BEACON FEN ENERGY PARK

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Revision History

Revision	Revision date	Details	Authorized	Name	Position

List of Outstanding Issues and Information

Outstanding issue/info.	Section/Paragraph	Responsibility	Action

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12. CLIMATE CHANGE

12.1 Introduction

12.1.1 This Chapter reports the preliminary assessment of the likely significant effects of the Proposed Development on climate and the vulnerability of the Proposed Development to climate change (together, "Climate Change"). In particular, it considers the likely significant effects of greenhouse gas (GHG) and carbon emissions on the global climate and the impacts of climate change on the Proposed Development.

12.1.2 This Chapter (and its associated appendix) is not intended to be read as a standalone assessment and reference should be made to the front end of this PEIR (Chapters 1 – 5) and particularly to the description of the Proposed Development in Chapter 2 which includes details about the Site, the design parameters and construction methodology, as well as the final chapter, 'Summary of Environmental Effects' (Chapter 17). This chapter is accompanied by the following Appendices and Figures:

- Appendix 12.1 Climate Change Guidance and Legislation

12.1.3 As set out within Chapter 1, the information set out within this Chapter is preliminary and intended to inform consultees (both specialist and non-specialist) about the likely environmental effects of the Proposed Development, helping to inform their consultation responses.

12.1.4 This chapter is presented in two parts to cover the following:

- Part A – Assessment of impacts on climate: An impact assessment that focuses on the potential effects of the Proposed Development (i.e. greenhouse gas emissions (GHG) on the climate through an assessment of whole life carbon). This includes an overview of how the Proposed Development aids in the mitigation of climate change.
- Part B – Assessment of climate resilience: A review of the resilience of the Proposed Development to projected future climate change impacts. This includes a qualitative discussion of the vulnerability and sensitivity of the Proposed Development to climate change impacts, with an assessment of the magnitude of potential effects.

12.2 Legislation and Policy

12.2.1 The legislation and policy considered relevant to the assessment of climate change are listed below, with details provided in Appendix 12.1

Legislative Framework

12.2.2 The applicable legislation includes:

- Climate Change Act 2008; and
- Infrastructure Planning (Environmental Impact Assessment) Regulations 2017.

Planning Policy

12.2.3 The applicable planning policy includes:

- Emerging Overarching National Policy Statement for Energy EN-1 (November 2023);
- Emerging National Policy Statement for Renewable Energy EN-3 (November 2023);
- Emerging National Policy Statement for Electricity Networks Infrastructure EN-5 (November 2023)
- The National Planning Policy Framework (as amended) (NPPF 2023);
- Central Lincolnshire Local Plan 2023, (April 2023); and Southeast Lincolnshire Local Plan 2011 – 2036 (March 2019).

Other relevant Policies and Strategies

12.2.4 Other applicable national policies include:

- Net Zero Strategy: Build Back Greener (2021);
- IPCC: Sixth Assessment Report (2023)
- CCC: Delivering a reliable decarbonisation power system (2023)
- Powering Up Britain: Net Zero Growth Plan (2023)

12.3 Consultation & Scope of Assessment

Consultation Undertaken to Date

12.3.1 Table 12.1 provides a summary of the consultation activities undertaken in support of the preparation of this Chapter.

Table 12.1: Summary of Consultation Undertaken to Date

ORGANISATION	SUMMARY OF CONSULTEE RESPONSE	HOW ADDRESSED IN THE PEIR
Planning Inspectorate (PINS)	The calculation of GHG emissions should take account of emissions across the full project lifecycle including, where relevant, any emissions arising through land use change, and direct and indirect emissions associated with the construction phase.	N/A
Lincolnshire County Council (LCC)	Council agrees this matter [Climate Change] should be 'scoped in' and appropriate assessments included as part of the ES. Take into account GHG emissions associated with the full life-cycle of the development and potential sources of GHG emissions. Identify the potential savings in GHG emissions associated with the operation of the development as a result of the consequent reduction in use of more carbon-emitting electricity generation methods.	WA have undertaken a Whole Lifecycle (WLC) assessment within the current scope, based on typical industry standard values for the embedded carbon obtained from peer reviewed studies for Solar PV, rather than bespoke modelling for specific panel manufacturers and site infrastructure. It is not possible to gather full detail on any increase in carbon emissions as a result of the need to transport / import food and crops from elsewhere, which would have otherwise been grown on the arable farmland as there

ORGANISATION	SUMMARY OF CONSULTEE RESPONSE	HOW ADDRESSED IN THE PEIR
	Assess any increase in carbon emissions as a result of the need to transport / import food and crops from elsewhere which would have otherwise been grown on the arable farmland that would be lost or removed from production as a consequence of the development. With regard to GHG emissions, this should directly be compared to the number of years it will take for development to be carbon neutral.	are too many variables to consider (e.g. which crops will be replaced, crops from which country/continent of origin would replace them, what type of machinery will be used to harvest them, etc.).
North Kesteven District Council (NKDC)	The approach to the assessment should consider the full life-cycle of the proposed development and potential sources of GHG emissions. GHG emissions offset through the production of lower carbon electricity compared to grid average emissions during the operational phase should also be accounted for within the GHG emissions calculations. The Council also requests consideration of methods to increase in-situ carbon sequestration from effectively leaving the land fallow for the expected 60 years (in the absence of any details of agricultural land impact ‘mitigation’ at this stage). This could include low growing plants as part of a BNG strategy that could assist with increasing the organic content of the soil and locking carbon. In principle the Council supports the mitigation measures proposed in section 10.8); the investigation of agrivoltaics would be encouraged, along with plant optimisation techniques and Sustainable Urban Drainage (SuDS).	WA have used industry standard embedded carbon and WLC figures obtained from peer reviewed studies for Solar PV. NKDC requested consideration of generation capacity in relation to BMV. It is assumed that this is a reference to considering the carbon associated with transporting crops if they are being displaced from BMV land by the solar development. WA’s response is as discussed above for LCC. The operational lifetime of the Proposed Development, following a 24 to 36 month construction period, is 40 years. Decommissioning will take 1 to 2 years. The resilience section has considered projected changes to the climate over a 45-year reference period which fully encompasses the project lifetime of 40 years. The GHG emission section bases its calculation on a 40 year operational period.
Forestry Commission	We would recommend that planting should be targeted to enhance existing woodland and ecological networks by buffering the existing woodland to create larger blocks of ideally at least 5ha. Species and provenance of new trees and woodland need to be considered to establish a more resilient treescape which can cope with the full implications of a changing climate.	It is anticipated that much of the planting associated with the development will be for the purpose of screening so this will not be targeted around enhancing the woodland but rather providing very localised shielding of sensitive receptors.

Scope of the Assessment

Characterisation of Impacts

12.3.2 The assessment is intended to ensure that the Proposed Development does not emit unacceptable levels of emissions, not only in an effort to reduce future climate change impacts, but also to contribute towards local, national, and global emission reduction targets.

12.3.3 The Proposed Development is a renewable energy project and therefore, provided it is well designed it should offset (through the displacement of fossil fuel generation) far more emissions over its lifetime than it emits. The time to pay back carbon has been calculated for the Proposed Development as 3.74 years.

12.3.4 The resilience of the Proposed Development to future changes in climate is also assessed using probabilistic climate projections for the region.

12.3.5 The categorisation of both of these assessments in relation to key determining criteria are explained, below.

- Positive or Negative – A positive impact is achieved if the relative emissions are below zero. A negative impact is characterised by relative GHG emissions being above zero.
- Extent – Any net GHG emissions contribute to climate change, which is a global issue. Localised effects are relevant to climate resilience but not GHG emissions. Further detail is given in Part B Assessment Methodology.
- Magnitude – A single scheme has a de-minimis impact on global climate change overall, but the assessment is still important to assess the Proposed Development's contribution to local and national targets. Additionally, the assessment considers magnitude in the context of emission reduction compared to baseline scenarios. For the purposes of determining the magnitude of impacts of climatic variables on the Proposed Development, a combination of the probability and consequence of likely events are used.
- Probability – This takes into account the chance of the climatic effect occurring over the relevant time period (e.g. lifespan) of the Proposed Development and the likely impact of this if the risk is not mitigated.
- Consequence – This reflects the geographical extent of the climatic effect, or the number of receptors affected (e.g. scale), the complexity of the impact, degree of harm to those affected and the duration, frequency, and reversibility of impact.
- Duration and Timing – The duration of the impacts extends from construction, through operational and to decommissioning phases of a given development. Research has shown that the operational phase typically accounts for around 90-95% of emissions across the lifetime of a development. The duration and timing of a future climatic event will affect resilience.
- Frequency – The majority of the emissions associated with the Proposed Development are expected to occur during construction and decommissioning, or else be embodied in the materials used in the production of the panels and site infrastructure. The operational phase will include some emissions relating to the maintenance of the Site and panels, and use of any consumables in the electrical infrastructure, cleaning or routine maintenance to ensure standard operation. When assessing the resilience of the Proposed Development to future climate, however, the frequency of projected

events is used to determine the likelihood and consequence of impacts.

- Reversibility – Once emitted into the atmosphere, GHGs are circulated and interact with different processes and reactions to create different molecules, with varying lifespans and impacts. This is essentially irreversible, but it is possible to take actions that can limit the emissions released. It is also possible to sequester certain gases and remove them from the atmosphere, such as through the use of green infrastructure and tree planting.
- Likelihood – Any form of activity or process will result in the release of GHGs to some degree. This includes activity associated with positive climate change action, such as the development of renewable energy or other low carbon technology. The likelihood of future climate risks is determined by the level of probability. This assessment aims to consider how the inevitable impact of emissions is minimised and reduced, as well as how the resilience to future climate change is increased, in the design and planning of the Proposed Development.

12.3.6 Mitigation has taken a prominent position within EIA, with GHG emissions mitigation considered from the outset and throughout the project's lifetime.

System Boundary

12.3.7 The scope of the climate change impact assessment is considered to be those activities associated with the Proposed Development that either directly or indirectly release GHG emissions that contribute to climate change effects, irrespective of their source, and across all relevant project lifecycle stages (i.e. whole lifecycle carbon emissions).

12.3.8 British Standard (BS) EN15978 and the Royal Institution of Chartered Surveyors (RICS) Professional Statement (PS) set out four stages in the life of a typical project, described as lifecycle modules. These lifecycle modules have been simplified in the diagram in Figure 12.1, below, but include the following:

- Module A1 – A5 (Product sourcing and construction stage);
- Module B1 – B7 (Use stage);
- Module C1 – C4 (End of life stage); and
- Module D (Benefits and loads beyond the system boundary).

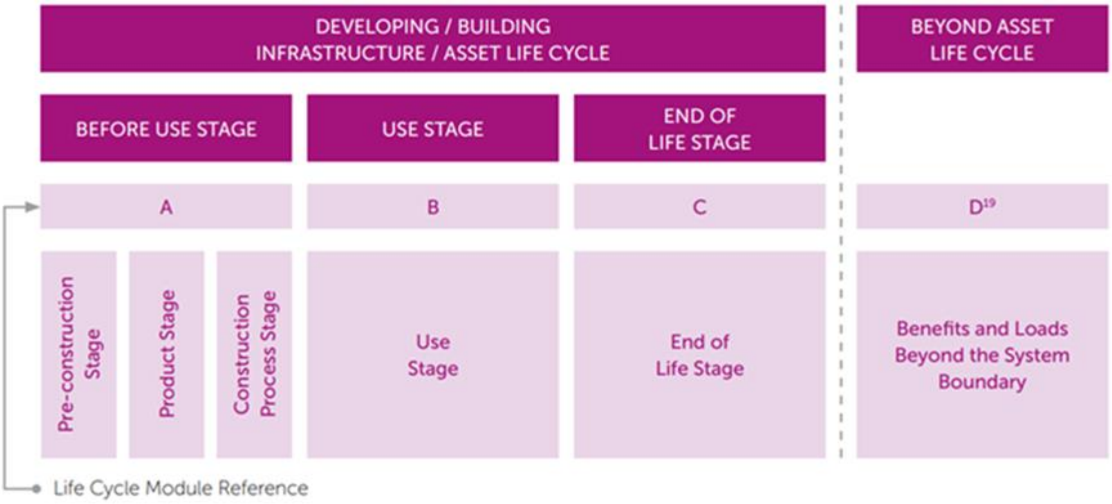

Figure 12.1 - Simplified Modular Lifecycle Stages for EIA GHG Emissions Assessment

(IEMA, 2022)

12.3.9 The system boundary applied for this assessment is cradle-to-grave and it will cover the entirety of modules A1 (raw material extraction and supply) through to C4 (end of life stage). Module D (beyond asset life cycle in Figure 12.1), is optional and involves a greater level of uncertainty, especially at this early stage of planning. The assessment is proportional to the nature and scale of the Proposed Development.

Temporal Boundary

12.3.10 The actual project lifetime is expected to comprise 24 to 36 months for construction, 40 years for the operational phase and 12 to 24 months for decommissioning and restoration and this forms the temporal boundary for the assessment.

Whole Lifecycle Carbon Emissions

12.3.11 A sum total of all emissions associated with the project over the entire lifecycle, which includes operational emissions from day-to-day energy use, is provided in order to assess the impacts associated with the Proposed Development over the reference study period. Emission savings achieved from any incorporated low carbon technologies during operation (e.g., renewable energy/heat generation) are taken into consideration. The assessment includes embodied carbon emissions, which consists of:

- Material sourcing;
- Fabrication of components;
- Transportation of materials to/from Site;
- Construction;
- Maintenance, repair and replacement; and
- Demolition, dismantling, and disposal.

12.3.12 The assessment considers the whole lifecycle carbon emissions from cradle (raw material extraction and supply) to grave (end of functional life) after the 40-year operational period for the solar farm (i.e. Solar Array Area) and Battery Energy Storage System (BESS) at Beacon Fen. It should be noted the assessment for the BESS includes estimated emissions for material sourcing, fabrication of components, transportation of materials, replacement, and recycling. The emissions from construction, maintenance and repair are deemed to be negligible.

Effects not considered within the Scope

Emissions from Land Use Change

12.3.13 Emissions relating to land use change and any vegetation clearance required during construction of the Solar Array Area and Cable Route Corridor have not been fully assessed within this PEIR.

12.3.14 Where very low emission levels are predicted in relation to soil disturbance, the approach of excluding these emissions is justified within the 2022 IEMA guidance, where it states: *“Activities that do not significantly change the result of the assessment can be excluded where expected emissions are less than 1% of total emissions and where all such exclusions total a maximum of 5% of total emissions; all exclusions should be clearly stated*”.

12.3.15 Based on the preliminary results from the soils assessment (PEIR Chapter 14), only Minor loss of soil and damage to soil is expected within the Solar Array Area, which is Not Significant in EIA terms. This assumes that trafficking of vehicles / plant and incorrect soil handling, which can cause damage to soil structure through compaction and smearing (both effects are sometimes referred to as ‘deformation’), are minimised through standard mitigation measures. There is also potential for soils to provide other ecosystem services during the operational phase including for biodiversity and carbon storage due to lower intensity agricultural land management strategies that will be adopted during operation.

12.3.16 Soils along the Cable Route Corridor have been subject to only desktop analysis at this stage, with further detailed survey analysis to follow as part of the environmental statement submitted as part of the Application; however, for the purposes of this preliminary assessment, it is considered that any long term (permanent in worst case) land use change would be limited to areas of built development such as access tracks. Further information can be found in Chapter 14. The presence of the underground cabling is expected to be a temporary impact as following construction the land above the cable route would be reinstated.

12.3.17 The sensitivity of receptors to the climatic impacts within the construction phase, in this case the construction workers, has not been formally assessed. This is because the sensitivity of the human receptors is low as the projected climatic changes will not occur in the immediate future (i.e. within the 2020s) when the construction phase will be carried out.

Limitations & Exclusions

12.3.18 The information within this Chapter is preliminary and intended to inform consultees. As such, this PEIR has been prepared at a point in the design process when parameters of the design are certain enough for an assessment to be based upon, but there is still sufficient flexibility to incorporate feedback from consultees.

PART A: ASSESSMENT OF IMPACTS ON CLIMATE (GREENHOUSE GAS EMISSIONS)

12.4 Assessment Methodology & Significance Criteria

Extent of the Study Area

12.4.1 The assessment considers the GHG emissions associated with the manufacture, construction, operation and maintenance and eventual decommissioning of the Proposed Development. The global climate as a whole is the receptor that is affected as GHG emissions are not geographically constrained. This study area differs from others generally listed within an EIA context as it is not at a distinct local scale, but a global one. A system boundary and a temporal boundary is applied to the assessment in order to determine the Proposed Development's impact on climate change in relation to the release of GHG emissions associated with the project across the entire lifecycle.

Assessment Methodology

12.4.2 The climate change impact assessment is based on the latest EIA guidance published by the Institute of Environmental Management and Assessment (IEMA).

12.4.3 Part A of the assessment follows the principles set out in the 2022 '*Environmental Impact Assessment: Guide to Assessing Greenhouse Gas Emissions and Evaluating their Significance*'. This is the most recent guidance available and is applicable to the UK. It is also considered to be the most holistic method of assessing GHG emissions as it applies a whole lifecycle methodology, incorporating not just the construction and operational phases of development, but also the decommissioning / end of life and beyond asset lifecycle stages. The whole lifecycle methodology allows for a more robust 'worst case scenario' to be applied which is proportionate to the nature and scale of the Proposed Development.

12.4.4 Several guidance publications have been produced containing suggested methods for establishing a GHG emissions baseline and limited advice on techniques for applying significance thresholds. The European Investment Bank (EIB) 2023 '*EIB Project Carbon Footprint Methodologies: Methodologies for the Assessment of Project GHG Emissions and Emission Variations*' guidance will be used to expand upon the IEMA guidance when considering baseline scenarios for the assessment. This goes into greater detail in terms of a baseline methodology and allows for easier comparison of impacts where there is no prior development in an area.

12.4.5 Guidance on the whole life cycle emissions of the Business as Usual (BaU) alternative baseline, in this case natural gas, is described through the United Nations Economic Commission Europe's (UNECE) assessment: Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources (2022).

Setting a Baseline

12.4.6 A baseline is a reference point against which the impact of a new project can be compared against, where assumptions are made on current or future GHG emissions. The baseline can take the form of:

A. GHG emissions within the boundary of the GHG quantification[1], but without the proposed project ('Baseline A'); or

B. GHG emissions arising from an alternative project design and/or BaU for a project of this type ('Baseline B').

12.4.7 This assessment considers both forms of baseline to provide a meaningful comparison of impacts associated with the project. As stated in the IEMA (2022) guidance, the goal of establishing a baseline is assessing and reporting the proposed project's net GHG impact.

Baseline A

12.4.8 In relation to Baseline A, there are limitations in estimating the GHG emissions associated with the current use as reliable data is unavailable. The IEMA guidance (2022) sets out that:

"*It may not always be possible to report on current baseline emissions, particularly with projects situated in areas with no physical development or activity. In this instance there would be zero GHG emissions to report at a site level*."

12.4.9 As such, in relation to Baseline A, the assessment will assume that the existing site is in equilibrium in relation to GHG emissions and the baseline emissions within the site boundary are zero. The IEMA (2022) guidance goes on to state that:

"*…alternative baselines can be used to supplement the analysis and address uncertainty…a realistic worst-case baseline should still be used for assigning significance*".

Baseline B

12.4.10 Baseline B forms this alternative and as is used for assigning significance as it provides a logical reference point in relation to legislative and policy-based climate commitments. In-line with industry best practice dictated by the IEMA guidance (2022), this baseline will capture all future emissions within the applied system boundary (Cradle-to-Grave).

12.4.11 The EIB (2023) provides further guidance on undertaking sectoral/BaU baseline assessments:

"*By definition, emissions prior to developing on a greenfield site are zero. Hence, applying a simple ''before and after'' approach gives rise to a zero baseline. By contrast, the baseline scenario … (i.e. without a project scenario) places no weight on whether a development is greenfield, brownfield or a partial replacement — the key issue is how the projected demand could*

[1] This is not the same as the boundary of the Site. The boundary for emissions quantification includes both upstream and downstream emissions from manufacturing and electricity transmission, many of which will occur outside of the Site boundary.

otherwise have been met, which is not addressed in the "before and after" scenario.

If the project is designed to replace a life-expired asset, a ''before and after" approach would use previous emissions as the baseline. However, this approach would lack credibility in many cases.

The project baseline scenario (or "without project" scenario) is defined as the expected alternative means to meet the output supplied by the proposed project...

…The baseline scenario must therefore propose the likely alternative to the proposed project which (i) in technical terms can meet required output; and (ii) is credible in terms of economic and regulatory requirements. The choice of baseline should normally be approached in the same way as the expected alternative scenario is determined for the project economic analysis."

12.4.12 The 2023 EIB guidance further states that, first, a baseline scenario should be identified that is able to meet the demands of the Proposed Development in technical terms, for instance the baseline must be able to technically meet the outputs of the Proposed Development. Secondly, that a baseline scenario is credible by meeting the following simplified tests:

- Socio-economic test: The baseline scenario should be financially viable with similar financial rates of return to that of the Proposed Development.
- Legal requirement test: The baseline emissions alternative scenario could not fail to comply with binding legal requirements.
- Life-expired test: The baseline alternative could not assume continuing use of existing assets beyond their economic life.

12.4.13 The 2023 EIB guidance outlines how the Proposed Development will be compared to a standardised development, which will form the baseline BaU scenario for the assessment. The standardised development, on an alternate site, would produce the same deliverables and meet the legislated and policy requirements. In-line with industry best practice dictated by the 2022 IEMA guidance, the future baseline will capture all emissions within the applied system boundary.

Estimating Emissions

12.4.14 The assessment is based on a combination of detailed information as supplied by the project design team, as well as UK default values for current industry standards and indicative material specifications for renewable energy products. The general equation for emission estimation is:

GHG emissions = Activity Data x Emission Factor

12.4.15 Activities where expected emissions are less than 1% of the total emissions can be excluded, but only where all exclusions total up to a maximum of 5% of total overall emissions associated with the Proposed Development across all project lifecycle modules within the applied system and temporal boundaries (the whole lifecycle carbon emissions).

12.4.16 Emissions are expressed in terms of tonnes of carbon dioxide equivalent (tCO_2e). This is a universal metric measure used to compare the emissions from various greenhouse gases on the basis of their global warming potential (GWP) by converting amounts of other gases to the equivalent amount of CO_2 with the same GWP.

Relative Emissions

12.4.17 The Proposed Development is assessed for its 'relative emissions' (Re) or net emissions, which is expressed as the difference between 'absolute emissions generated by the Proposed Development' (Ab) and the 'baseline emissions from the BaU scenario' (Be):

Relative Emissions (Re) = Absolute Emissions (Ab) – Baseline Emissions (Be)

12.4.18 The Ab are equivalent to the type B baseline described above and describe the calculated total emissions from within the emissions quantification boundary.

12.4.19 The relative emissions are used a reference point in combination with industry expertise on carbon reduction targets to evaluate the project against the significance criteria defined below.

Significance Criteria

12.4.20 Effects that are deemed to be 'Significant' for the purposes of this assessment are different to those associated with other technical ES chapters.

12.4.21 All sources of GHG emissions will contribute to global climate change. The atmospheric concentration of GHG emissions is defined by IEMA (2022) as being of High sensitivity to further emissions. Therefore, all emissions are considered to have an adverse and permanent impact on climate change in the long-term.

12.4.22 The significance of the impacts associated with the Proposed Development has been assessed in-line with the criteria set out within the 2022 IEMA guidance, as summarised in Table 12.2. Where GHG emissions cannot be avoided, the goal of the EIA process is to reduce the Proposed Development's residual emissions at all lifecycle stages within the applied system boundary.

Table 12.2: Significance Criteria for Assessment of Impacts from GHG Emissions

CRITERIA	IMPACT	SIGNIFICANCE
The project's GHG impacts are not mitigated or are only compliant with do-minimum standards set through regulation, and do not provide further reductions required by existing local and national policy for projects of this type. A project with major adverse effects is locking in emissions and does not make a meaningful contribution to the UK's trajectory towards net zero.	Major adverse	Significant
The project's GHG impacts are partially mitigated and may partially meet the applicable existing and emerging policy requirements but would not fully contribute to decarbonisation in line with local and national policy goals for projects of this type. A project with moderate adverse effects falls short of fully contributing to the UK's trajectory towards net zero.	Moderate adverse	Significant
The project's GHG impacts would be fully consistent with applicable existing and emerging policy requirements and good practice design standards for projects of this type. A project with minor adverse effects is fully in line with	Minor adverse	Not Significant

CRITERIA	IMPACT	SIGNIFICANCE
measures necessary to achieve the UK's trajectory towards net zero.		
The project's GHG impacts would be reduced through measures that go well beyond existing and emerging policy and design standards for projects of this type, such that radical decarbonisation or net zero is achieved well before 2050. A project with negligible effects provides GHG performance that is well 'ahead of the curve' for the trajectory towards net zero and has minimal residual emissions.	Negligible	Not Significant
The project's GHG impacts are below zero and it causes a reduction in atmospheric GHG concentration, whether directly or indirectly, compared to the without-project baseline. A project with beneficial effects substantially exceeds net zero requirements with a positive climate impact.	Beneficial	Significant

12.4.23 With consideration to the 2022 IEMA guidance, minor adverse and negligible effects are considered to be Not Significant (see Table 12.2). However, impacts are only considered to be minor adverse if the project's GHG impacts are fully consistent with existing and emerging policy requirements and good practice. Impacts are only considered to be negligible if the development goes well beyond existing policy and design standards. It needs to be viewed as well 'ahead of the curve' for the net zero trajectory and have minimal residual emissions. Projects that actively reverse (rather than only reduce) the risk of severe climate change can be judged as having a beneficial effect.

12.5 Baseline Conditions

Current Baseline Conditions (Baseline A)

12.5.1 The current baseline represents existing GHG emissions from a site prior to construction and operation of the project under consideration. This is equivalent to Baseline A as described in 12.5.1.

12.5.2 The Site, comprising the Solar Array Area and the Cable Route Corridor, consists mainly of fields in arable use, divided by ditches with sparse tree cover that is limited to small woodland blocks and scattered hedgerow trees. The Solar Array Area is approximately 517 ha in size.

12.5.3 In the absence of a detailed assessment of the carbon balance of the agricultural system, which is likely to fluctuate dramatically from year to year as crops change or some areas are left fallow, a zero emissions baseline will be assumed. This is likely to represent a worst-case scenario in practice as most agricultural systems import carbon in the form of fertilisers and fuels for machinery which is then lost from the system through the sale of crops and emissions to air.

Sensitive Receptors

12.5.4 The Proposed Development will impact on global GHG concentrations across all project lifecycle stages, which will have a permanent, long-term and adverse effect on the climate through contributing to the human-induced global warming effect. Within a climate change context, therefore, the key sensitive receptor to the impacts of the Proposed Development will be global climate, which has a high sensitivity to further emissions. The Proposed Development will also be affected by future changes to the climate. This global receptor differs to the other local scale receptors listed within an EIA context as it is not within a predefined site boundary.

Future (Sectoral) Baseline Conditions (Baseline B)

12.5.5 As set out in Section 12.4 Assessment Methodology, for the purposes of the assessment in this PEIR Chapter, the absolute emissions (Ab) are compared to 'a sectoral future baseline' (Be) that has been developed to provide a credible comparison of relative effects, as recommended by the 2023 EIB guidance. The baseline BaU emissions scenario (Be) represents Baseline B as described in Section 12.4 Assessment Methodology. This is different to other Chapters, which describe a 'no development' scenario as the future baseline.

12.5.6 The baseline BaU emissions scenario assumes that the expected energy generation of an alternative development on the site of the proposed solar farm is instead obtained from an alternative energy source, in this case fossil fuels (i.e. natural gas) or onshore wind power. Annual emissions and whole life carbon emissions have been calculated based on the method explained in Section 12.4 Assessment Methodology. Lifetime covers project lifecycle stages A1 (raw material extraction and supply) through to C4 (end of functional life).

Natural Gas Generation

12.5.7 The efficiency of a Combine Cycle Gas Turbine (CCGT) is estimated to be 55% and this represents the most common technology for gas generation in the UK. Generating 1kWh of electricity will, therefore, require 1.82kWh of gas to be fed into the turbine. Using the UK Government's GHG Conversion Factors for Company Reporting[2], a natural gas emission conversion factor of 0.20226kgCO_2e/kWh is used to estimate the emissions (net calorific value (CV)) that are produced by the combustion of gas in the turbine, representing the operational emissions.

12.5.8 The whole lifecycle carbon emissions associated with the Proposed Development are calculated based on the United Nations Economic Commission for Europe (UNECE) assessment[3] to generate benchmark carbon emission figures that are then multiplied by the equivalent energy generation from the Proposed Development.

12.5.9 The UNECE assessment calculates the whole life cycle impact of 1kWh of natural gas power production (excluding carbon capture and storage) as 434gCO_2e/kWh. It has been assumed that this figure covers lifecycle stages A1 (raw material extraction and supply) through to C4 (end of functional life) and is, therefore, representative of the system boundary applied for this assessment. This figure has been applied to estimate baseline BaU lifetime

[2] Natural Gas emission factor from "*Greenhouse gas reporting: conversion factors 2023, full set (for advanced users)*", Department of Energy Security and Net Zero, published 7 Jun 2023, Updated 28 Jun 2023 https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023, [Accessed 30/08/2023].

[3] United Nations Economic Commission Europe (UNECE), "*Life Cycle Assessment of Electricity Generation Options*", 2022 https://unece.org/sites/default/files/2022-04/LCA_3_FINAL%20March%202022.pdf, [Accessed 28/08/2022].

(whole lifecycle carbon emissions) for the reference study period for this assessment.

Onshore Wind Generation

12.5.10 The future sectoral baseline is extended to include onshore wind generation as a comparison with natural gas generation. Since onshore wind is a form of renewable generation, emissions associated with the operation of the wind turbines are negligible. There will be a minimal component of emissions related to periodic maintenance, but these have been omitted for the purpose of this assessment. There will, however, remain emissions associated with the construction process, including site preparation, installation of access tracks, foundations, and grid infrastructure, etcetera. There will also be embodied emissions from manufacturing the turbines and transporting them to site.

12.5.11 The UNECE assessment calculates the whole life cycle impact of 1kWh of onshore wind power production as 12.4gCO_2e/kWh. As with the natural gas equivalent, it has been assumed that this figure covers lifecycle stages A1 (raw material extraction and supply) through to C4 (end of functional life) and is, therefore, representative of the system boundary applied for this assessment.

Future (Sectoral) Baseline Emissions

The Modelled Energy Generation for a Solar PV Farm of the same proportions as the Proposed Development, based on the annual energy generation of the solar PV farm, is 543,390MWh/yr (megawatt hours per year). The baseline BaU emissions scenario (Be), as calculated based on the energy generation of the natural gas and onshore wind equivalents, is indicated in Table 12.3, below. This will form part of the baseline for the assessment of impacts associated with the Proposed Development (Baseline B).

Table 12.3: Baseline BaU Emissions Scenario

BASELINE 1: NATURAL GAS EQUIVALENT				
	No. Years	**Energy Generation (MWh)**	**Operational Emissions (tCO_2e) *(Nat Gas Emissions Factor: 0.20226kgCO_2e/kWh)***	**Whole Lifecycle Carbon Emissions (tCO_2e) *(Assuming 0.434kgCO_2e/kWh)***
Annual	1	543,390	199,829	-
Lifetime	40	21,735,600	7,993,168	9,433,250
BASELINE 2: ONSHORE WIND EQUIVALENT				
	No. Years	**Energy Generation (MWh)**	**Operational Emissions (tCO_2e) *(Onshore Wind Emissions Factor: 0kgCO_2e/kWh)***	**Whole Lifecycle Carbon Emissions *(tCO_2e)* *(Assuming 0.0124kgCO_2e/kWh)***
Annual	1	43,648	0	-
Lifetime	40	1,745,920	0	269,521

12.5.12 The Baseline B scenarios estimate emissions from alternative forms of generation based on published studies showing the whole lifecycle carbon associated with each technology. These have been derived from experiences recorded with actual generators. However, they are presented as average figures per MWh.

12.5.13 Figures per MWh are probably most appropriate for a Combined Cycle Gas Turbine (CCGT) where the whole lifecycle emissions are heavily related to operational phase and the combustion of fuel on a per hour basis. In such a case, the longer the gas turbine is operating, the higher its WLC emissions will be, and emissions will increase with every MWh of generation.

12.5.14 However, for a renewable energy technology, most of the emissions are embodied in its initial raw materials and construction processes. Only net carbon savings arise from the operational phase, and each MWh of electricity generated results in slightly lower lifecycle emissions. In this case, emissions given based on the installed capacity of the generator (i.e. per MW installed or per MWp) will be more appropriate and this figure is used in preference (where such an emission factor is available). Here, the longer the renewable generator is in place, the better. Such a figure has been used for the solar generation.

12.5.15 For wind generation, where a reliable WLC emissions factor per MW installed has not been identified, a figure per MWh has been used as the best available alternative, but this represents a limitation in the assessment methodology. As a result, whole lifecycle emissions will appear to increase with a longer project lifetime rather than decreasing as would logically be the case with more fossil fuel generation being offset.

12.5.16 At present, no assessment of actual emissions associated with the change of use of the land have been calculated. At this stage, it is intended that further consideration of this element will be provided in the ES.

12.6 Assessment of Effects

Design Solutions and Assumptions

12.6.1 The assessment considers the operational CO_2e emissions over the 40-year operational lifetime period, including the embodied emissions. It has been assumed that energy generated will remain the same, year on year, throughout the assessment period, ignoring the effect of any potential panel degradation. The assessment has used an emissions calculation based on installed capacity of the solar panels. This is due to the vast majority of the lifecycle emissions coming from the before use stage.

12.6.2 This comparison between the onshore wind and natural gas energy generation scenarios (Baseline B), that are the equivalent of the energy generated by the solar farm, allows for the calculation of the emission saving potential of the solar array.

Absolute Emissions and Emissions Compared to Baseline A

12.6.3 The absolute emissions (Ab) of the Proposed Development will be zero or minor because it is assumed that the renewable energy *"will displace (at least in part) fossil fuels"* that are used to create grid electricity generation. Table 12.4 states the Ab based on the energy generation of the solar PV farm.

12.6.4 The emissions from BESS have been provided separately. The emissions from BESS were calculated using 72.9kgCO_2e/kWh for the cradle-to-gate emissions[4]. The transportation emissions were calculating assuming the batteries were shipped from South Korea to London and then transported on

[4] Aichberger, C. (2020) *Environmental Life Cycle Impacts of Automotive Batteries Based on a Literature Review.* Available from: https://www.mdpi.com/1996-1073/13/23/6345

HGVs to the Site. The emissions from recycling the batteries is based on a figure of 3.65kgCO_2e/kWh[5].

Table 12.4: Absolute/Total Emissions

GROUND MOUNT SOLAR PV				
	No. Years	**Energy Generation (MWh)**	**Operational Emissions (tCO_2e) *(Solar PV Emissions Factor: 0kgCO_2e/kWh)***	**Whole Lifecycle Carbon Emissions (tCO_2e) *(Assuming 615kgCO_2e/kWp)***
Annual	1	543,390	0	-
Lifetime	40	21,735,600	0	362,850
BESS				
Capacity (MWh)			**Operational Emissions (tCO_2e) *(BESS Emissions Factor: 0kgCO_2e/kWh)***	**Whole Lifecycle Emissions (tCO_2e)**
1,200			0	383,753

12.6.5 The potential impact of the whole lifecycle carbon emissions associated with the Proposed Development is interpreted, below, for each project stage.

Embedded Mitigation

12.6.6 It is assumed that, as part of the embedded mitigation, a number of decisions will be incorporated into the design, construction operation and decommissioning of the Proposed Development.

12.6.7 These may include:

- Consideration of embodied carbon during the procurement process;
- Minimisation of material use and avoidance of waste generation;
- Optimisation of transportation and construction efficiency and minimisation of fuel use;
- Reuse of materials onsite and recycling of waste materials;
- Landscape enhancement, planting and biodiversity net gain;
- Preferential use of low carbon site maintenance options, where possible/practicable;
- Reuse/recycling of applicable materials following decommissioning.

Assessment of Effects

Construction Phase

12.6.8 The construction phase spans the project lifecycle modules A1 through to A5. This includes the embodied carbon contained within the materials and components that form the solar arrays, from extraction of the raw material [A1] through to manufacturing of the end products [A2-A3], as well as transportation of materials to the Site [A4] and the construction and installation process [A5].

12.6.9 Embodied carbon emissions of a solar farm and battery storage development are emissions arising from upstream processes that include:

- Raw material extraction;

[5] Quanwei Chen, Xin Lai, Huanghui Gu, Xiaopeng Tang, Furong Gao, Xuebing Han, Yuejiu Zheng (2022) *Investigating carbon footprint and carbon reduction potential using a cradle-to-cradle LCA approach on lithium-ion batteries for electric vehicles in China*.

- Materials production;
- Module manufacture;
- System/plant component manufacture; and
- Installation and plant construction.

12.6.10 The embodied carbon of solar PV modules, batteries and infrastructure can vary considerably as it is dependent on various factors, such as country of manufacture type of PV technologies (e.g. monocrystalline silicon, polycrystalline silicon, and thin film), and source of energy to extract and produce the materials.

12.6.11 Prior to 2020, the figure of 2,560kgCO_2/kWp was commonly referenced as the assumed embodied carbon of a monocrystalline photovoltaic (mPV) system[6]. The more recent research published by Etude in 2021[7], based on the work by Louwen et al. (2016) and Pehl *et al.* (2017), found that embodied carbon of solar was much less at around 615 kgCO_2e/kWp of installed capacity.

12.6.12 Kilowatt peak (kWp) is a unit of measurement that represents the maximum power output of a PV system under standardised test conditions.

12.6.13 Etude's (2021) research indicates that the reduction in embodied carbon is:

"…*mainly driven by improvements in manufacturing process and the ongoing global decarbonisation of electricity, based on academic papers and sustainability reporting by manufacturers. Looking forward to 2040, research projects a drop to 325kgCO_2/kWp and by 2050 additional research projects just 205kgCO_2/kWp, a 92% reduction compared to currently assumed values*."

12.6.14 Using the 615kg/kWp embodied carbon figure, the assumed total embodied carbon for the solar array is 362,850 tCO_2e. The lifecycle emissions from the BESS have been added to this figure to give total embodied carbon of 746,603 tCO_2e, as stated in Table 12.5. Based on the annual operational emission savings provided in Table 12.5, it will take approximately 3.74 years to pay back the embodied carbon of the solar PV system.

Table 12.5: Estimated Embodied Carbon for the Proposed Development

ESTIMATED EMBODIED CARBON FOR THE PROPOSED DEVELOPMENT	
Embodied carbon per unit (kgCO_2e/kWp)	0.615
Installed capacity (kWp)	590,000
Sequestered carbon (tCO_2)	0
Total embodied carbon (tCO_2e)	746,603
Years to pay back carbon (years)	3.74

12.6.15 As stated in the 2022 IEMA guidance "*GHG emissions have a combined environmental effect that is approaching a scientifically defined environmental limit[8]; as such any GHG emissions or reductions from a project might be*

[6] Worboys, C. (2021). '*The rapid fall of solar's embodied carbon*'. LinkedIn. [Online]. Available at: https://www.linkedin.com/pulse/rapid-fall-solars-embodied-carbon-chris-worboys/ [Accessed 30 August 2023].
[7] Etude (2022). '*The (low) embodied carbon of solar PV*' [Online Article]. Available at: https://etude.co.uk/how-we-work/low-embodied-carbon-of-pv/ [Accessed 30 August 2023].
[8] This principle is related to the IPCC carbon budget definition. The IPCC's Sixth Assessment Report (WG1: The Physical Science Basis, Table SPM.2) indicates that the remaining global carbon budget from 2020 that

considered to be significant". It is, therefore, determined that all unmitigated construction emissions are individually adverse and Significant.

12.6.16 As efficiencies in the production of solar arrays are beginning to be realised, it is possible for the embodied carbon impacts to be further reduced. Etude (2021) propose that 20-34gCO_2/kWh is a reasonable range for embodied carbon within solar arrays at this time. The United Nations (UN) states under European Union (EU) conditions, solar PV technologies shows lifecycle GHG emissions of about 37gCO_2e/kWh for ground and roof-mounted systems.

12.6.17 Although based on real life averages, attempting to forecast embodied carbon as a function of total energy generated means that figures are completely dependent on the lifetime of the solar farm, with the longer the solar farm lifetime, the higher the predicted embodied carbon. This cannot be correct as it would suggest a more long-lived solar farm has higher levels of embodied carbon. Since an estimated 99% of the embodied emissions for solar PV relate to the manufacturing process, the project lifetime is largely an independent variable. For this reason, the 615kg/kWp embodied carbon figure is used in this assessment to present a 'worst-case' scenario of impacts associated with the Proposed Development across all relevant project lifecycles.

Operational Phase

12.6.18 The operational phase spans the project lifecycle modules B1 (Use) through to B7 (operational water use) and includes the operational energy use [B6].

12.6.19 In relation to the operational water use [lifecycle module B7], there are currently few studies that have investigated the water use of solar PV electricity, which may be due to the low water demand of PV systems during operation. A recent study by the International Energy Agency (IEA)[9] assessed the water consumption and water withdrawal of electricity generated by PV systems by considering all life cycle stages for the manufacture of monocrystalline silicon (mono-Si) and cadmium telluride (CdTe) PV modules, and by taking account of country-level regional differences in water availability.

12.6.20 This research found that: *"…The water consumption of electricity generated by mono-Si and CdTe PV systems amounts to 1.5 and 0.25 L/kWh, respectively. …The electricity demand in the production of mono-Si and CdTe PV modules is an important driver of the total water stress impact. …The water stress impact of process or cooling water used directly in the manufacture of PV modules amounts to 16 % for the mono-Si and 3 % for the CdTe technology, whereas the input materials contribute 2 % and 20 % to the water stress impact, respectively. Water consumption during operation of the European rooftop mono-Si and CdTe PV systems is negligible (<1 %).*"

12.6.21 In-line with the EIB (2023) methodology, the absolute operational emissions of the development will be "zero or minor absolute emissions except for hydropower with large reservoir storage". This is in relation to the operational energy use [lifecycle module B6]. Solar power, through the production of low carbon electricity, reduces the exploitation of fossil fuel (coal and natural gas)

provides a two-thirds likelihood of not exceeding 1.5°C heating is 400 GtCO_2; for an 87% likelihood it is 300 GtCO_2.

[9] P. Stolz, R. Frischknecht, G. Heath, K. Komoto, J. Macknick, P. Sinha, A. Wade, (2017), 'Water Footprint of European Rooftop Photovoltaic Electricity based on Regionalised Life Cycle Inventories.' IEA PVPS Task 12, International Energy Agency (IEA) Power Systems Programme, Report IEA-PVPS T12-11:2017.

by generating electricity from a renewable source. This development offsets the emissions associated with non-renewable methods of electricity generation and, therefore, mitigates the impact of climate change.

Decommissioning Phase

12.6.22 Emissions associated with decommissioning will largely be the equivalent to emissions associated with the construction phase, with broadly similar activities involved in removing the components from Site as required to install them. It is not possible to accurately predict the technological advancements that may occur before decommissioning phase takes place; there could well be considerable decarbonisation of vehicles and processes before that time. Assuming the decommissioning emissions are approximately equivalent to the construction phase emissions would represent a worst-case scenario. In this instance, these emissions are estimated within the embodied carbon figures provided.

Relative Emissions

12.6.23 Against the existing baseline, which is assumed to be zero, we end up in a scenario where the effects are based upon the total lifetime emissions from the solar farm. This gives a number that is hard to contextualise when considering effects on the climate. This baseline scenario does not acknowledge the displacement of fossil fuels that the Proposed Development is expected to bring about. It is, therefore, limited in its ability to accurately reflect the reality of emission reductions associated with deploying renewables. It shows zero operational emissions from the Proposed Development, but absolute emissions from the embodied carbon during manufacturing and construction set the project at a deficit of 362,850 tCO_2e over its lifecycle, which suggests a significant adverse impact. It is, therefore, preferable to assess the development against the future sectoral baseline (Baseline B) as described above and resulting in the more balanced assessment (presented below).

12.6.24 In this instance, it is more appropriate to consider the relative emissions of solar PV compared to natural gas generation rather than onshore wind power. This is because the solar PV generation is intended to be a replacement for natural gas generation, alongside the onshore wind generation. A comparison with onshore wind is provided for information purposes, but the principal intent of the Proposed Development is not to displace or directly compete with wind generation as both technologies are needed to help ameliorate the negative impacts of fossil fuel generation on the climate.

12.6.25 The emissions from the BESS have not been included in the calculation as the lifecycle emission factors for natural gas and onshore wind do not include BESS so would not be directly comparable.

12.6.26 Taking the natural gas scenario, the relative emissions are negative, therefore, showing a net reduction in whole lifecycle carbon emissions. These negative emissions have been determined to have a beneficial impact on climate change.

12.6.27 The emissions savings from using solar PV, instead of using natural gas over the lifetime of the project total approximately 9,070,400 tCO_2e, as shown in Table 12.6. This positive impact, derived from the negative Relative

Emissions, demonstrates the substantial lifetime emission savings associated with energy generated from the solar farm, compared to the equivalent amount of electricity supplied from natural gas.

Table 12.6: Total Emission Savings of the Proposed Development Compared to Natural Gas Equivalent

TOTAL EMISSION SAVINGS OF THE PROPOSED DEVELOPMENT COMPARED TO NATURAL GAS EQUIVALENT	
Baseline Emissions (tCO_2e)	9,433,250
Absolute Emissions (tCO_2e)	362,850
Relative Emissions (tCO_2e)	**-9,070,400**
Total Emission Savings (tCO_2e)	**9,070,400**

12.6.28 Compared to onshore wind, the Proposed Development represents an increase in total emissions. Total emissions are projected to be 93,329 tCO_2e higher over the lifetime of the solar farm compared to the equivalent wind generation as seen in Table 12.7.

12.6.29 Due to the restrictions imposed on onshore wind energy generation following the Written Ministerial Statement in 2015[10] and its subsequent integration into the NPPF, it is considered unlikely that planning for a wind farm would be permitted in England at this time.

Table 12.7: Total Emission Savings of the Proposed Development Compared to On Shore Wind Equivalent

TOTAL EMISSION SAVINGS OF THE PROPOSED DEVELOPMENT COMPARED TO ON SHORE WIND EQUIVALENT	
Baseline Emissions (tCO_2e)	269,521
Absolute Emissions (tCO_2e)	362,850
Relative Emissions (tCO_2e)	**93,329**
Total Emission Savings (tCO_2e)	**-93,329**

12.6.30 The Proposed Development is assessed to have a substantial beneficial impact on climate change when compared against natural gas.

12.7 Mitigation

12.7.1 Electricity production in the UK is a significant source of the UK's carbon emissions based on our current mix of technologies generating electricity at the utility scale. This development offsets the emissions associated with non-renewable methods of electricity generation and, therefore, mitigates the impact of climate change.

12.7.2 Emissions associated with the routine and periodic maintenance of the PV panels, electrical infrastructure and general site upkeep will be fairly limited but should still be minimised where practical to do so, generally by following

[10] House of Commons: Written Statement (HCWS42), Department for Communities and Local Government, Written Statement made by: Secretary of State for Communities and Local Government (Greg Clark) on 18 Jun 2015. Available at: https://www.parliament.uk/globalassets/documents/commons-vote-office/June-2015/18-June/1-DCLG-Planning.pdf [Accessed 30/08/2023].

the same approach as suggested in Paragraph **Error! Reference source not found.**.

12.7.3 No additional mitigation measures proposed at this stage.

12.8 Residual Effects

12.8.1 Residual effects are those effects of the Proposed Development that remain after any identified mitigation measures have been implemented.

Construction Phase

12.8.2 The Proposed Development will result in the short-term release of GHG emissions during construction (including embodied emissions), which has a long-term and permanent adverse effect contributing to global warming and climate change. The residual effects during construction are as assessed in Part A Section **Error! Reference source not found.** (Assessment of Effects), as being 362,850tCO_2e. This is considered to be a moderate adverse effect that is **significant**.

Operational Phase

12.8.3 The residual effects during operation of the Proposed Development, when compared to the generating technology it is most intended to replace, are as assessed in Part A Section **Error! Reference source not found.** Assessment of Effects. The emissions from the BESS increase the overall emissions from the project. However, it will also allow the project as a whole to offset much higher carbon generating assets such as gas peaking plant or diesel generation which is generally deployed when the grid is under stress. An emission saving of 9,070,400tCO_2e is predicted, when the renewable electricity generation is compared with a natural gas equivalent, which is considered to be a beneficial effect that is **significant**.

Overall Project

12.8.4 The lifetime emissions savings from solar generated energy result in an overall beneficial impact regarding GHG emissions; that being the negative emissions associated with the operational phase of the development counteract emissions created during construction and decommissioning of the Proposed Development. Overall, the Proposed Development is considered to have a negligible, **not significant** impact on climate change in that exceeds the requirements of the UK net zero trajectory but does not contribute to carbon reduction in all development phases. The IEMA guidance recognises this as a high bar and that the project will help to ensure the UK remains on track to achieve net zero by 2050 and the worst effects of climate change.

Monitoring

12.8.5 No formal monitoring is required.

12.9 Assessment of Cumulative Effects

12.9.1 It is considered that there is potential for cumulative Climate Change effects during the construction and operational phases of the Proposed Development, however a review of the other developments identified have been scoped out for the reasons as explained below.

Intra-Cumulative Effects

12.9.2 Intra-cumulative effects (i.e. climate change effects in combination with other environmental effects on a common receptor) are unrealistic to appraise. Climate change effects manifest as effects considered within other environmental disciplines, but do not have a quantifiable direct effect on local receptors. The effects act on a global receptor, but the individual contribution from a single development of this scale is almost indistinguishable. It is the cumulative effects from all the combined development going on around the world that poses the potential catastrophic threat.

Inter-Cumulative Effects

12.9.3 In terms of climate change, which is a global issue, comprehensive consideration of inter-cumulative effects (i.e. effects of this Proposed Development in combination with other developments) would need to account for every other development and activity that generates carbon emissions or releases other greenhouse gas effects. As this encompasses, to varying degrees, most of the activity on the globe, it is not practical to consider inter-cumulative effects beyond recognising that it is necessary for each development to reduce carbon emissions as well as having a duty to minimise its own emissions as far as technically viable.

12.9.4 It is unreasonable for the purposes of a planning application to quantify all sources of emissions from other third-party developments for the following reasons:

- Large technical data requirements from other developments are not accessible;
- It would require a huge interlinking scope of assessment that would exceed that expected of a planning application for any one development;
- It is not feasible to undertake a high-level chemical assessment to analyse likely synergistic impacts between different emissions from varying developments; and
- Complicated, unpredictable chemical reactions driven by atmospheric, climatic and behavioural factors are beyond the Applicant’s control.

PART B: ASSESSMENT OF CLIMATE CHANGE RESILIANCE

12.10 Extent of the Study Area

12.10.1 The impact of climate change on the proposed development is assessed based on global climate projections and regional climate projections for a 25 km grid surrounding the application site.

Assessment Methodology

12.10.2 Part B of the climate change assessment will apply the 2020 IEMA '*Environmental Impact Assessment Guide to: Climate Change Resilience and Adaptation*' guidance as this is the most recent available and is applicable to the UK.

12.10.3 The following guidance documents have also been used to inform both parts of the climate change impact assessment:

- European Commission, 'Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment' (2013);
- Royal Institution of Charted Surveyors (RICS), 'Whole life carbon assessment for the built environment' (1st Edition 2017, Draft 2nd Edition 2023); and
- BSI - PAS 2080:2023 'Carbon Management in buildings and infrastructure'.

12.10.4 The following methodology applies to the whole lifecycle of the Proposed Development.

12.10.5 In addition to an assessment of the potential impacts of a Proposed Development on climate, the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 also requires an assessment of a Proposed Development's vulnerability to climate change. This would ensure that the risk of the Proposed Development to climate change effects are identified and mitigated if required.

12.10.6 Assessing the vulnerability of the Proposed Development to the impacts of Climate Change varies from the assessment of impacts arising from the Proposed Development in other environmental aspects, since it focusses on the global impact of an external factor (climate change) on the Proposed Development, rather than the local impact of the Proposed Development on receptors in a confined geographical location.

Characterisation of impact

12.10.7 The resilience of the Proposed Development to future changes in climate is assessed using probabilistic climate projections for the region. The categorisation of this in relation to the following criteria is explained, below, by the following:

- Magnitude – For the purposes of determining the magnitude of effects of climatic variables on the Proposed Development, a combination of the probability and consequence of likely events are used.

- Probability – This takes into account the chance of the climatic effect occurring over the relevant time period (e.g. lifespan) of the Proposed Development and assesses the likely impact if the risk is not mitigated.
- Consequence – This reflects the geographical extent of the climatic effect, or the number of receptors affected (e.g. scale), the complexity of the effect, degree of harm to those affected and the duration, frequency and reversibility of effect.
- Duration and Timing – The duration and timing of a future climatic event would affect resilience.
- Frequency – When assessing the resilience of the Proposed Development to future climate, the frequency of projected events is used to determine the likelihood and consequence of impacts.
- Likelihood – Any form of activity or process will result in the release of GHGs to some degree. This includes activity associated with positive climate change action, such as the development of renewables or low carbon technology. the likelihood of future climate risks is determined by the level of probability. this assessment aims to consider how the inevitable impact of emissions is minimised and reduced, as well as how the resilience to future climate change is increased, in the design and planning of the Proposed Development.

Climate Scenarios and Timelines Considered

12.10.8 Climate change projections for the UK (UKCP18) are based on global climate simulation models to explore regional responses to climate change. UKCP18 considers the effects arising from a series of emissions scenarios and Representative Concentration Pathways (RCP), which project how future climatic conditions in the UK are likely to change at a regional level, taking account of naturally occurring climate variations. The RCPs show how the climate could change up to the year 2100, compared to a 1981-2000 baseline. The RCPs are probabilistic projections and provide a range of possible climate change outcomes and their relative likelihoods (ranging from the 10^{th} to 90^{th} percentiles).

12.10.9 The Proposed Development was assessed against a high (RCP 8.5) emissions scenario to allow for comparisons between best and worst-case across the 45-year reference period, which encompasses the construction, operational and decommissioning periods.

12.10.10 It is anticipated that the Proposed Development would be constructed between 2024 and 2027 and decommissioned in the 2060s. The UKCP18 climate projections for the 2030s (2030-2049) and 2050s (2050-2069) time periods have been selected to correspond with the proposed timescales for the Proposed Development’s construction and demolition, and operational phases.

12.10.11 The conservative approach recommended as best practice by the 2020 IEMA guidance is to use the central estimate (50^{th} percentile) for the high emissions scenario (RCP8.5) to establish the likely worst-case changes to climatic conditions.

Future climate baseline

12.10.12 This assessment considers the regional variations in Heckington, East of England during the periods identified above. A reference range is provided in each case, using the 10% probability level as a lower limit and the 90% probability level as an upper limit. These scenarios and probability levels were used to provide credible projected changes including an indicative level of uncertainty.

12.10.13 A summary of a range of projected changes to climate variables will be provided, which can be used to build up a holistic view of future climate and assess potential impacts. According to UKCP18, relative probabilities for specific outcomes are typically much higher near the 50% cumulative probability level (median) of the distribution, than for outcomes lying either below the 10% cumulative probability level or above the 90% cumulative probability level.

Climate Vulnerability and Sensitivity of Receptors

12.10.14 The resilience of the Proposed Development to climate change is assessed based on the susceptibility and vulnerability of a range on different receptors. Potential receptors within elements of the project relevant to the location, nature and scale of the development have been identified and receptor groups include the following:

- Buildings and infrastructure receptors (including equipment and building operations);
- Human health receptors (e.g., construction workers, occupants and site users);
- Environmental receptors (e.g., habitats and species); and
- Climatic systems.

12.10.15 The Design of Future Climate Report[11] published in 2010 identifies three broad risk categories to buildings from future climate change in the UK. These are:

- Risk to comfort and energy performance: warmer winters will reduce heating requirements, but the increased use of cooling systems in the summer will present a challenge to energy consumption and carbon emissions;
- Risk to construction: resistance to extreme conditions, detailing, and the behaviour of materials; and
- Risk to water management: management of water during both flooding and drought events, and changes in soil composition.

12.10.16 Combined, these categories can be considered climate change threats that could result in increased energy demands, economic losses, and losses of life.

12.10.17 The 2020 IEMA guidance describes the sensitivity of the receptor / receiving environment as "*the degree of response of a receiver to a change and a function of its capacity to accommodate and recover from a change if it is affected*". Therefore, in-line with the IEMA guidance, the following factors have

[11] Thompson, M., Cooper, I., & Gething, B. 2010. The business case for adapting buildings to climate change: niche or mainstream. Available at: BusinessCaseForAdaptingBuildings.pdf (arcc-network.org.uk) [Accessed 27h July 2023].

been considered to ascribe the sensitivity of receptors in relation to potential climate change effects:

- Value or importance of receptor;
- Susceptibility of the receptor (e.g., ability to be affected by a change); and
- Vulnerability of the receptor (e.g., potential exposure to a change).

12.10.18 The susceptibility and vulnerability of the receptor is determined using the scales detailed in Table 12.8, below.

Table 12.8: Measure of receptor susceptibility to climatic impact

MEASURE OF RECEPTOR SUSCEPTIBILITY TO CLIMATIC IMPACT	
Scale	**Susceptibility**
Low	Receptor has the ability to withstand or not be altered much by the projected changes to the existing/prevailing climatic factors.
Medium	Receptor has some limited ability to withstand or not be altered by the projected changes to the existing/prevailing climatic conditions.
High	Receptor has no ability to withstand or not be substantially altered by the projected changes to the existing/prevailing climatic factors.

12.10.19 Table 12.9 details the scale used to determine the vulnerability of the receptor.

Table 12.9: Measure of receptor vulnerability to climatic impact

MEASURE OF RECEPTOR VULNERABILITY TO CLIMATIC IMPACT	
Scale	**Vulnerability**
Low	Climatic factors have little influence on the receptors.
Medium	Receptor is dependent on some climatic factors but able to tolerate a range of conditions.
High	Receptor is directly dependent on existing/prevailing climatic factors and reliant on these specific existing climate conditions continuing in future or only able to tolerate a very limited variation in climate conditions.

Magnitude of Impacts

12.10.20 The magnitude assigned to the impact considers control mechanisms that may already be in place (e.g. due to legislation and commonly occurring standards), which would reduce the probability or the consequence of the impact and, therefore, the overall level of effect.

12.10.21 The IEMA guidance uses a combination of probability and consequence to reach a reasoned conclusion on the magnitude of the impact of climate change on the Proposed Development. The IEMA guidance states that magnitude is based on a combination of:

- Probability, which takes into account the chance of the impact occurring over the lifespan of the Proposed Development if the risk is not mitigated; and
- Consequence, which reflects the geographical extent of the impact, or the number of receptors affected (e.g. scale), the complexity of the impact, the sensitivity of receptors and the duration, frequency and reversibility of impact.

12.10.22 Definitions of likelihood and magnitude will vary between schemes and are tailored to the specific project. Project lifetime is considered to include demolition/construction and operational stages and a 'reference period' of 45 years has been taken for this assessment of climate risk, to ensure this fully encompasses the anticipated project lifetime of 40 years.

12.10.23 The guidance indicates that the greater the probability of an impact, the more likely it is to occur, meaning the magnitude of the impact on the Proposed Development will be greater if the projected changes in climate are not considered at the outset of the project.

12.10.24 A likelihood category is detailed in Table 12.10, which is based on the probability of the regional climate impact identified using the future climate baseline.

Table 12.10: Definitions of the likelihood of the climate impact effecting the receptors

DEFINITIONS OF THE LIKELIHOOD OF THE CLIMATE IMPACT EFFECTING THE RECEPTORS	
Likelihood Category	**Description (Probability and Frequency of Occurrence)**
Very High	The event occurs multiple times during the lifetime of the project (assumed 45 years), e.g. approximately annually, typically 45 events.
High	The event occurs several times during the lifetime of the project (45 years), e.g. approximately once every five years, typically 9 events.
Medium	The event occurs limited times during the lifetime of the project (45 years), e.g. approximately once every 20 years, typically 2 events.
Low	The event occurs during the lifetime of the project (45 years), e.g. once in 45 years.
Very Low	The event may occur once during the lifetime of the project (45 years).

12.10.25 From this, the consequence of impact is determined, as indicated in Table 12.11.

Table 12.11 Consequence of climatic impact and the description of varying consequence of impact on the receptor

CONSEQUENCE OF CLIMATIC IMPACT AND THE DESCRIPTION OF VARYING CONSEQUENCE OF IMPACT ON THE RECEPTOR	
Consequence of Impact	**Description of Impact**
Extreme Adverse	National-level (or greater) disruption lasting more than 1 week.
Major Adverse	National-level disruption lasting more than 1 day but less than 1 week. Or Regional-level disruption lasting more than 1 week.
Moderate Adverse	Regional-level disruption lasting more than 1 day but less than 1 week.
Minor Adverse	Regional-level disruption lasting less than 1 day.
Negligible	Isolated disruption to the immediate locality lasting less than 1 day.

Assumptions and Limitations

12.10.26 Using data provided by UKCP18, the RCP8.5 scenario is modelled and changes to such climate factors as temperature and precipitation are projected and assumed to occur over the next 80 years.

12.10.27 The 2020 IEMA guidance explains how climate is changing, but there remain uncertainties in the magnitude, frequency and spatial occurrence, either as changes to average conditions or extreme conditions, which generally makes it difficult to assess the impacts of climate change in relation to a specific project. Therefore, scientific assumptions must be made to assess the resilience of new developments to any future changes in climate.

12.10.28 Whilst the Applicant can implement measures to reduce the impacts and increase climate resilience according to global and regional climate projections with relevance to the scale of the Proposed Development, uncertainties associated with probabilistic climate projections are outside of the Applicant's control and cannot be fully mitigated against.

12.10.29 This assessment relies on data provided by third parties with other technical disciplines providing information regarding the embedded mitigation to determine the development's resilience to climate change. Therefore, WA accepts no responsibility for inaccuracies carried forward from third party information.

12.10.30 Currently only climate projections are available to help understand the likely future weather conditions, and these follow a range of different scenarios. A current 'worst-case' scenario has been adopted for this assessment. This will be especially important in the event that there is any deviation from the projected patterns or increased volatility in the system that risks compromising the Proposed Development's climate resilience.

Significance Criteria

12.10.31 The IEMA (2020) guidance indicates that the greater the probability of a climatic effect, the more likely it is to occur, meaning that the consequence of impacts is likely to be high, and the magnitude of the effect(s) on the Proposed Development will be greater, if these projected changes in climate are not considered at the outset of the project.

12.10.32 The magnitude of effects of climate change impacts on the Proposed Development is determined using the Significance Matrix for Assessing Climate Resilience (Table 12.2), and then an associated level of significance is applied for the Proposed Development as also indicated in Table 12.12, below.

Table 12.12: Significance Matrix for Assessing Climate Resilience

SIGNIFICANCE MATRIX FOR ASSESSING CLIMATE RESILIENCE						
Climate Resilience Significance Matrix		Measure of Likelihood				
		Very Low	Low	Medium	High	Very High
Measure of Consequence (Impact)	Negligible	Negligible (Not Significant)	Negligible (Not Significant)	Negligible (Not Significant)	Minor Adverse (Not Significant)	Minor Adverse (Not Significant)
	Minor	Negligible (Not Significant)	Minor Adverse (Not Significant)	Minor Adverse (Not Significant)	**Moderate Adverse (Significant)**	**Moderate Adverse (Significant)**
	Moderate	Minor Adverse (Not Significant)	Minor Adverse (Not Significant)	**Moderate Adverse (Significant)**	**Moderate Adverse (Significant)**	**Moderate Adverse (Significant)**
	Major	Minor Adverse (Not Significant)	**Moderate Adverse (Significant)**	**Moderate Adverse (Significant)**	**Major Adverse (Significant)**	**Major Adverse (Significant)**
	Extreme	Minor-Moderate Adverse (Not Significant)	**Moderate Adverse (Significant)**	**Moderate-Major Adverse (Significant)**	**Major Adverse (Significant)**	**Major Adverse (Significant)**

12.11 Baseline Conditions

Current Baseline Conditions

12.11.1 England is classified under Köppen Geiger as having a ‘Cfb’ climate, more commonly known as a ‘temperate oceanic climate’. These are typically mid-latitude climates with warm summers and mild winters. The average temperature in all months will be below 22°C and there is not an identifiable dry / wet season (i.e. precipitation rates are similar year-round). The mean average annual temperature in England is approximately 9°C. Within the region, significant variations in temperature arise from the combined effects of proximity to the coast, topography and, to a lesser extent, urban development.

12.11.2 The Solar Array Area is located in an area to the east of Sleaford and to the north of Heckington, in the East of England. The Solar Array Area lies within the administrative area of North Kesteven District, Lincolnshire. The average temperature in this area is 14.4°C with an average rainfall of 594 millimetres (mm) per year[12].

[12] Coningsby (Lincolnshire) UK climate averages - Met Office. [Accessed 30 August 2023].

Climate Change Projections

12.11.3 The global Climate Change issues that will affect the resilience of a development within the UK are listed in Table 12.13.

Table 12.13: Projected Global Impacts of Climate Change

PROJECTED GLOBAL IMPACTS OF CLIMATE CHANGE	
Climate Change Issue	**Projected Global Impacts**
Solar Radiation	Long-term projected changes in surface solar radiation, because of global warming, would suggest a decrease in available solar power due to a decrease in downwelling shortwave radiation, likely linked to the increase of water vapour and hence cloud presence. Anthropogenic strengthening of 'natural' decadal variability in irradiance, known as global dimming and brightening, is influenced by synoptic weather patterns, cloud variations and atmospheric aerosols.
Increased Global Mean Surface Temperature (GMST)	As stated within Intergovernmental Panel on Climate Change (IPCC) Special Report[13], "*The increase GMST, which reached 0.87°C in 2006–2015 relative to 1850–1900, has increased the frequency and magnitude of impacts".* This strengthens the evidence of how a 1.5°C increase or more, in GMST, could impact natural and human systems.
Heat Waves	The IPCC predict that temperature extremes will increase more rapidly than global mean surface temperature, with the number of hot days projected to increase in most land regions. In the 1.5°C warming scenario heat waves in mid latitudes could warm by up to 3°C.
Extreme Rainfall and Flooding	IPCC and Met Office both suggest a general uncertainty in the projection of changes in heavy precipitation for the UK due to position in the transition zone between north and south Europe's contrasting projected changes. It is generally agreed that Northern Europe is one of the regions that will experience the largest increase in heavy precipitation events for 1.5°C to 2°C warming. Overall, the UK is expected to see a general increase in precipitation trends up to the year 2100. With slightly wetter winters and drier summers expected to occur annually during the project lifetime.
Storms and Winds	Atmospheric circulations have large variability across interannual through to decadal time scales, which makes forming projections with any reasonable confidence very difficult. There is more robust evidence in the Northern Hemisphere that, since the 1970s, there has been a general poleward shift of storm tracks and jet streams and near-surface terrestrial wind speeds have been declining by approximately 0.1-0.14 ms^{-1} per decade across land. Despite anemometers being used for decades to measure near surface wind speed, the data has rarely been used to analyse trends and lacks important instrumentation meta data. In general, confidence is low in wind speed projections due to large uncertainties across global data sets.
Cold Spells and Snow	It has been observed the spring snow cover has been continuing to decrease in extent in the Northern Hemisphere and that cold temperature extremes are projected to decrease along with the number of frost days.

Regional Climate Change Projections

12.11.4 Climate change projections for the UK (UKCP18) are based on global climate simulation models to explore regional responses to climate change. UKCP18 considers the effects arising from a series of emissions scenarios and RCP, which project how future climatic conditions in the UK are likely to change at

[13] Intergovernmental Panel on Climate Change (IPCC). 2018. *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

a regional level, taking account of naturally occurring climate variations. Probabilistic projections provide a range of possible climate change outcomes and their relative likelihoods (ranging across 10th to 90th percentiles).

12.11.5 The UKCP18 dataset provides future climate change projections for land and marine regions, as well as observed climate data for the UK. Analysing time series plume data from UKCP18 provides an indication of climate projections for the regional 25km grid that encompasses the Site.

12.11.6 The following graphs are based on the four RCPs and show how the climate at Beacon Fen could change up to the year 2100, compared to a 1981-2000 baseline. The RCPs are used to analyse how different emission scenarios could affect climate projections. These range from RCP2.6 where atmospheric emission concentrations are strongly reduced through to the worst-case scenario, RCP8.5, where emission concentrations continue to rise unmitigated.

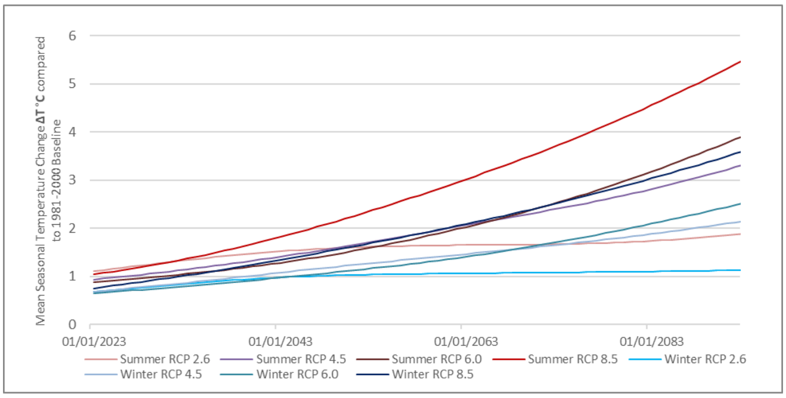

Figure 12.2: Projected changes in mean seasonal air temperature across four RCP scenarios, from 2023 - 2100 compared to the 1981 - 2000 baseline, using the probabilistic projections (50th Percentile)

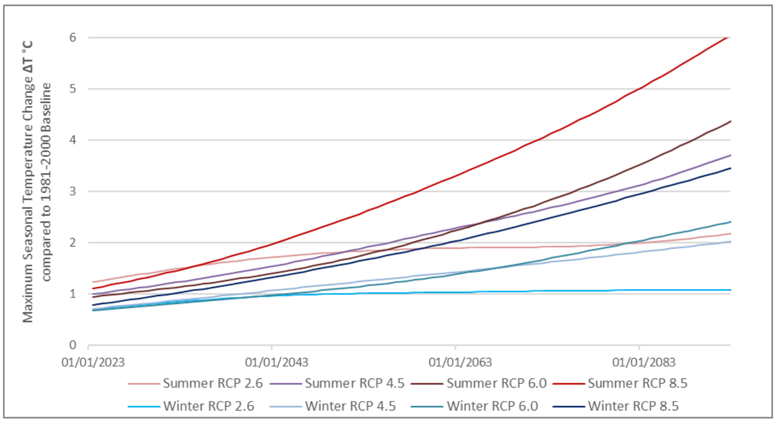

Figure 12.3: Projected changes in maximum seasonal air temperature across four RCP scenarios, from 2023 - 2100 compared to the 1981 - 2000 baseline, using the probabilistic projections (50th Percentile)

12.11.7 Figure 12.2 and Figure 12.3 show that the temperature is set to rise in summer and winter, even in a best-case scenario (RCP2.6), until the end of the century. Over the 45-year reference time period, the average temperature rise (Figure 12.1) could be between 1.66°C (RCP2.6) and 3.43°C (RCP8.5) in the summer; and 1.08°C (RCP2.6) and 2.35°C (RCP8.5) in the winter. By 2069, maximum temperatures (Figure 12.2) could increase between 1.91°C (RCP2.6) and

3.8°C (RCP8.5) in the summer; and 1.05°C (RCP2.6) and 2.31°C (RCP8.5) in the winter.

12.11.8 Figure 12.4, below, shows that summer precipitation rates are reducing over the 45-year reference time period, from between -19.96 mm (RCP2.6) to -30.6 mm (RCP8.5). Climate projections suggest that winter precipitation rates will increase from between 6.54mm (RCP2.6) to 12.69mm (RCP8.5) by 2069.

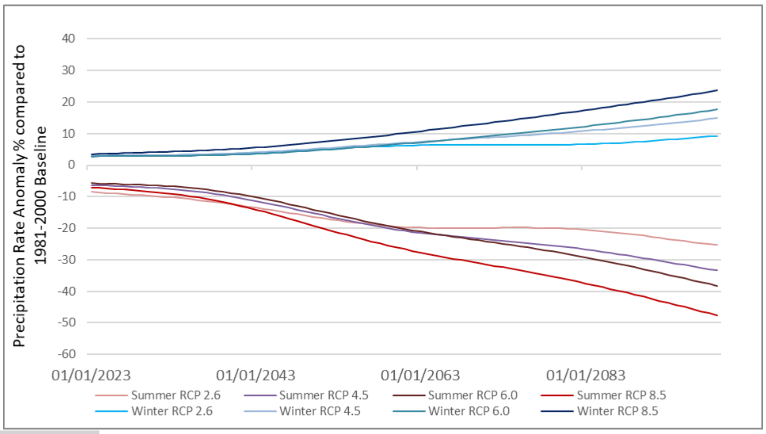

Figure 12.4: Projected changes in seasonal precipitation rate (%) across four RCP scenarios, from 2023 - 2100 compared to the 1981 - 2000 baseline, using the probabilistic projections (50th Percentile)

Future Baseline Conditions

12.11.9 A summary of a range of projected changes to climate variables is provided in Table 12.14, which can be used to build-up a holistic view of future climate and assess potential impacts to determine a future climate baseline.

Table 12.14 Quantitative summary of the future baseline for key climatic variables in Beacon Fen, Lincolnshire, UK

QUANTITATIVE SUMMARY OF THE FUTURE BASELINE FOR KEY CLIMATIC VARIABLES IN BEACON FEN, LINCOLNSHIRE, UK			
Season	**Variable**	**Time period**	**Projected change at 50th percentile**
Winter	**Mean Temperature (ºC)**	2030s	0.99
		2050s	1.58
		2070s	2.38
	Mean Precipitation (%)	2030s	4.23
		2050s	7.12
		2070s	12.88
Summer	**Mean Temperature (ºC)**	2030s	1.33
		2050s	2.19
		2070s	2.49
	Mean Precipitation (%)	2030s	-9.00
		2050s	-18.8
		2070s	-30.8

12.11.10 The future climatic impacts that may occur as a consequence of projected future climate baseline conditions are detailed in Table 12.15, below.

According to a study[14], photovoltaic systems are vulnerable to hail, wind, and extreme temperatures.

12.11.11 Table 12.15 discusses how the climatic factors will affect various receptors during the development's operational phase.

Table 12.15: Potential Impacts on Proposed Development

POTENTIAL IMPACTS ON PROPOSED DEVELOPMENT			
Climatic Factor	**General Impact**	**Receptors**	**Component/Sub Structure Impact**
Increase in temperature	Increases in average and maximum annual temperature will affect efficiency of PV modules and potentially the operation of the Proposed Development.	Solar PV array structure, Battery energy Storage System (BESS), substations, customer cabin and onsite electrical equipment.	Higher temperatures may cause overheating of mechanical and electrical equipment affecting lifespan, reliability and potential maintenance and safety issues. Some studies[15] have shown that high temperatures can impact solar output; *"Solar cell output typically decreases by about 0.5% (most crystalline cells) for each temperature rise of 1°C"*[16].
Extreme Rainfall and Flooding	Increase and decrease will affect water tables and durability of the PV system and substations. Flood risk for surrounding infrastructure / buildings.	Solar PV array structure	Maintenance costs may be increased in winter, with associated cleaning requirements. Durability and risk of water ingress will be affected by combination of precipitation increase and gales.
		Substations, BESS, customer cabin and onsite electrical equipment.	Water may impact electrical elements of PV infrastructure. Flooding risk for customer cabin.
Solar Radiation	Reduced amount of shortwave radiation received at the ground	Solar PV modules.	Reduced amount of direct sunlight that the modules utilise for the provision of energy that is converted into electricity.
Snow and Ice	Increase will affect productivity of the PV system and BESS.	Solar PV modules, BESS	Solar farms are not especially vulnerable to cold temperatures although should snow cover the panels then generation would be reduced or prevented. The panels are mounted at an angle to the horizontal which would aid in snow sliding from the panels. Climate change projects are not expected to have a material effect on the solar farm's operational ability.
Gales, Storms, Extreme Weather	Increase will affect the stability and productivity of the array structure and surrounding infrastructure, which	Solar PV array structure, BESS, substations, customer cabin and	Static loading calculations will be analysed for the site, including a margin for error, to ensure the framework and panels remain fixed in position during strong wind events.

[14] Patt, A., S. Pfenninger, and J. Lilliestam. 2010. Vulnerability of solar energy infrastructure and output to extreme events: Climate Change implications. http://africabusiness.com/2010/11/30/vulnerability-of-solar-energy-infrastructure-and-output-to-extreme-eventsclimate-change-implications/. [Accessed 30 August 2023].
[15] Patt, A., Pfenninger, S., Lilliestam, J. 2013. Vulnerability of solar energy infrastructure and output to climate change. Climate Change 121 pp93-102.
[16] ADB. 2012. Climate Risk and Adaptation in the Electric Power Sector. Available at: Climate Risk and Adaptation in the Electric Power Sector (adb.org).

POTENTIAL IMPACTS ON PROPOSED DEVELOPMENT			
Climatic Factor	**General Impact**	**Receptors**	**Component/Sub Structure Impact**
	will affect efficiency of the system.	onsite electrical equipment.	
Cloud Cover	Increase/decrease in Solar PV efficiency.	Solar PV modules	Clouds affect the number of sunshine hours and hence the amount of solar irradiance reaching the earth's surface which the PV modules utilise for the production of energy. Research[16] states that "*during cloud cover, solar photovoltaic panel output can decrease by 40%–80% within a few seconds, increasing just as dramatically when the sky clears. For large arrays, this rapid fluctuation can cause localized voltage and power quality concerns because shading of one panel affects the entire array connected to a single inverter.*"

12.12 Assessment of Effects

Embedded Mitigation

12.12.1 Research[17] findings suggest that climate change may enhance the weather variability and, therefore, increase the power intermittency generated from the solar PV system. Research states that future climate change (as modelled under the RCP4.5 scenario) will change the frequency of weather conditions and increase average temperatures, which may lead to very low PV power outputs. The efficient operation of the BESS requires a limited temperature range with extreme heating or cooling affecting the performance of the system[18].

12.12.2 At the end of the 45-year reference time period, temperatures within the RCP8.5 scenario are projected to increase by 3.8°C.

12.12.3 Typically, the temperature coefficient of solar panels is around a 0.4% decrease per degree. With the projected 3.8°C increase of the RCP8.5 scenario, it can be expected that the power efficiency will reduce by a maximum of 1.52% by the end of the project lifetime.

12.12.4 Therefore, the impact of increased temperature from the projected climatic changes of a RCP8.5 scenario on the efficiency of the panels is negligible.

12.12.5 The panels are proposed to be a maximum of 4.5 m above ground. This will allow for sufficient air flow beneath the mounted structure and reduce heat gain. This will reduce the impact of increasing temperature on output efficiency. With less than a 1.2% change in efficiency and air ventilation, the impact of increased temperature on Proposed Development is minor.

[17] Feron, S., Cordero, R. R., Damiani, A., and Jackson, R. B. 2021. Climate Change extremes and photovoltaic power output. *Nature Sustainability.* Vol 4, pp 270 276.
[18] https://ieeexplore.ieee.org/document/9998028. [Accessed 30 August 2023].

12.12.6 The risk of flooding to areas downstream of the site may increase as a result of development due to an increase in impermeable area and an increase in rainfall intensity (i.e. climate change) resulting in increased rates and volumes of surface water runoff. To mitigate this increased risk, it is proposed that surface water runoff from the development is managed in a sustainable manner and in accordance with Environment Agency and LLFA guidelines.

12.12.7 A surface water management plan for the site is proposed. This aims to mimic the existing greenfield characteristics of the site, with surface water discharges restricted to Greenfield rates for all storm events up to and including the 1 in 100 year event, including an allowance for climate change.

12.12.8 Areas of the Site are shown to be at risk of flooding from fluvial, surface water and artificial sources. Similarly, climate change and increases in impermeable area are likely to result in increased surface water runoff rates and volumes.

12.12.9 There is always a possibility that the design standards of any proposed flood risk management measures will be exceeded by an extreme storm event. As any mitigation will be designed in accordance with the EA guidelines, it is considered that the residual risk will be minimal.

12.12.10 Further flood modelling will confirm whether it is necessary to raise ground levels within the site area to help protect sensitive electrical equipment. If the capacity of any proposed drainage features is exceeded during an extreme storm event exceeding the design return period, it is considered that exceedance flows would follow the existing topography with no risk to areas previously unaffected by surface water flooding. Where these routes extend beyond the site boundaries, this would impact agricultural land only with no risk to dwellings or developed areas.

12.12.11 The Site benefits from fluvial flood defences along Hodge Dike and Car Dyke. The condition of the earth embankments is generally shown to be 'Fair' in the EA data.

12.12.12 Key points are noted below regarding mitigation measures that have been designed into the Proposed Development for certain receptors and climate variables are outlined below:

- Structures are strong enough to withstand higher winds;
- Design improves passive airflow beneath PV mounting structures, reducing panel temperature and increasing power output; and
- Modules have heat-resistant PV cells and module materials designed to withstand short peaks of very high temperature.
- With the proposed embedded mitigation, it is considered that the proposed mitigation features will be sufficient in ensuring that the Proposed Development is resilient to increased flood risk with climate change.

Assessment of Effects

Construction Phase

12.12.13 At more localised levels, the effects of climate change can manifest in different ways and, therefore, the most appropriate strategies should be selected on a site-specific basis. A coastal village may be at most risk from sea-level rises and storm surges, while at inland locations, the threat of heat waves or high winds might be more significant. Adaptation involves developing resilience and preparedness to deal with the likely consequences of climate change. The Proposed Development needs to consider and mitigate against the likely impacts of increased overheating events in summer months and intense precipitation events in winter.

12.12.14 Overall, the impact of the proposed changes to climatic factors, as seen in the future climate baseline, for the construction phase of the Proposed Development is determined to be of very low likelihood and, therefore, Negligible (i.e. consequences for receptors within the construction phase). In this assessment, this refers to the impact of climatic effects on construction workers; the only receptor existing solely within the construction phase. The overall magnitude of the climatic impacts on receptors within the construction phase is **Negligible** and the effect would be **Not Significant**.

Operational Phase

12.12.15 The results of the assessment of the susceptibility and vulnerability of receptors existing within the operational phase are given in Table 12.16, below.

Table 12.16: Assessment of Susceptibility and Vulnerability of the Proposed Development during the operational phase to Future Climate Baseline

ASSESSMENT OF SUSCEPTIBILITY AND VULNERABILITY OF THE PROPOSED DEVELOPMENT DURING THE OPERATIONAL PHASE TO FUTURE CLIMATE BASELINE				
Climate Change Issue	**Receptors Impacted**	**Susceptibility *(Low / Medium / High)***	**Vulnerability *(Low / Medium / High)***	**Likelihood**
Temperature	Array structure, substations, BESS and customer cabin	Low	Low	Low
Precipitation		Low	Medium	Low
Snow and Ice		Low	Low	Very Low
Gales, Storms, Extreme Weather		Low	Medium	Low
Solar Radiation		Low	Medium	Very Low
Cloud Cover		Low	Low	Low

12.12.16 The level of likelihood for the climate change issue was also identified according to the future climate baseline outlined in 12.11.9. The proposed mitigation measures are considered within the analysis of likelihood.

Magnitude of Impacts

12.12.17 The level of consequence considers the likelihood of the event occurring and both the value and sensitivity of the receptor to the climatic impact. The latter has been determined based on the susceptibility and vulnerability of the receptor to the various climatic impacts.

Table 12.17: Assessment of Magnitude of Impact on the Proposed Development from Future Climate Baseline

ASSESSMENT OF MAGNITUDE OF IMPACT ON THE PROPOSED DEVELOPMENT FROM FUTURE CLIMATE BASELINE			
Climate Change Issue	**Likelihood**	**Consequence**	**Magnitude of Effects**
Temperature	Low	Minor Adverse	Minor Adverse
Precipitation	Low	Minor Adverse	Minor Adverse
Snow and Ice	Very Low	Minor Adverse	Minor Adverse
Gales, Storms and Extreme Weather	Low	Minor Adverse	Minor Adverse
Solar Radiation	Very Low	Minor Adverse	Minor Adverse
Cloud Cover	Low	Minor Adverse	Minor Adverse

12.12.18 The impact of changes to the future climate baseline for the Proposed Development during the operational phase (summarised in Table 12.17) has been assessed to be of low or very low likelihood and minor consequences with the consideration of embedded mitigation.

Significance Matrix

12.12.19 In-line with the IEMA guidance, the significance matrix is used to reach a reasoned conclusion on the magnitude of the impact of climate change on the Proposed Development, as shown in Table 12.12, is based on a combination of the probability (which considers mitigation) and consequence (which considers the receptor sensitivity) of the climate change impact on the Proposed Development.

Table 12.18: Assessment of Significance

ASSESSMENT OF SIGNIFICANCE		
Climate Change Issue	**Level of Effect**	**Significance**
Temperature	Minor Adverse	Not Significant
Precipitation	Minor Adverse	Not Significant
Snow and Ice	Minor Adverse	Not Significant
Gales, Storms and Extreme Weather	Minor Adverse	Not Significant
Solar Radiation	Minor Adverse	Not Significant
Cloud Cover	Minor Adverse	Not Significant

Decommissioning Phase

12.12.20 Activities carried out during the decommissioning phase will likely mirror the construction phase but the climate may have altered substantially during the intervening period. Although weather during the decommissioning phase may be more erratic and volatile than during construction, the process will be short and temporary and, provided suitable planning is made to ensure site safety during this time, there are not expected to be any excessive risks. The overall magnitude of the climatic impacts on receptors within the decommissioning phase is **Negligible** and the effect would be **Not Significant**.

12.13 Mitigation

12.13.1 As the embedded mitigation measures demonstrate the level of effects as minor adverse and not significant, no additional mitigation measures are required.

12.14 Residual Effects

12.14.1 According to the IPCC 2018 Special Report on Global Warming of 1.5°C, there is high confidence that climate-related risks for natural and human systems depend on the magnitude and rate of warming, geographic location, levels of development and vulnerability, and on the choices and implementation of adaptation and mitigation options. The report states: "*Pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems (high confidence). These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options (medium confidence)*".

12.14.2 The Applicant can implement the measures above to reduce the impacts and increase climate resilience according to global and regional climate projections, but uncertainties associated with probabilistic climate projections are outside of the Applicant's control and cannot be fully mitigated against.

12.14.3 Over the 40-year operational lifetime of the Proposed Development, there is the potential to generate 21,735.6 GWh of renewable electricity, which saves 9,070,400 tCO_2e (after embodied carbon payback) from the equivalent energy sourced from the natural gas.

12.14.4 Solar power, through the production of low carbon electricity, reduces the exploitation of fossil fuel (coal and natural gas) by generating electricity from a renewable source. This development offsets the emissions associated with non-renewable methods of electricity generation and therefore mitigates the impact of climate change.

12.14.5 The residual effects remain as per those identified in the assessment of effects sections above. The Proposed Development is considered to have a **minor adverse** and **not significant** impact on climate change when compared against the most realistic alternative of natural gas.

12.15 Assessment of Cumulative Effects

Intra-Cumulative Effects

12.15.1 Intra-cumulative effects (i.e. climate change effects in combination with other environmental effects on a common receptor) are also unrealistic to appraise. Climate change effects manifest as effects considered within other environmental disciplines, but do not have a quantifiable direct effect on local receptors. The effects act on a global receptor, but the individual contribution from a single development of this scale is almost indistinguishable. It is the cumulative effects from all the combined development going on around the world that poses the potential catastrophic threat.

Inter-Cumulative Effects

12.15.2 In terms of climate change, which is a global issue, comprehensive consideration of inter-cumulative effects (i.e. effects of this Proposed Development in combination with other developments) would need to account for every other development and activity that generates carbon emissions or releases other greenhouse gas effects. As this encompasses, to varying degrees, most of the activity on the globe it is not practical to consider inter-cumulative effects, beyond recognising that it is necessary for each development to reduce carbon emissions as well as having a duty to minimise its own emissions as far as technically viable.

12.15.3 It is unreasonable for the purposes of a planning application to quantify all sources of emissions from other third-party developments for the following reasons:

- Large technical data requirements from other developments are not accessible;
- It would require a huge interlinking scope of assessment that would exceed that expected of a planning application for any one development;
- It is not feasible to undertake a high-level chemical assessment to analyse likely synergistic impacts between different emissions from varying developments; and
- Complicated, unpredictable chemical reactions driven by atmospheric, climatic and behavioural factors are beyond the Applicant's control.

12.16 Summary

12.16.1 In terms of the Proposed Development's resilience to climate change, the consequence of climatic impacts on the solar farm and BESS is low based on the sensitivity of the receptors to various climatic factors.

12.16.2 The likelihood of the climatic impact on the Proposed Development occurring is also low. This assessment considers the embedded mitigation measures, particularly those associated with enhancing the resilience of the development to increased temperature and precipitation that is expected to occur with climate change.

12.16.3 The combination of consequence and likelihood determined a **minor adverse** effect from various climatic impacts on the Proposed Development. From this, the level of the effect has been assessed as **Not Significant**.

12.16.4 With embedded mitigation in place, the Proposed Development is deemed to be resilient to climate change impacts, even those within the RCP8.5 scenario that are proposed to occur over the 45-year project lifetime.

12.16.5 A summary of the likely significant residual effects of the Proposed Development on the receptors considered within this chapter are summarised in Table 12.19 below.

BEACON FEN ENERGY PARK

Table 12.19: Discipline - Summary Assessment Matrix

ISSUE	DESCRIPTION OF IMPACT	GEOGRAPHICAL SIGNIFICANCE							IMPACT	NATURE	SIGNIFICANCE	MITIGATION MEASURES
		I	N	R	C	D	P	L				
Climate Change												
Greenhouse Gas (GHG) Emissions	Construction: Project lifecycle modules A1 through to A5	X							Moderate Adverse	Lt, Ir	Significant	Mitigation may include, inter alia: • Sourcing materials locally where possible to reduce transport miles; • Identifying lower carbon options as part of any procurement process where technically and economically viable to do so; • Using local employees and contractors where possible to reduce travel requirements; • Using more efficient, modern construction vehicles and equipment where available; • Using low carbon fuels as far as possible (electric vehicles, blends of biodiesel etc); Reusing materials, minimising waste and recycling where possible
	Operation: Project lifecycle modules B1 (Use) through to B7 (operational water use) and includes the operational energy use [B6]	X							Beneficial	Lt, Ir	Significant	Electricity production in the UK is a significant source of the UK's carbon emissions based on our current mix of technologies generating electricity at the utility scale. This development offsets the emissions associated with non-renewable methods of electricity generation and therefore mitigates the impact of climate change.
	Decommissioning: Assuming the decommissioning emissions are approximately	X							Moderate Adverse	Lt, Ir	Significant	Assuming no big technological breakthroughs in work practice,

	equivalent to the construction phase emissions would represent a worst-case scenario											machinery or equipment use over the life of the project, similar emissions will be recorded. However, over the extended project lifetime it is highly likely that there will be some (or many) technological improvements and hence greater mitigation options available

Key:
Geographical Significance: I = International N = National R = Regional C = County D = District P = Parish L = Low to Local
Nature*:* St = Short Term Mt = Medium Term Lt = Long Term R = Reversible Ir = Irreversible

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