the electricity generated by the solar PV by the current natural gas emissions intensity factor (204 kgCO_2e/kWh).

CPPA

1.4.21 As detailed within the Energy Efficiency and Climate Change Adaptation Design Statement (HDR, 2024), 30% of the energy demand of the data centres will be met by renewable sources. Less than 1% of such energy demand has been calculated to be met by the onsite generation by solar PV in the first year of operation, the remainder will be met by purchased electricity via CPPAs.

1.4.22 Annual energy output from the solar PV (accounting for annual degradation of the panels) was subtracted from 30% of the annual estimated regulated energy demand (following energy efficiency reductions) to give the remainder of the regulated energy consumption to be met by CPPA. In the first year of operation this totals 624,609 MWh, and 31,252,234 MWh over the Project's lifetime.

1.4.23 The commitment to a CPPA enables the Project to avoid 207,370 tCO_2e per annum, or 10,375,742 tCO_2e over the Project lifetime. This has been calculated by scaling the above energy consumption to be met by CPPA by the current electricity intensity factor (332 gCO_2e/kWh) and does not account for targeted decarbonisation of the electricity network.

Summary

1.4.24 Emissions associated with the unregulated energy demand have been summarised within Table 1-8, below, detailing the reductions enabled by the designed-in renewable energy measures. In combination, such measures (including the use of gas generators in place of total energy demand sourced solely from grid electricity) results in an emissions reduction of 57%.

Table 1-8: Unregulated energy demand mitigation measures.

	Annual Energy Demand (MWh)	Annual Emissions (tCO_2e)
No mitigation		

	Annual Energy Demand (MWh)	Annual Emissions (tCO_2e)
Total	**2,091,466**	**694,367**[2]
Embedded emissions reduction measures		
Solar PV[1]	-2,830	
CPPA[1]	-624,609	
Total	**1,464,026**	**298,661**[3]
Total percentage reduction	**-30%**	**-57%**

[1]Accounting for the first year of operation only. Over the lifetime of the solar PV array panel degradation will result in reduced output. Given 30% of energy demand must be met by renewable sources, this will result in an uplift throughout the Project's lifetime in the energy demand to be met within the CPPA.

[2]Emissions have been scaled by SEAI emissions factors for electricity (332 gCO_2e/kWh)

[3]Emissions have been scaled by SEAI emissions factors for natural gas (204 gCO_2e/kWh) to account for the use of gas generators in the onsite provision of electricity.

BESS

1.4.25 For the purpose of providing uninterrupted and conditioned power, each data centre building will have a dedicated BESS system. The storage capacity provides a back-up energy source to the data centres, in addition the BESS adds resilience to the wider electricity network as it will have the capacity to provide immediate export of energy to the grid, or the capacity to store excess electricity generated externally, if required.

1.4.26 The role of the BESS in providing a back-up energy source to the data centres has not been assessed, given it is unknown to what extent the BESS will provide support over the Project's lifetime. Further, emissions associated with the energy consumption from the data centres has already been calculated (see sections above), and as such, any energy consumption and resultant emissions arising from discharge from the BESS to the data centres has already been accounted for. This assessment of the operational effects of the BESS therefore focuses on their role in exporting electricity to the grid.

1.4.27 The magnitude of impact of the BESS on the Project's operational GHG impact is determined by the quantity of electricity sourced to charge the BESS, the quantity of peaking plant generation it displaces, and the associated GHG impacts of each.

1.4.28 The BESS may be charged from a number of sources: the grid, or surplus energy generated by the on-site gas turbines.

1.4.29 When charged by the grid, it is assumed that as the penetration of non-dispatchable renewable energy resources in the Irish grid increases, energy market price mechanisms will be in place to ensure that, insofar as is possible, stationary grid-scale batteries only charge using surplus renewable energy. However, as it is not certain that this would be the case in all market conditions, an analysis of the sensitivity of the GHG impacts of the BESS to the carbon intensity of an alternative source has been undertaken.

1.4.30 When charged by the on-site gas turbines, the BESS will not be avoiding the use of gas peaking plants (given the electricity will be generated from gas turbines, in place of renewable or lower carbon alternatives), emissions associated with electricity provision to the grid by the BESS has been calculated by scaling the annual energy input (consistent with that listed in Table 1-9) with Ireland's natural gas emissions factor (204 gCO_2e/MWh) (SEAI, 2023).

1.4.31 Table 1-9 displays the annual energy input and output values for the BESS associated with a single data centre, and the parameters by which they are determined by.

Table 1-9: BESS energy flows (per data centre)

Parameter	Value	Unit	Source
Input Parameters			
Rated power	40	MW	Project design parameters
Discharge time	0.33	hrs	Project design parameters
Storage capacity	13.2	MWh	Project design parameters
Round trip efficiency (RTE)[5]	0.85		Cole & Frazier, 2019
Depth of discharge	0.8		IEA, 2020
Annual cycles	365		Project design parameters
Output Parameters			
Annual energy input	3,854	MWh	
Annual energy output	3,276	MWh	

1.4.32 Wind energy generation accounted for 17.4% of electricity generated in 2021 (including both renewables and non-renewables) (SEAI, 2021). In Ireland and Northern Ireland, renewable energy is predominantly sourced from onshore wind. In 2022, the total wind energy generated in Ireland and Northern Ireland was 13,676 GWh, while 1,280 GWh of wind energy was dispatched down[6]. This represented 8.5% of the total available wind energy in 2022 (EirGrid, 2023). In the future, a higher percentage of this energy mix will come from offshore wind, as the Government have committed an additional resource for 7,000 MW of offshore wind generation by 2030 (SEAI, 2022a).

1.4.33 As such, it is expected that wind energy is the source of renewable energy that is most likely to be curtailed during periods of low demand. Therefore, for the purposes of this assessment, the indirect GHG emissions associated with charging the battery are assumed to be equal to those associated with the operation of wind generation.

1.4.34 The current literature surrounding LCAs for wind turbines is characterised by a high degree of variability in the published GHG figures and, therefore, a high degree of uncertainty occurs in selecting any one of these figures as a means of analysing the operational emissions resultant from wind generation. As a means of dealing with this uncertainty, the primary source of emissions factors was a study by the National Renewable Energy Laboratory (NREL, 2013) Life Cycle Assessment Harmonization Project, and Dolan and Heath (2012).

1.4.35 The NREL (2013) study was based on the output of the Dolan and Heath (2012) paper, and as such the Dolan and Heath paper has been referenced hereafter. This study (Dolan and Heath, 2012) conducted an exhaustive literature search, extracting normalized life cycle GHG emission estimates from published LCA literature. Data was screened to select only those references that met stringent quality and relevant criteria.

1.4.36 The median estimates of GHG emissions intensity figures were identified for both onshore and offshore wind across the whole life-cycle (Dolan and Heath, 2012). The NREL (2013) study further broke down and detailed the separation of intensity across each life cycle stage, attributing 9% of life-cycle emissions to operation and maintenance activities. This estimated percentage has been

[5] The RTE of a battery refers to the ratio of energy required to charge a battery compared to the available energy during discharge. The source used in this assessment for determining RTE has considered a range of recent and relevant published RTE values and selected a mid-point value. The RTE includes losses associated with cooling systems and battery control equipment; as such, this assessment takes into account the implications of the operational energy use of onsite electrical equipment.

[6] Dispatch-down of renewable energy refers to the amount of renewable energy that is available but cannot be used by the system. This is because of broad power system limitations, known as curtailments, or local network limitations, known as constraints.

applied to the Dolan and Heath intensity (11 gCO_2e/kWh), to give an operational emissions intensity of 0.99 gCO_2e/kWh.

1.4.37 To account for scenarios where market conditions may not favour renewable energy supply, the grid electricity carbon intensity (332 gCO_2e/kWh) (SEAI, 2023) has been applied to the estimated electricity input requried to charge the BESS.

1.4.38 The magnitude of the GHG impact of displacing peaking plant generation depends on its carbon intensity. Representative project examples have been used to establish the carbon intensity of peaking plants (RPS, 2020; and VPI Immingham, 2019), which has been assumed to be 0.504 tCO_2e/MWh.

1.4.39 Table 1-10 and Graph 1-1 display the total additional emissions (positive values) and avoided emissions (negative values) associated with all BESS to be installed across the Project. This accounts for their phased introduction, in line with the construction phasing associated with the data centre construction. The magnitude of GHG impact varies according to the energy source assumed for battery charging (i.e. applying the carbon intensity of offshore wind and the SEAI (2023) grid-average and natural gas carbon intensities). It is likely that emissions associated with the BESS will fall within this range.

Table 1-10: Avoided GHG Impacts from BESS

Year of operation	Year	Input (MWh)	Output (MWh)	Cumulative GHG Impacts 100% Gas	Cumulative avoided GHG impacts (tCO2e)		
					100% Wind Scenario	100% Grid Average Scenario	50% Wind, 50% Grid Average Scenario
1	2026	3,854	3,276	786	-1,767	-491	-847
2	2027	7,709	6,552	2,359	-5,300	-1,472	-1,129
3	2028	11,563	9,829	4,718	-10,600	-2,945	-3,386
4	2029	15,418	13,105	7,863	-17,667	-4,908	-6,773
5	2030	15,418	13,105	11,008	-24,733	-6,872	-11,288
6	2031	19,272	16,381	14,940	-33,567	-9,326	-15,803
7	2032	19,272	16,381	18,871	-42,400	-11,780	-21,446
8	2033	23,126	19,657	23,589	-53,000	-14,725	-27,090
9	2034	23,126	19,657	28,307	-63,600	-17,670	-33,863
10	2035	23,126	19,657	33,024	-74,200	-20,615	-40,635
11	2036	23,126	19,657	37,742	-84,800	-23,560	-47,408
12	2037	23,126	19,657	42,460	-95,400	-26,505	-54,180
13	2038	23,126	19,657	47,178	-106,000	-29,450	-60,953
14	2039	23,126	19,657	51,896	-116,600	-32,395	-67,725
15	2040	23,126	19,657	56,613	-127,201	-35,340	-74,498
16	2041	23,126	19,657	61,331	-137,801	-38,285	-81,270
17	2042	23,126	19,657	66,049	-148,401	-41,230	-88,043
18	2043	23,126	19,657	70,767	-159,001	-44,175	-94,815
19	2044	23,126	19,657	75,485	-169,601	-47,120	-101,588
20	2045	23,126	19,657	80,202	-180,201	-50,065	-108,360
21	2046	23,126	19,657	84,920	-190,801	-53,010	-115,133
22	2047	23,126	19,657	89,638	-201,401	-55,954	-121,905
23	2048	23,126	19,657	94,356	-212,001	-58,899	-128,678
24	2049	23,126	19,657	99,073	-222,601	-61,844	-135,450
25	2050	23,126	19,657	103,791	-233,201	-64,789	-142,223
26	2051	23,126	19,657	108,509	-243,801	-67,734	-148,995

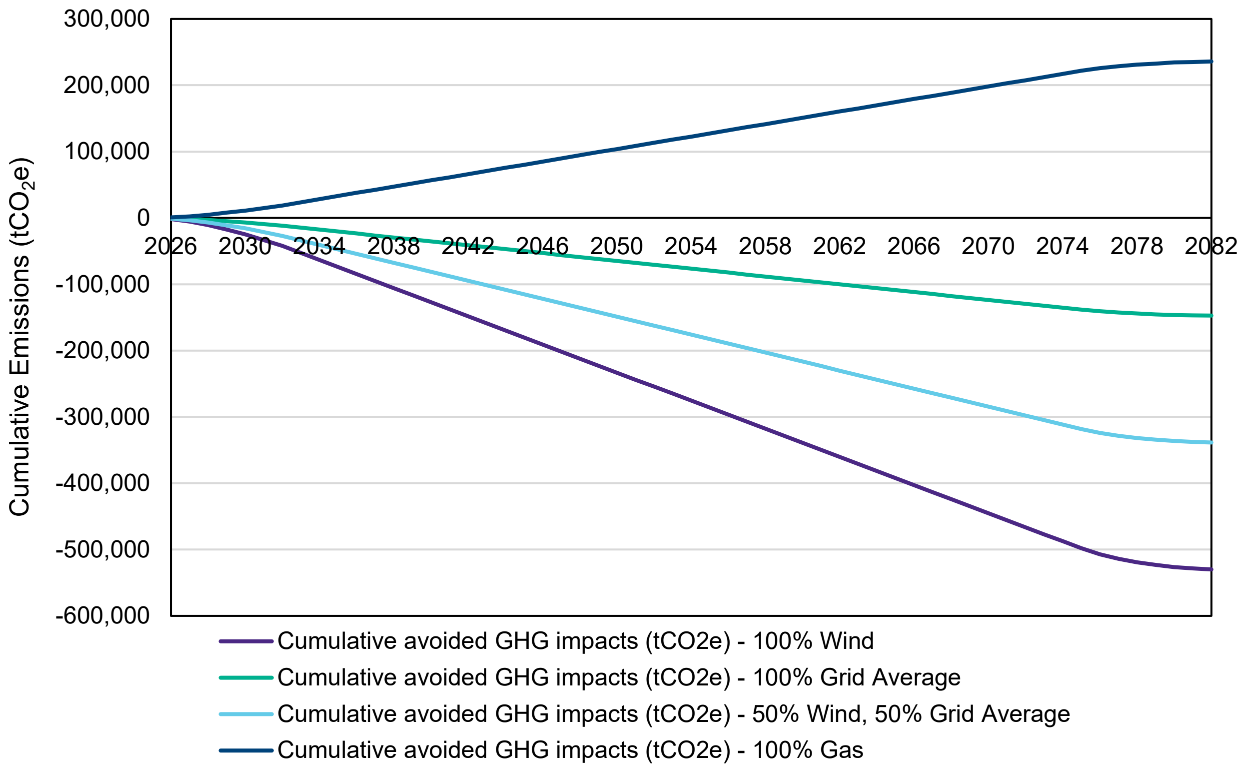
Year of operation	Year	Input (MWh)	Output (MWh)	Cumulative GHG Impacts 100% Gas	Cumulative avoided GHG impacts (tCO2e)		
					100% Wind Scenario	100% Grid Average Scenario	50% Wind, 50% Grid Average Scenario
27	2052	23,126	19,657	113,227	-254,401	-70,679	-155,768
28	2053	23,126	19,657	117,945	-265,001	-73,624	-162,540
29	2054	23,126	19,657	122,662	-275,601	-76,569	-169,313
30	2055	23,126	19,657	127,380	-286,201	-79,514	-176,085
31	2056	23,126	19,657	132,098	-296,801	-82,459	-182,858
32	2057	23,126	19,657	136,816	-307,401	-85,404	-189,630
33	2058	23,126	19,657	141,534	-318,001	-88,349	-196,403
34	2059	23,126	19,657	146,251	-328,601	-91,294	-203,175
35	2060	23,126	19,657	150,969	-339,201	-94,239	-209,948
36	2061	23,126	19,657	155,687	-349,801	-97,184	-216,720
37	2062	23,126	19,657	160,405	-360,401	-100,129	-223,493
38	2063	23,126	19,657	165,122	-371,002	-103,074	-230,265
39	2064	23,126	19,657	169,840	-381,602	-106,019	-237,038
40	2065	23,126	19,657	174,558	-392,202	-108,964	-243,810
41	2066	23,126	19,657	179,276	-402,802	-111,909	-250,583
42	2067	23,126	19,657	183,994	-413,402	-114,854	-257,355
43	2068	23,126	19,657	188,711	-424,002	-117,799	-264,128
44	2069	23,126	19,657	193,429	-434,602	-120,744	-270,900
45	2070	23,126	19,657	198,147	-445,202	-123,689	-277,673
46	2071	23,126	19,657	202,865	-455,802	-126,634	-284,445
47	2072	23,126	19,657	207,583	-466,402	-129,579	-291,218
48	2073	23,126	19,657	212,300	-477,002	-132,524	-297,990
49	2074	23,126	19,657	217,018	-487,602	-135,469	-304,763
50	2075	23,126	19,657	221,736	-498,202	-138,414	-311,535
51	2076	19,272	16,381	225,667	-507,035	-140,868	-318,308
52	2077	15,418	13,105	228,813	-514,102	-142,831	-323,952
53	2078	11,563	9,829	231,171	-519,402	-144,304	-328,467
54	2079	7,709	6,552	232,744	-522,935	-145,285	-331,853
55	2080	7,709	6,552	234,317	-526,469	-146,267	-334,110
56	2081	3,854	3,276	235,103	-528,235	-146,758	-336,368
57	2082	3,854	3,276	235,889	-530,002	-147,249	-337,497

1.4.40 Table 1-11 and Graph 1-2 summarises total emissions resultant from the operational phase of the BESS to be installed at the project. The magnitude of GHG impact varies according to the energy source assumed for battery charging. Negative values signify avoided emissions, while positive values are additional emissions. It is likely that avoided emissions will fall within this range.

Table 1-11: Avoided GHG Emissions from BESS - Summary

Test	Cumulative avoided GHG impacts (tCO_2e)	Unit
100% gas	235,889	tCO_2e
100% onshore wind	-530,002	tCO_2e
100% grid-average	-147,249	tCO_2e
50% onshore wind, 50% grid-average	-338,625	tCO_2e

Graph 1-1: Avoided GHG Emissions from BESS



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