Proposed Solar PV Development

Byers Gill Solar
EN010139

8.16 Comments on Deadline 3 Submissions

Planning Act 2008

APFP Regulation 5(2)(q)

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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RWE
14 Bird Street
London
W1U 1BU
United Kingdom
www.rwe.com

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1. Introduction

1.1. Purpose of this document

1.1.1. This document provides comments from RWE (the Applicant) on submissions made by Interested Parties at Deadline 3 (19 September 2024) of the Examination of Byers Gill Solar (the Proposed Development). Submissions by Interested Parties at Deadline 3 were limited in number, and primarily relate to comments on the Applicant's response to the first written questions (ExQ1), and other submissions made at Deadline 2.

1.1.2. This document also provides an update on matters discussed at earlier Deadlines, where there has been progression since the submissions made at that time, and where this falls outside of the Statement of Common Ground (SoCG) process.

2. Comments on Deadline 3 Submissions

2.1.1. The table below provides the Applicant's comments on submissions made at Deadline 3. This sets out the document that was submitted at Deadline 3, the Interested Party that submitted the document, and a summary of the content that the Applicant wishes to comment on, before providing the Applicant comment.

2.1.2. The Applicant has sought to summarise only the parts of any submission that it wishes to comment on. As such, elements of any submission to which the Applicant has no response are not included in the below table.

Table 2-1 Applicant comments on submissions at Deadline 3

Examination Library Reference	Interested Party	Summary	RWE Response
REP3-013	Environment Agency	The EA provided comment on the updated DCO submitted at Deadline 2 [REP2-030]. The EA request that Requirement 4 is amended to define that commencement includes remedial work in respect of contamination or other adverse ground conditions, and site clearance (including vegetation removal, demolition of existing buildings and structures).	The Applicant notes the Environment Agency's (EA) request for site preparation works to be included as commencement works and for Requirement 4 of the draft DCO [REP2-029] to be amended regarding this. The Applicant is considering this matter and will provide an update a future deadline, anticipated to be Deadline 5.
REP3-013	Environment Agency	The EA acknowledges the modification to Article 7b and Schedule 11, Part 4 of the draft DCO submitted at Deadline 2 [REP2-030] to remove the disapplication of Regulation 12 (requirement for Environmental Permit) of the Environmental Permitting (England and Wales) Regulations 2016(a), and removal of EA Protective Provisions, respectively.	The Applicant and the EA are now agreed on these matters. This will be reflected in the updated Statement of Common Ground (SoCG) with the EA anticipated to be submitted at Deadline 7.
REP3-013	Environment Agency	The EA welcome changes to Requirement 4 (CEMP) and Requirement 8 (Materials Management) of the draft DCO submitted at Deadline 2 [REP2-030] to require consultation with the EA.	The Applicant and the EA are now agreed on these matters. This will be reflected in the updated Statement of Common Ground (SoCG) with the EA anticipated to be submitted at Deadline 7.
REP3-013	Environment Agency	The EA requests amendments to Requirement 4(2) to capture the commitment in the Outline Construction Environment	The Applicant and the EA are now agreed on these matters. This will be reflected in the updated Statement of Common

Examination Library Reference	Interested Party	Summary	RWE Response
		Management Plan (CEMP) [APP-110] regarding an impact assessment and appropriate mitigation in relation to Directional Drilling.	Ground (SoCG) with the EA anticipated to be submitted at Deadline 7.
REP3-013	Environment Agency	The EA requests amendments to Requirement 4(2) to capture the commitment in the Outline Construction Environment Management Plan (CEMP) [APP-110] regarding an impact assessment and control measures in relation to groundwater / surface water interaction concerns.	The Applicant and the EA are now agreed on these matters. This will be reflected in the updated Statement of Common Ground (SoCG) with the EA anticipated to be submitted at Deadline 7.
REP3-013	Environment Agency	The EA stated that it has not reviewed the updated FRA submitted at Deadline 2 [REP2-014] as further information was shared for review on 5 September 2024, which is under review.	Since Deadline 3, the EA and the Applicant has engaged regarding a further updated FRA and flood modelling. As discussed as the Issue Specific Hearing 3 on 15 October 2024, the EA has confirmed that it has no comment on these documents and they are now agreed. This is further reflected via a written update to the Applicant on 16 October 2024, that the EA do not have any comments to raise with regards to the model construct or calculated flows. The EA have confirmed that they are "*happy that the solar panel support frames would not increase flood risk off-site where they are placed in areas that flood (only area D02). [They] were also happy that the solar panels would be raised sufficiently to be above the 1 in 100 year plus higher central climate change level.*" The updated Flood Risk Assessment and Drainage Strategy (Document Reference 6.4.10.1, Revision 4) and Little Stainton Beck Hydraulic Modelling Technical Note (Document Reference 8.18) are provided at Deadline 4. The agreement on these matters will be reflected in the updated Statement of Common Ground (SoCG) with the EA anticipated to be submitted at Deadline 7.

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REP3-013	Environment Agency	The EA included a 'Work Package Tracker' under REP3-013 which set out the EA position on matters discussed to date with the Applicant.	Some of the points in the Work Package Tracker duplicate those considered above, and therefore are not commented on, however those that are not otherwise repeated in REP3-013 are commented on below.
REP3-013	Environment Agency	Under Row 1 of the Work Package Tracker, further updates to the outline CEMP [APP-110] regarding mitigation and management measures for otters are requested.	The Applicant has accepted that additional control should be included within the outline CEMP to address this concern, which will be included in the next iteration of that document to be submitted to examination and has been committed to via the ES Errata and Management Plans Proposed Updates [REP2-012].
REP3-013	Environment Agency	Under Row 3 of the Work Package Tracker, an updated Water Framework Directive (WFD) Assessment is requested to be updated to demonstrate that directional drilling will not adversely affect WFD status.	The Applicant intends to submit an updated WFD at a future deadline. The final construction solution for the cable routes has not been finalised as it requires both the selection of a preferred cable corridor, as well as the appointment of a contractor who would wish to review the construction methods. At this stage, it is not considered that HDD works would take place within 10m of a watercourse. The Outline CEMP [APP-110] contains a commitment for further engagement with the EA for the final design of watercourse crossings, including any further survey or management requirements, which will be agreed with the EA as part of Requirement 4 of the DCO [REP2-029]. The Applicant is confident that there would not be any adverse impacts on the WFD waterbodies.
REP3-013	Environment Agency	Under Rows 5-10 of the Work Package Tracker, the EA provide comment relating to flood risk assessment, including the Sequential Test and Exception Test.	Since Deadline 3, the EA and the Applicant has engaged regarding a further updated FRA and flood modelling. As discussed as the Issue Specific Hearing 3 on 15 October 2024, the EA has confirmed that it has no comment on these documents and they are now agreed. This is further reflected via a written update to the Applicant on 16 October 2024, that

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			the EA do not have any comments to raise with regards to the model construct or calculated flows. The EA have confirmed that they are "*happy that the solar panel support frames would not increase flood risk off-site where they are placed in areas that flood (only area D02). [They] were also happy that the solar panels would be raised sufficiently to be above the 1 in 100 year plus higher central climate change level.*" The updated Flood Risk Assessment and Drainage Strategy (Document Reference 6.4.10.1, Revision 4) and Little Stainton Beck Hydraulic Modelling Technical Note (Document Reference 8.18) are provided at Deadline 4. The agreement on these matters will be reflected in the updated Statement of Common Ground (SoCG) with the EA anticipated to be submitted at Deadline 7.
REP3-013	Environment Agency	Under Row 12 of the Work Package Tracker, further updates to the outline CEMP regarding a Bentonite Breakout Plan are requested.	The Applicant and the EA are now agreed on these matters. This will be reflected in the updated Statement of Common Ground (SoCG) with the EA anticipated to be submitted at Deadline 7.
REP3-013	Environment Agency	Under Row 15 of the Work Package Tracker, further updates to the outline CEMP regarding a Construction Surface Water Management Plan are requested.	The Applicant has accepted that additional control should be included within the outline CEMP to address this concern, which will be included in the next iteration of that document to be submitted to examination and has been committed to via the Environmental Statement (ES) Errata and Management Plans Proposed Updates (page 6) [REP2-012].
REP3-014	Environment Agency	REP3-014 provides the EA's comments on both EA and Applicant responses to ExQ1.	The Applicant considers that no further points are raised in REP3-014 beyond those captured in REP3-013 and therefore defers to the comments made above.

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REP3-015	National Highways	National Highways has provided a belated response to ExQ1 CA.1.8: *National Highways are the registered landowners of plots 1/1 and 3/1 identified in the Book of Reference (AS-017). The Applicant has also identified National Highways as the freehold owner of the unregistered Plots 1/2 and 3/6 after applying the ad medium filum rule ie. the presumption that adjacent landowners to a highway own land abutting a road up to the middle line.* *Plots 1/1, 3/1 and 3/6 concern the subsoil to the public highway Aycliffe Lane and Plots 1/1/ and 1/2 concern the subsoil to public highway Lime Lane. Darlington Borough Council are the highway authority for Lime Lane and Aycliffe Lane. On the basis National Highways is not the highway authority for either Lime Lane or Aycliffe Lane and therefore have no interest in these plots we do not have any comments in relation to their compulsory acquisition. Now that this ownership anomaly has been brought to our attention National Highways will take steps to regularise the position by ensuring that ownership of the subsoil beneath the local road network passes to the local highway authority. In the meantime, should the local highway authority wish to object to the compulsory acquisition of these plots then we would support that objection whilst registered as the owner.*	The Applicant acknowledges the information provided by National Highways in relation to the plots referenced, and confirms that Darlington Borough Council are listed as the highway authority of the plots referenced in the Book of Reference. National Highways remain an Affected Party until such time that the ownership is passed to the local highway authority and will update our records in due course once confirmation is received.
REP3-015	National Highways	National Highways has provided a belated response to ExQ1 CA1.17: *National Highways is of the view that compulsory powers are not necessary in respect of cabling within the highway (or its subsurface). Street authorities routinely permit such works pursuant to the New Roads and Street Works Act 1991 (NRSWA). This does not involve an undertaker having to acquire the subsurface of the*	The Applicant acknowledges the position of National Highways in relation to the approach of compulsory acquisition for on-road cabling. Since this submission, the Applicant has proceeded with a Change Application to the ExA, made on 18 October 2024, in order to seek compulsory acquisition of subsoil rights for on-road cabling. The approach and

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		highway as is being proposed here. The draft DCO already contains the equivalent NRSWA provisions to authorise the street works. The only thing missing is the consent to enter the subsoil, which would otherwise be a trespass if the cabling is taking place at a depth beneath the highway zone of ordinary use. This could easily be addressed by a simple drafting tweak to the relevant street works article such that the street authority provides its consent (subject to reasonable conditions). This would negate the need for CA powers which are considered unnecessary and disproportionate in these circumstances. Given this reasonable alternative to CA it cannot be said that the undertaker has made out its case to satisfy the necessary tests for CA being an option of last resort.	justification for this is provided in the Change Notification Letter [AS-021] and the subsequent Change Application.
REP3-015	National Highways	In commenting on the revised DCO submitted at Deadline 2 [REP2-030], National Highways requests to for Requirement 5 of the draft DCO to be amended to require consultation with National Highways on the Decommissioning Traffic Management Plan (DTMP). This would align with the change made by the Applicant for National Highways to be a consultee on the CTMP under Requirement 6.	Following discussion of this matter as ISH4 on 16 October 2024, the Applicant will incorporate this change into the next iteration of the draft DCO, to be submitted prior to the close of Examination. As set out in the SoCG with National Highways [REP1-008], all matters are considered agreed.
REP3-016	Bishopton Villages Action Group (BVAG)	*Overarching comment from the Applicant: the BVAG submission provides comments on the Applicant's response to some questions asked under ExQ1, as submitted at Deadline 2 [REP2-007]. The Applicant notes that BVAG has sought to summarise the Applicant response to ExQ1 before making further comment. The Applicant contends that these summaries are not an accurate representation of its response and would direct the ExA to its original response as presented in REP2-007. Notwithstanding that point, the Applicant provides comment in the rows below limited to points made by BVAG which are unique (i.e. the Applicant does not think that they have been raised in previous submissions by BVAG) or which are factually incorrect and/or require clarification.*	
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to ExQ1 GCT.1.6, BVAG do not consider that this proposal meets with the principles of the Government's policy on energy, namely with reference to the introduction of the Great British Energy Bill and the recent consultation on the National Planning Policy Framework, which seeks that local	The Applicant notes the reference to Great British Energy Bill and the consultation on the NPPF. However, the Great British Energy Bill is not yet an Act, and the NPPF consultation has not yet resulted in an updated NPPF. As such, these have limited bearing on the determination of the Proposed Development.

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		planning authorities' identify suitable areas for renewable and low carbon energy sources and supporting infrastructure.	The relevant and primary policy for the determination of the Proposed Development is the National Policy Statements (NPSs). However, the Applicant acknowledges the status of the current NPPF in the decision making process through paragraphs 4.2.7 to 4.2.15 and Section 5 of the Planning Statement [APP-163].
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to ExQ1 GCT.1.6, The ExA are asked to consider why expanding the budget for the upcoming Contracts for Difference Auction to £1.5bn, up by £500m from last year, the majority is set for offshore wind power.	The Applicant would draw attention to the positive decisions on large scale solar schemes that have been made since the new Government entered power as well as the results of the most recent Contract for Difference auction (AR6) which included support for a large number of ground based solar schemes. The Applicant considers that solar remains at the heart of a future energy mix under the new government.
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to GCT.1.7, BVAG identifies locations where it considers the Proposed Development could be reduced, in order to reduce impact on local villages and the amount of Best and Most Verstatile (BMV) land used. These are: 1. Brafferton - Grade 3a land to immediate south-east of village. 2. Great Stainton – Grade 3a land to immediate east of village. 3. Bishopton – Grade 2 land to north-east and Grade 3a east of Old Stillington.	The Applicant notes BVAG's concerns regarding the use of Best and Most Versatile (BMV) agricultural land, understanding of the Government's position on using agricultural land and regarding the assessment of agricultural land. The Applicant has addressed this in the submitted document Comments on Deadline 2 Submissions including Written Representations and Responses to ExQ1 [REP3-004].
REP3-016	Bishopton Villages Action Group (BVAG)	BVAG reference anecdotal evidence of a local farmer who considers that land benefits from being actively farmed and can take many years to become productive again. BVAG note that topsoil removal should be minimised.	Solar farms help regenerate soil quality, and so are helping to ensure the continued availability of high quality agricultural acreage for future generations. The impact on soil is outlined in ES Chapter 9 Land use and Socioeconomics [APP-032]. There is predicted to be a moderate adverse effect on soil resources

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			during construction, with a moderate beneficial effect on soil resources at decommissioning due to improved soil health. Topsoil will not be removed from all areas but will remain in situ and undisturbed for the lifetime of the Proposed Development over the vast majority of the land. The only requirement to remove topsoil will be mostly temporary and short-term for construction access tracks, construction compounds and laying the underground cables; as well as for areas of operational infrastructure such as operational access tracks, substation, BESS, inverters, switchgear and spare containers. These have been sited mostly on moderate quality Subgrade 3b land, with only 0.2ha of BMV Subgrade 3a land required for these elements of the Proposed Development.
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to ExQ1 GCT.1.15, BVAG raise concerns regarding the impact on horses being ridden through and near arrays and fenced corridors.	The Applicant addressed this point in its response to paragraph 4.6.15 of the BVAG Written Representation [REP3-005] (page 79). Of particular relevance is the reference this response made to the 'Advice on Solar Farms' document produced by the British Horse Society (BHS)[1], which states: "*They [standard photovoltaic panels] are designed to absorb rather than reflect light for efficiency (reflected light is wasted energy) and although the amount of reflection varies with the component materials and the angle, the incidence of glare or dazzle is very low compared with glass and will not be uniform throughout a period of sunlight, assuming that the panel is static. Any reflection is unlikely to be a direct problem to horses, riders or carriage-drivers because of the angles and distances involved.*"

[1] BHS (undated) 'Advice on solar farms near routes used by equestrians (solar-0424.pdf (bhs.org.uk)

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REP3-016	Bishopton Villages Action Group (BVAG)	BVAG consider that the Applicant's response to GCT.1.17 should have included reference to flooding and how this was taken into account in relation to climate change.	The Applicant's response to GCT.1.17 [REP2-007] did refer to increased rainfall and storm intensity. However, for the avoidance of doubt, ES Appendix 10.1 Flood Risk Assessment and Drainage Strategy (Document Reference 6.4.10.1, Revision 4) includes a site-specific Flood Risk Assessment and changes in rainfall attributed to climate change have been incorporated into the assessment of flood risk. Resilience to impacts from climate change has been assessed within ES Appendix 5.2 Climate Change Resilience (CCR) Assessment [APP-124]. Following engagement with the EA, the Applicant has produced further modelling work for the areas of the Proposed Development which lie within areas of highest risk, and this provides further evidence to demonstrate the level of risk. The EA have considered the results of this modelling and agree with the model outputs and findings with an updated ES Appendix 10.1 Flood Risk Assessment and Drainage Strategy (Document Reference 6.4.10.1, Revision 4) submitted at Deadline 4.
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to GCT.1.20, BVAG note supply chain concerns regarding solar energy infrastructure, in particular an overreliance on materials from China.	The assessment in ES Chapter 5 Climate Change [APP-028] takes account of the embodied carbon of materials, including an assumption that PV cells will be sourced in China. Table 5-9 of the assessment considers the impact on the transportation of products and materials to the Proposed Development. ES Chapter 5 Climate Change [APP-028] concludes that there would be no significant adverse effects arising from the Proposed Development, with a significant beneficial effect arising from the production of low carbon energy during operation.

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REP3-016	Bishopton Villages Action Group (BVAG)	In relation to GCT.1.20, BVAG request that the Applicant provides employment scenarios and estimates of local jobs, and from how far and wide the workers are likely to come from, including local, regional, UK wide and overseas.	ES Chapter 9 Land Use and Socioeconomics (Document Reference 6.2.9) provides an assessment of the effects of the Proposed Development in relation to employment. Paragraphs 9.10.3 to 9.10.13 provide an estimate of the workforce required during construction and the likely source of workers, based on experience at the time of assessment. This concludes a total net employment of 142 staff from the immediate study area of Darlington, Stockton-on-Tees and Durham local authority areas, (circa 60%), and 95 staff from the wider North-East region or beyond (circa 40%). The assessment concludes a beneficial (not significant) effect arising from the Proposed Development in relation to employment and supply chain opportunities.
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to PPD.1.5, BVAG ask the Applicant to clarify the wattage of the assumed solar PV panels.	The Applicant confirms that the panels which have informed the design work to date are 570W Jinko panels.
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to PPD.1.13 and DES.1.3, BVAG considers that the Proposed Development is over-planted and could use a smaller land take to generate the required energy.	The Applicant has explained its position on over-planting in the submitted Energy Generation and Design Evolution Document [REP2-010] and this was further discussed at Issue Specific Hearing 2 on 15 October 2024, as set out in the Post-hearing submissions including written submissions of oral cases as heard at ISH2, ISH3, ISH4 and CAH1 (Document Reference 8.15).
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to PPD.1.14, BVAG note local opposition to the Proposed Development. And the position of Darlington Borough Council in their Local Impact Report [REP1-023] that the Proposed Development is not policy compliant.	The Applicant acknowledges the objection of BVAG to the Proposed Development and continues to engage with BVAG through the Statement of Common Ground process. The Applicant has demonstrated through the Planning Statement [APP-13] and the Policy Compliance Document [APP-164] that the Proposed Development is in compliance with national and local policies.

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REP3-016	Bishopton Villages Action Group (BVAG)	In relation to EIA 1.3, BVAG request that the Applicant provide details of how often solar panels, inverters and BESS units would need to be replaced during operation. BVAG also request that the Applicant confirm whether replacement may occur due to upgrades, rather than wear and tear.	The assumptions around replacement of parts are set out in paragraph 1.11.6 of ES Appendix 2.3 Assessment of Likely Waste Arisings [APP-107]. It states: "*• Solar PV modules – will be replaced depending on efficiency. It is expected to replace 10% of these over the lifetime of the Proposed Development;* *• All the supporting equipment is assumed to require replacement once, with a further 50% requiring replacement twice, during the design life; and* *• All BESS cells are assumed to require replacement once, with a further 50% requiring replacement twice, during the design life.*" The Applicant can confirm that replacement due to upgrades in technology would not take place.
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to EIA 1.3, BVAG ask the Applicant to comment on the risks of disruption to maintenance and operation given global dependence on China for solar panel equipment, citing the disruption caused to energy supplies as a result of the war in Ukraine.	The Applicant considers that current supply chains for solar panels and other infrastructure are sufficient for the construction and operation of the Proposed Development. Though the majority of solar panels are manufactured in China, there are European suppliers. During operation, maintenance would be carried out by RWE and its contractors based in the UK, so would not be disrupted by global events.
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to EIA 1.3, BVAG note that construction of Whinfield Solar nearby has overrun, partly due to labour and materials shortages, and query whether the Applicant's construction assumptions of 18-24 months should be longer.	The Applicant cannot comment on the specific issues affecting another scheme. The Applicant remains confident in the construction scenarios it has defined and which have informed the EIA assessment. In relation to ecology surveys, the walkover surveys undertaken prior to development do not seek to replace and update the baseline reported in the ES, but

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		BVAG additional query how a walkover survey post-consent is sufficient to replace and update baseline ecological surveys.	to confirm that they remain valid and that there are no new or different risks that require management through the relevant management plans for construction, operation and decommissioning. If the walkover survey identifies a new risk, further detailed surveys would be undertaken and appropriate management action embedded into the management plans for approval by the local planning authority.
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to ExQ1 EIA 1.4, BVAG reiterates its concerns regarding the geophysical surveys in the vicinity of the motte and bailey.	The Applicant has addressed this in the submitted document Comments on Written Representations REP2-042 (Bishopton Villages Action Group) and REP2-044 (Landscape & Visual Review) [REP3-005].
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to ExQ1 BIO1.1, BVAG query the independence of the ecological assessment provided to date, and request an independent Ecological Clerk of Works.	ES Appendix 1.1 Competent Expert Evidence [APP-104] sets out the qualifications of the specialists, or 'competent experts' that have undertaken the EIA, including the biodiversity assessment. The activities of the Ecological Clerk of Works (ECoW) during construction would similarly be of the required qualification and expertise, and would have independent oversight through the discharge of DCO requirements process, in which the activities to be carried out by the ECoW would be defined and approved by the local planning authorities.
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to ExQ1 DES1.1, BVAG asks the Applicant to confirm where ballast is going to be used for mounting solar panels.	The Applicant confirmed in its response to ExQ1 DES1.1 [REP2-007] that '*based on survey work undertaken to date, the Applicant is proposing the ballast structures on approximately 16ha across the Order Limits and estimates that a further circa 11ha may require this mitigation by design based on the geophysical survey results. The areas where ballast foundations are proposed are shown on the Mitigation Areas and Type Plan [REP2-024] submitted at Deadline 2 with the remainder of the panels utilising the usual pole mounting structures.*'

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REP3-016	Bishopton Villages Action Group (BVAG)	In relation to ExQ1 DES.1.8, BVAG request that '*the applicant comment on the extent to which the scheme remains viable – and therefore what would be the maximum corridor which could potentially provide for a viable scheme - and look to exclude BMV land and even utilise potential brownfield and grey belt land. The relationship between MW, acres (scale) and search corridor provide a rationale behind the search for alternative rather than 'convenient' sites.*'	The Applicant confirmed in its response to ExQ1 DES1.8 [REP2-007] that during the site selection process, a 6km search corridor was expanded to 12km taking into account the scale of the Proposed Development and its ability to viably accommodate the greater costs of a longer cable route. The Applicant has set out its position on the site selection process and energy generation requirements in the Energy Generation and Design Evolution Document [REP2-010]. As stated in paragraph 4.3.9 of NPS EN-1, the NPSs "contain no general requirement to consider alternatives or to establish whether the proposed project represents the best option from a policy perspective". The Applicant does not consider it necessary to consider further vague alternative proposals such as that presented in the comment from BVAG.
REP3-016	Bishopton Villages Action Group (BVAG)	BVAG remains concerned about the risks to human and environmental health resulting from incidents such as a BESS thermal runaway event.	The Applicant notes BVAG's reference to concerns regarding human and environmental health in relation to the BESS, as raised in BVAG's Landscape & Visual Review [REP2-044]. The Applicant provided a response in Comments on Written Representations REP2-042 (Bishopton Villages Action Group) and REP2-044 (Landscape & Visual Review) [REP3-005].
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to ExQ1 HEN1.5, BVAG reiterates its concern that impacts on the Scheduled Monument Motte and Bailey castle in Bishopton has been insufficient and does not recognise the significance and setting of the asset.	The Applicant acknowledges BVAG's disagreement with conclusions regarding cultural heritage. The Applicant considers this is a matter that it and BVAG will not be able to agree upon. The Applicant's assessment is provided in ES Chapter 8 Cultural Heritage and Archaeology [APP-031] and a detailed response to ExQ1 HEN1.5 provided at Deadline 2 [REP2-007]. This matter was further discussed at Issue Specific Hearing 2 on 15 October 2024, as summarised in Post-hearing submissions

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			including written submissions of oral cases as heard at ISH2, ISH3, ISH4 and CAH1 (Document Reference 8.15). The Applicant has reached an agreed position with HE on heritage and archaeology matters and this is reflected in the SoCG with HE [REP1-014]. The position with DBC on heritage and archaeology is also agreed as set out through the Councils LIR [REP1-023] and the Applicants Response to the LIR [REP2-008].
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to ExQ1 LSV.1.9, BVAG request the Applicant provides an update regarding potential impacts of flooding, to livery businesses and to construction traffic on Mill Lane in relation to the proposed car park for Bishopton Primary School.	The Applicant does not propose to use Mill Lane for construction traffic. The proposed car park at the primary school has been taken into account in the assessment reported in the Environmental Statement, in which no significant effects are identified relating to construction traffic, flooding or socioeconomics. The Applicant provided a detailed response to queries raised by the Cobby Castle Livery in its comments on Deadline 2 submissions [REP3-004].
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to ExQ1 TT.1.23, BVAG raise concern regarding proposed site accesses, particularly to Panel Area A.	The Applicant notes BVAG's concerns regarding the access to Panel Area A, referencing BVAG's Landscape & Visual Review [REP2-044]. Comments have been provided regarding this in the submitted document Comments on Written Representations REP2-042 (Bishopton Villages Action Group) and REP2-044 (Landscape & Visual Review) [REP3-005]. The Applicant considers the accesses to be sufficient, with detailed design to be developed post-consent. However, as discussed at the Issue Specific Hearing 2 on 15 October 2024, the Applicant and Darlington Borough Council Highways Department have been in recent discussion on the accesses, including sharing of visibility splays. An update on these discussions is expected by Deadline 5.

Examination Library Reference	Interested Party	Summary	RWE Response
REP3-016	Bishopton Villages Action Group (BVAG)	In relation to ExQ1 TT.1.33, BVAG raise concern regarding the liability of the Applicant to repair any damage to public highways caused during the construction of the development.	As noted in Comments on Written Representations REP2-042 (Bishopton Villages Action Group) and REP2-044 (Landscape & Visual Review) [REP3-005], the Applicant is willing to commit to undertaking pre-commencement condition surveys and regular inspections of the HGV routes to site. The Outline CTMP [APP-112] will be updated to include this requirement, alongside a commitment for the Principal Contractor to advise the local Highway Authority of any deterioration of the HGV routes attributable to the actions of the undertaker, and to resolve any damage either through payment of reasonable and proportionate compensation, or through acting as the Council's agent to rectify the highway directly. This is set out in the ES Errata and Management Plans Proposed Updates submitted at Deadline 2 [REP2-012], with the updated CTMP incorporating the update expected to be submitted at Deadline 6.
REP3-017	Durham Bird Club	Durham Bird Club has provided a further representation regarding the potential for some bird species to mistake solar arrays for water features and its request for a monitoring condition to require any collisions to be reported to the appropriate authority. The representation under REP3-017 includes information from the British Trust for Ornithology which confirms that there is a lack of evidence relating to this topic. Durham Bird Club considers that this '*provides further evidence to support my original comment that, if consent is granted, there should be a monitoring condition that would ensure that any bird strikes on the panels are reported. Only in this way will there be evidence to show if there is in fact a problem in this regard. I believe this would be relevant to Question BIO.1.1 as the question of birds, particularly waterfowl, flying over the site has not been addressed particularly at night or in poor quality conditions. Waterfowl do exist in some numbers in this area and water*	The Applicant acknowledges the lack of research raised in the representation regarding the impact of solar energy generating infrastructure on birds, in particular waterbirds. The Proposed Development has been designed to avoid being close to existing waterbodies and therefore the Applicant considers risks to be low. The Natural England publication submitted into the Examination [REP1-045] seems to concur that evidence of such impacts is lacking and studies have shown / suggested that species are adapting to solar panels. Furthermore, the Applicant made reference in response to Durham Bird Club to a literature review undertaken by RSK – the Applicant's competent expert for biodiversity – which further supports the position that there is no actual published evidence of birds mistaking solar panels for water. This study is appended to this document.

Examination Library Reference	Interested Party	Summary	RWE Response
		features that attract them (such as Castle Lake at Bishop Middleham and any potential new water features resulting from Discover Brightwater project) are reasonably close to the site.'	However, recognising the concern of the Durham Bird Club, in the Applicant's Comments on Deadline 2 Submissions [REP-3-004], the Applicant committed to reporting any deceased species found on site as part of maintenance activity, for review by an ecologist to establish whether there is any link to bird strike. This can be incorporated into the outline LEMP [APP-118] which will be updated at a future deadline (expected to be Deadline 6).

3. Update on Matters Raised at Earlier Deadlines

3.1. Introduction

3.1.1. The sections below provide an update on matters raised in submissions at earlier Deadlines, including where the Applicant has committed to providing further information or clarification.

3.2. Noise modelling

3.2.1. Under reference 5.12.4-6 of its response to the DBC LIR [REP2-008], the Applicant committed to review and discuss queries raised that had been raised relating to the noise assessment, and in particular the existing sensitive receptors (ESRs). The Applicant has now completed a review of this matter and has identified that some ESRs were not correctly depicted in ES Figure 11.1 or ES Appendix 11.4. These have been updated to include the full suite of ESRs, as provided at this deadline in ES Appendix 11.4 BS4142 Assessment Calculations (Document Reference 6.4.11.4, Revision 2) and ES Figure 11.1 Sensitive Receptor Location Plan (Document Reference 6.3.11.1, Revision 2).

3.2.2. Furthermore, in response to matters raised in the DBC LIR and by Interested Parties regarding construction noise, including on livery businesses [REP2-059, RR-209, RR-533], the Applicant has undertaken further construction noise modelling. This is presented in the ES Chapter 11 Noise and Vibration Addendum – Construction Noise (Document Reference 8.17).

3.3. Further response regarding heritage

3.3.1. At Deadline 2, the BVAG Landscape and Visual Review [REP2-044] made reference to potential archaeological features such as a medieval deer park that had not otherwise been identified in the Applicant's heritage analysis. This was identified by the BVAG representative as running around 400m west of the Scheduled Monument at Bishopton, to the west of Folly Bank Lane, where there is a deep ditch followed by a steep bank. The Applicant, in responding at Deadline 3 [REP3-005, Page 42] committed to review this in detail and provide an update at Deadline 4.

3.3.2. The Applicant's heritage expert has reviewed available information including Historic Environment Record (HER), LiDAR and historic mapping and has concluded that it does not suggest that the bank is representative of a former deer park. There are no other extant field boundaries in the area which follow the bank, or any visible on historic mapping which could have been removed later. The earthwork is also not traceable on the LiDAR data beyond the short section noted on Folly Bank while no record exists within the HER of such a feature having been present. While the provenance of the bank is unknown at this point in time, the Applicant considers that it is unlikely such a feature would be of more than low significance and as a result will fall under the requirements set out within the Archaeological Management Strategy for preservation by record [APP-149].

A.1 RSK Literature Review – Impacts of Solar Farms on Biodiversity

Longfield Solar Energy Farm Ltd

A SUMMARY OF THE PUBLISHED EVIDENCE ON THE IMPACTS OF SOLAR FARMS ON BIODIVERSITY

Richard Delahay & Danielle Sherman - RSK Biocensus

DOCUMENT REFERENCE: PRJ00059-LONG-PLN-HSE-REP-000002

1 Document Control

SIGN OFF		
Name (Role)	Signature	Date
Mark Lang (Technical Director, RSK Biocensus)	Mark Lang	09/05/2023

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2 Introduction

2.1 Background

Solar farms can make a significant contribution to the transition to renewable energy sources required to reduce carbon emissions and limit global warming. In that regard, solar alongside other renewable energy sources, can be viewed as benefiting biodiversity by reducing the detrimental effects of fossil fuel derived pollution and climate change.

Like all developments solar farms will impact on local biodiversity during their construction and subsequent operation. The magnitude of such effects will be largely determined by local conditions and the net impact on biodiversity once a solar installation is operational will depend on the characteristics of the modified habitat in relation to what it replaced. Clearly, there are opportunities to design and manage these modified habitats, that sit beneath, between and in the immediate vicinity of solar panels and associated infrastructure, in the interests of enhancing biodiversity. Hence carefully designed schemes could deliver net gains in biodiversity, particularly where they are sited in nature-depleted locations. However, to realise such gains, it will also be important to understand any negative impacts on biodiversity that arise from solar farms.

2.2 Aims

In this report we describe the current evidence base relating to the impacts of solar farms on biodiversity. We particularly focus on the evidence for negative and positive impacts of operational solar farms and associated habitat management practices. Consequently, we do not consider in any detail the potential impacts that the development footprint may have as these will vary widely amongst sites and are dealt with as part of site-specific ecological impact assessments. The over-arching purpose of this review is to understand the nature of the existing evidence base relating to risks and opportunities for biodiversity on solar farms, identifying common themes and important knowledge gaps.

3 Approach

3.1 Review of published articles

The scope of the literature review was defined as follows,

- Subject matter restricted to solar panels (or photovoltaic panels), excluding other solar power generation methods such as condensing or parabolic arrays.
- Articles published in the last 20 years (period 2002 to 2022 inclusive).
- A focus on studies of likely relevance to temperate regions (such as the UK).
- Articles should include an abstract/executive summary in the English language.

We searched the Web of Science (WoS) database of research publications and citations for published scientific articles. Search terms were 'solar farm', 'solar panel' or 'solar array', each in combination with one of a series of other secondary terms (see Table 1). The choice of secondary search terms reflected the need to identify any articles describing broad impacts on biodiversity, but also included specific groups of organisms of particular interest (e.g., pollinators, birds, bats).

3.2 Review of 'grey literature'

The same search strategy as described above was used to find relevant 'grey literature' such as reports, guidance notes, policy statements and other articles not published in the scientific press. The terms above (see also Table 1) were therefore used in conventional internet searches using Google©. All articles identified on the first ten pages of search results were collated.

3.3 Screening search results

Results of the searches were combined, and duplicates removed before being screened independently by the authors for relevance based on the title and/or abstract content. The resulting sample of articles was then subjected to a second screening whereupon each article was examined in more detail for relevance and was classified according to several criteria. For each article we determined whether it involved the collection of primary data from solar farms (the alternative being that it either didn't include any data or cited the results of other studies), the geographic region it covered (i.e. Africa, Asia, Australasia, Europe, North America, South America or Global) and whether it targeted a particular taxonomic group (i.e. plants, invertebrates, birds, mammals, others). We also identified studies that included quantitative assessment of the effects of habitat management at solar farms, and those that reported any negative impacts of solar farm operation on biodiversity.

4 Results

The WoS search identified 471 hits in total (see Table 1). However, after screening out all the duplicates this was reduced to 381 articles. Further screening, initially on titles and/or abstracts and subsequently on other content, identified a sub-set of 29 articles of direct relevance to the impacts of solar farms on biodiversity. These articles themselves cited a further 10 relevant publications which had not been identified by the original search, resulting in a final total of 39 articles. The internet searches for grey literature resulted in 184 hits which after the removal of duplicates and screening for relevance revealed 18 sources of relevant information. Hence the final number of relevant articles identified by the searches was 57, comprising 33 published scientific papers, 15 reports and 9 miscellaneous documents (see Appendix for complete list).

Although our searches included any articles published during the last 20 years, none published prior to 2010 survived the screening process. Nevertheless, the literature searches clearly indicate that the number of articles on biodiversity on solar farms has increased in recent years (Figure 1). Although this general trend is apparent for both scientific papers and other articles, it is most pronounced for the former.

The overwhelming majority of articles on biodiversity and solar farms related to studies originating from Europe and North America (Figure 2). Where articles focused on particular taxonomic groups the most common were birds, closely followed by insects, then plants, with fewer studies on mammals (Figure 3). However, all four species groups were equally represented in studies published in scientific journals indicating that the variation was driven entirely by other article types. Very few articles of either type focused on other species.

Only 19 (33.3%) articles included the collection of primary data from solar farms and only 8 (14.0%) involved any empirical assessment of the impact of different habitat management regimes on biodiversity. Of the latter, all involved the collection of primary data, except one article (Blaydes et al., 2021) which included a meta-analysis of results from several other studies. Plants were the most frequent taxonomic group of interest in articles reporting on primary data collection from solar farms, featuring in 11 (57.9%) such studies. Insects and birds were the subject of on-site field studies in six and five instances respectively, with mammals only appearing in two studies. Many articles (n=32, 56.1%) described negative effects of operational solar farms on biodiversity, but few (n=7, 12.3% of the total number of articles) demonstrated such effects from on-site collection of primary data.

Table 1 : Search terms and numbers of articles identified from the searches of the WoS bibliographic database (for articles in the scientific press) and of the internet (for other articles).

PRIMARY TERMS	SECONDARY TERMS	NUMBER OF HITS	NUMBER OF HITS FROM FIRST TEN PAGES
solar farm* OR solar panel* OR solar array*	Biodiversity	76	20
	Ecology	85	14
	Wildlife	34	13
	Ecological impact*	117	17
	Impact on birds	32	17

	Impact on bats	7	14
	Impact on vegetation	73	18
	Impact on pollinators	1	5
	Botanical surveys	0	10 (only four pages of results)
	Impact on insects	15	13
	Impact on butterflies	2	14
	Impact on bees	4	5
	Impact on moths	1	8 (only three pages of results)
	Soil diversity	24	16

*Indicates any additional letters (e.g., to account for plurals).

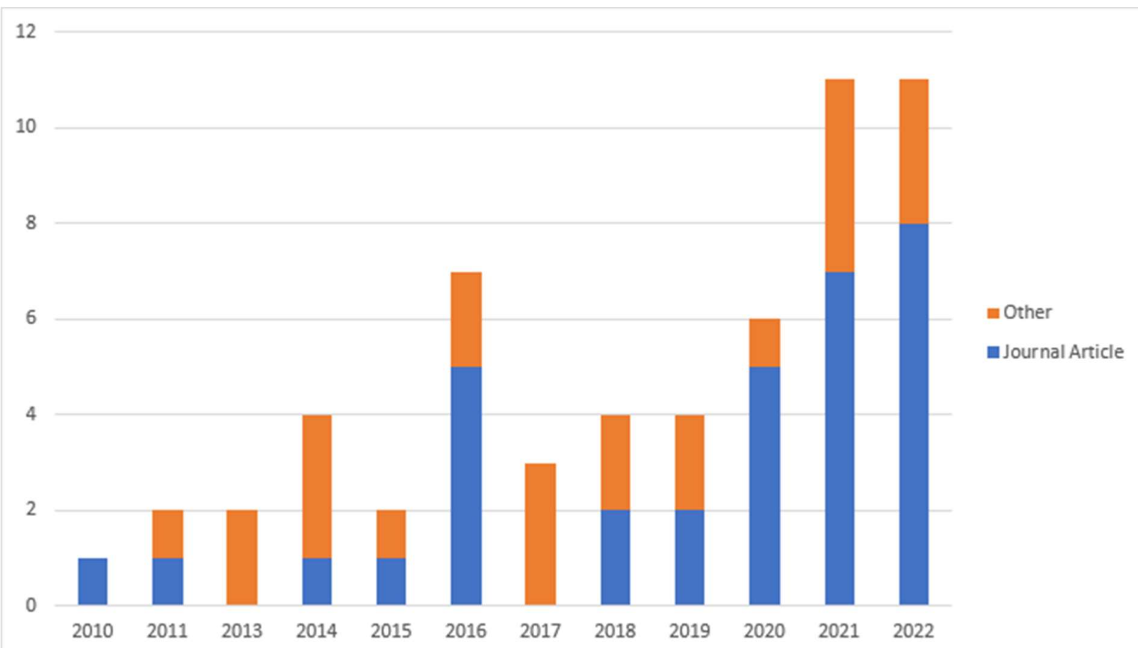

Figure 1: Numbers of articles on biodiversity and solar farms published in the scientific press (Journal Article) or available elsewhere in the public domain (Other) since 2010.

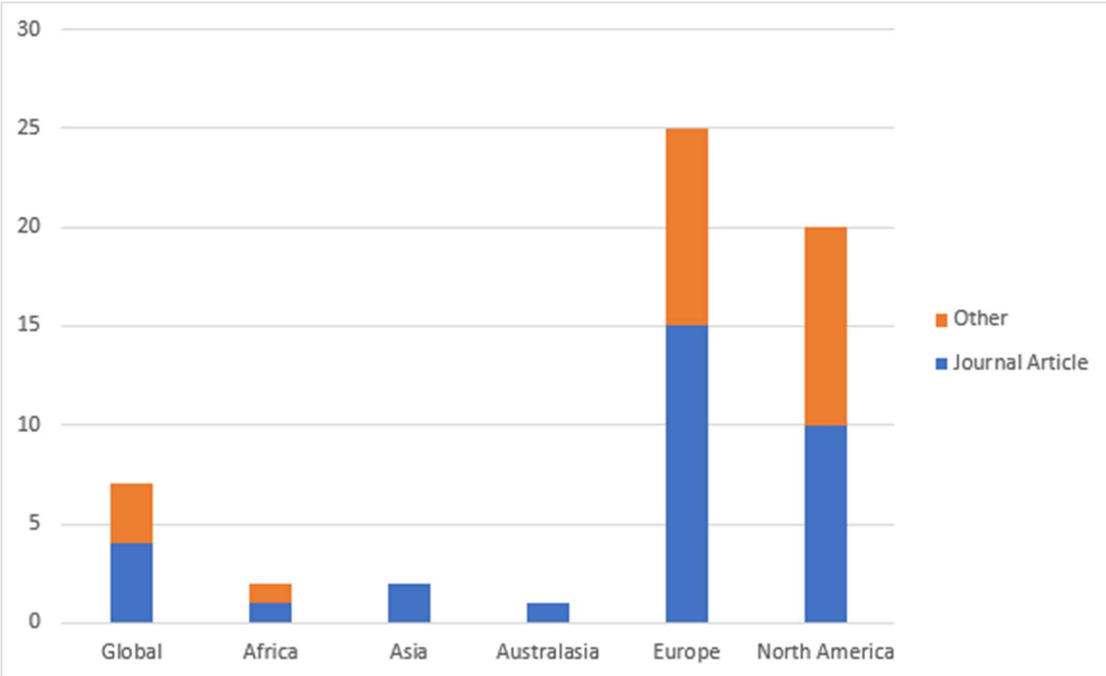

Figure 2: Numbers of articles on biodiversity and solar farms published in the scientific press (Journal Article) or available elsewhere in the public domain (Other), shown by geographic region.

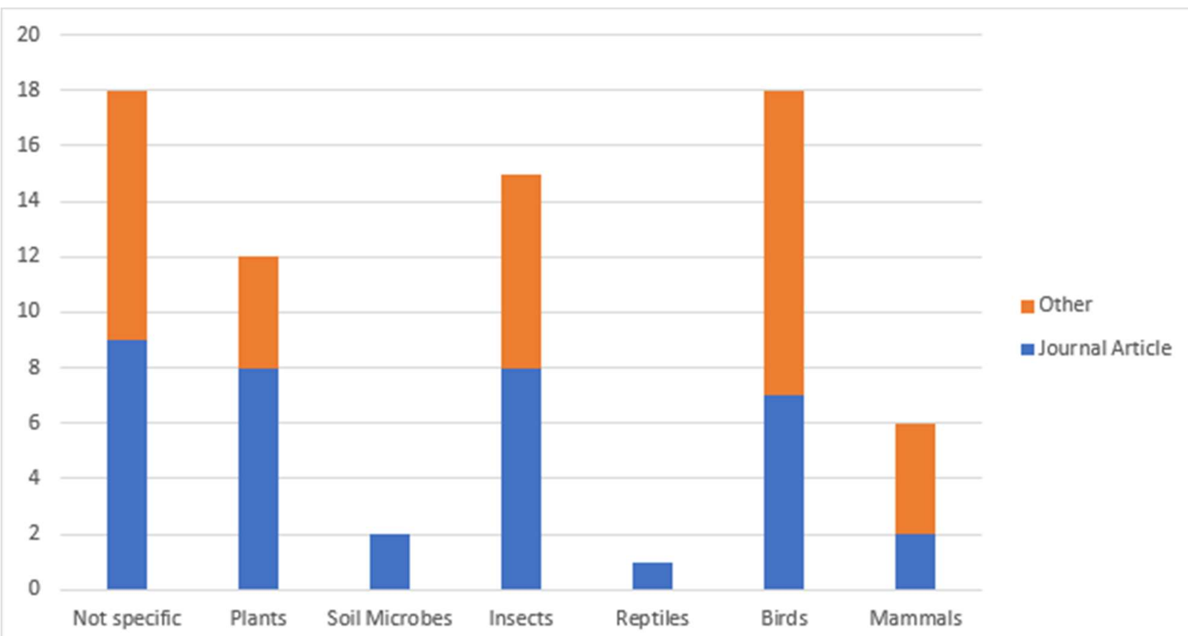

Figure 3: Number of articles on biodiversity and solar farms per taxonomic group showing the proportion published in the scientific press (Journal Article) or available elsewhere in the public domain (Other). The totals per taxonomic group sum to more than the 57 articles identified by the literature search as several studies involved more than one group.

5 Discussion

Our review of the available literature suggests that the evidence base relating to biodiversity impacts of solar farms is relatively limited. We were only able to identify 33 scientific articles and 24 other relevant publications from the period 2002 to 2022 inclusive. Although our literature search will not have identified every relevant article published during this period (as for example we only used a single bibliographic database) it is likely to include the majority of most influential works as we scanned all articles for citations of other relevant studies. This also suggests that our sample of articles is sufficient to infer broad trends in the evidence base.

Of the 57 articles identified in the literature search, only a third involved direct data collection from solar farm sites. Hence, the evidence base underpinning current practice and recommendations does not appear to be well developed. The paucity of studies involving collection of primary data from solar farms also suggests that the broad referencing of negative impacts on biodiversity (56.1% of all articles described negative effects) is based on relatively little empirical data. Although the majority of articles originated from Europe and North America, this was partly the result of our general focus on evidence of relevance to temperate regions, but their dominance was such that this may also reflect real regional differences in publication interest.

The land take required to create solar farms can be relatively large compared to other energy generating operations (Fthenakis & Kim, 2009) and so, depending on location, the loss and fragmentation of existing habitats could be potentially significant. Net impacts of solar farm construction on biodiversity will reflect the relative values of the previous habitats and those that are created subsequently. Protected areas, priority and sensitive habitats should clearly be avoided, and further research on threshold distances from solar farms for any detrimental effects on biodiversity would allow conservation buffer zones to be identified (Smith & Dwyer, 2016). Dhar et al. (2020) reviewed the evidence for environmental impacts of solar panel developments and concluded that most of the impacts (including habitat fragmentation and loss of biota) could be minimised through appropriate management and monitoring. Developments on agricultural and brownfield sites of low biodiversity value for example may be able to achieve significant net benefits for biodiversity if appropriately designed and managed (Lammerant et al., 2020). For example, Armstrong et al. (2016) demonstrated the development of species-rich meadow on solar farm land that was previously arable, whilst a study of 11 solar farms in the UK revealed greater abundance of several native species groups compared to control plots on adjacent undeveloped farmland (Montag et al., 2016).

Impacts on existing habitats may include removal of large areas of topsoil and hence alteration of soil composition (including carbon content), biotic communities and the composition of regenerating vegetation. Significantly less carbon and nitrogen has been observed in solar farm soils compared to undeveloped adjacent land, likely due to the removal of topsoil during construction (Choi et al., 2020). However, stripping of topsoil from agricultural land that has been 'improved' by the addition of fertilisers is a well-established technique for the restoration of native plant communities which thrive better in nutrient poor soils. A study of three solar farms in France showed that although soil quality, the flow of carbon and microbial activity were similar to that in recently abandoned agricultural land and lower than in semi-natural habitats, this did not impair early successional plant communities (Lambert et al., 2021).

The installation of solar panels creates new microclimatic conditions at the soil surface beneath them, including lower temperatures, irregular distribution of rainwater, enhanced moisture retention (Choi et al., 2020; Lambert et al., 2021; Vervloesem et al., 2022), reduced organic matter and lower microbial activity (Moscatelli et al., 2022). However, despite such changes Moscatelli et al. (2022) concluded that this should not compromise reversion to agricultural land, whilst Macknick et al. (2013) cited evidence that the reduced temperatures beneath solar panels may increase their efficiency. Solar panels also provide some shelter from strong solar radiation, which Tanner et al. (2020) found improved plant species richness in a desert environment. In contrast, several European studies reported that the conditions beneath solar panels resulted in reduced plant biomass and diversity (Armstrong et al., 2016; Uldrijan et al., 2022; Vervloesem et al., 2022). Conflicting results have been reported in relation to crop growth beneath solar panels (see Marrou et al., 2013). Hence, effects are likely to vary with the prevailing conditions and so optimising biodiversity gains beneath the panels may require careful consideration of which plant species to use in revegetation schemes. Nevertheless, the intrinsic heterogeneity in microclimate on solar farms might be beneficial in terms of favouring a diversity of niches for plant and invertebrate species (Choi et al., 2020; Blaydes et al., 2021; Nordberg et al., 2021). It is important to recognise that microclimate and soil characteristics will also vary according to solar farm design, particularly the distance between panels and arrays, the height and orientation of panels (Lammerant et al., 2020). There is a clear need for better evidence on how to maximise biodiversity and ecosystem service benefits through habitat management beneath solar panels. Beatty et al. (2017) suggested that adjusting panel height and spacing could be used to reduce any detrimental effects on soil quality and plant growth, enhance structural complexity and thereby enhance biodiversity benefits. A study in Germany provided evidence that wider gaps between rows of solar panels could yield multiple benefits for biodiversity (Peschel et al., 2019) indicating how additional benefits could be achieved through design change.

The UK's Building Research Establishment (BRE) estimates that solar farm infrastructure typically disturbs less than 5% of the ground, that panels cover only 25-40% of the development footprint and that sites have an expected lifespan of at least 20 years (BRE, 2014). This suggests there are considerable opportunities for the creation of biodiverse habitats on solar farms, and there is no shortage of published recommendations on how to achieve this (e.g. BRE, 2014; Fox & Bennett, 2019; Lammerant et al., 2020; Miller et al., 2013; Parker & Monkhouse, 2022; Solar Energy UK, 2022; Steinberger, 2021). These potential opportunities for biodiversity gains have been recognised by several conservation organisations, some of which have engaged actively in the production of guidance (see BRE, 2014). Nevertheless, our literature search identified very few studies that presented empirical evidence for the relative effectiveness of different habitat management regimes. Hence, many of the recommendations available in published guidance for enhancing biodiversity on solar farms are based on well-established general principles of habitat creation and restoration, rather than on evidence derived from in-situ studies. But the potential for collating such evidence is increasing as relevant management interventions become more commonplace.

Planting with native species can relatively quickly create extensive plant cover under solar arrays, for example Beatty et al. (2017) describe achieving native grassland cover within three years. Lambert et al. (2022) also demonstrated success by seeding rather than relying on natural regeneration when restoring Mediterranean grassland beneath solar panels. Rapidly establishing vegetation cover will likely provide additional benefits such as controlling soil erosion and rainwater runoff (Beatty et al., 2017). Sowing traditional grasses or wildflowers (e.g. fine grasses and herbs) may also provide vegetation cover that is more drought resistant than agricultural crops or pasture grasses, since they tend to have deeper roots (Gazdag & Parker 2019). This may be important in maintaining biodiversity and other ecosystem services of species-rich grasslands (e.g. carbon storage) in the face of global climate change. Low intensity livestock grazing can be employed as an effective means of managing grassland habitats (also called conservation grazing). Sinha et al. (2018) demonstrated that seeding with native flora followed by periodic grazing resulted in greater richness of plant and animal species on a solar farm compared to adjacent undeveloped land. Similar biodiversity benefits have been observed elsewhere although they will decline as grazing pressure increases (e.g. Parker and McQueen 2013). The timing of grazing is also important as native plants can be allowed to flower and set seed by suspending grazing at particular times of year, such as in either spring or summer to favour early or late flowering species in the UK (BRE, 2014). By combining conservation grazing with animal production it may be possible to devise strategies that produce biodiversity benefits (and other ecosystem services) whilst also generating income (Nordberg et al., 2021).

Habitat creation on solar farms provides opportunities to substantially enhance these locations for invertebrates. One UK study showed that the abundance of butterflies and bumblebees was greater on a sample of 11 solar farms compared to adjacent undeveloped farmland, and on solar farms that been managed in the interests of wildlife the diversity of these species was also higher (Montag et al., 2016). In another UK study the density of bumblebees and their nests was enhanced on solar farms that were entirely managed as wildflower meadows compared to those with only wildflower margins (Blaydes et al., 2022). Comparison of a pollinator-friendly versus a turfgrass solar farm showed higher plant and insect diversity on the former, with the added benefit of the flower-rich habitat providing a cooling effect which improved the energy output of the panels under certain conditions (Martin, 2022). Several articles provide recommendations to improve habitats on solar farms for the benefit of insects (e.g. BRE, 2014; Fox & Bennett, 2019), but in many cases supporting empirical evidence is not provided. Notable exceptions are reviews by Dolezal et al. (2021) and Blaydes et al. (2021). The latter included a systematic assessment of information relating to the effectiveness of management interventions proposed to benefit pollinators, which led to ten evidence-based recommendations on improving solar farm management for pollinators. Recommendations arising from these two reviews include providing a diverse mix of flowering plants including native perennials, ensuring season-long access to foraging resources, creating habitats for nest sites and minimising the use of agrochemicals. Such approaches have the capacity to substantially increase the attractiveness of solar farm habitats to invertebrates above that of adjacent species-poor agricultural land. Furthermore, enhancing rurally located solar farms for invertebrates could potentially provide a source of pollinating and pest-predating insects to the benefit of surrounding agricultural land (Dolezal et al., 2021; Blaydes et al., 2021). Solar farms managed as wildflower meadows have been shown to have more foraging bumblebees in the immediately surrounding area than those comprised of turf (Blaydes et al., 2022). It has been suggested that locating honeybee hives on solar farms could also boost local pollination services, although this would require careful consideration given the potential for detrimental impacts on native pollinators (Armstrong et al., 2021).

Parts of the solar farm that are not dominated by the arrays of panels, such as field margins and areas around access routes, can provide opportunities for a range of generic interventions to benefit wildlife. Examples include retained or planted hedgerows, clumps of shrubs, ponds, log and brash piles and ditches or swales (e.g. BRE, 2014; Solar Energy UK, 2022). However, it will be necessary to better understand the potential for detrimental effects of solar panels on various species groups (see below), such as bats, birds and aquatic invertebrates in particular, to assess whether they are likely to benefit from such enhancements.

There is conflicting evidence for the abundance and diversity of bird species on solar farms in relation to surrounding areas. One study in the US identified lower bird species diversity on sites with solar panels compared to adjacent grassland, but substantially higher densities of certain species on the former (DeVault et al., 2014). Visser et al. (2019) observed reduced abundance and diversity of bird species on a solar facility compared to adjacent land. In contrast a comparative study by Montag et al. (2018) indicated that bird species diversity was higher overall on solar farm sites than adjacent undeveloped agricultural land, and bird abundance was higher on two of the solar farms. They attributed these benefits to the more diverse habitat providing better foraging and the availability of perching opportunities on the solar panels. Other studies have also identified birds using solar panels for perching, shade and providing nesting opportunities (Parker & McQueen, 2013; DeVault et al., 2014; Hernandez et al., 2014).

Despite calls for more studies on the potential adverse impacts of operational solar farms on wildlife (e.g. RSPB, 2014; Harrison et al., 2017; US Department of Energy, 2021) empirical evidence remains limited. This is captured by our literature search which only identified 19 articles (33.3% of the total) that described the collection of primary field data from solar farm sites. Potential impacts on birds were mentioned widely in the literature, although often the same small number of primary data sources were cited as supporting evidence. There is a clear lack of observational and experimental studies on impacts of solar farms on wildlife, and several articles identified a need for standardised approaches to assessing and monitoring solar farms for adverse impacts on birds and bats in particular (Walston et al., 2015; Conkling et al., 2021). Bird conservation groups have highlighted the absence of sufficient monitoring data from a range of sites to be able to determine whether solar farms are likely to have significant impacts on bird populations (e.g. RSPB, 2014) and have consequently developed best-practice guidance on monitoring and assessment methods (Jenkins et al., 2017). Specific guidance has also been developed for monitoring bird mortality associated with large-scale solar installations (Huso et al., 2021).

Collision with infrastructure on solar farms has been reported as a cause of mortality in birds, including endangered species (Penniman & Duffy, 2021), although the frequency of such incidents varies amongst sites (e.g. Kagan et al., 2014; Visser et al., 2019; Kosciuth et al., 2020), with one UK study finding no evidence of bird mortalities from solar panels (Feltwell, 2013). Avian mortality data from solar farms is subject to many potential biases and variation relating to the type of solar development and location. For example, mortality rates varied widely amongst different types of solar installation in a US study, with estimated collision rates for solar panel facilities being lower than for condensing or parabolic arrays (Kagan et al., 2014; Walston et al., 2016). Also, studies of mortality rates from the USA have focused on very large installations in arid environments, and so may not be reliably extrapolated to circumstances elsewhere. The majority of reports of bird mortality on solar farms suggest that collisions with infrastructure such as transmission lines may be more important than direct collisions with solar panels (e.g. Harrison et al., 2016; Kagan et al., 2014). Walston et al. (2016) concluded that passerine species were most at risk but using empirical data on bird collisions from a range of studies they estimated that overall mortality related to solar installations was likely to be negligible compared to other anthropogenic causes of death (e.g. wind turbines, power plants, other infrastructure). However, even relatively low levels of mortality could potentially have cumulative effects, particularly where clusters of solar developments occur (Birdlife Europe, 2011).

Some concern has been expressed that birds might collide with solar panels if they were to mistake them for waterbodies, a phenomenon sometimes referred to as the 'lake effect' (Kagan et al., 2014). It might be expected that such an effect would pose the greatest risk to migratory waterbirds and although a relatively high proportion of 'water-dependent' species were amongst the collision fatalities recorded at one large solar installation (Kagan et al., 2014) there is no evidence to directly support the 'lake effect' (Kosciuch et al., 2020). It has also been suggested that birds which drink on the wing (e.g. swallows) may be at risk (Bernath et al., 2001; Harrison et al., 2017), although evidence is again lacking. Measures that have been suggested to mitigate these perceived collision risks include avoiding provision of waterbodies on solar farms (Smith & Dwyer, 2016) and tilting solar panels to an upright position at night to reduce reflection of moonlight (Penniman & Duffy, 2021). However, the value of such measures is unclear as the question of whether solar farms contribute to bird mortality through collisions requires further investigation. Future studies should employ standardised monitoring approaches (Walston et al., 2015) and consider the potential for cumulative effects. It would also be useful to better understand whether solar farms may have indirect adverse impacts on bird populations (Lammerant et al., 2020), for example through enhanced predation (Smith & Dwyer, 2016).

One potential adverse impact of solar farms that has benefited from experimental studies is the issue of flying insects being attracted to solar panels. Mayflies, stone flies, long-legged flies, and horse flies have been shown to be attracted to solar panels as they use highly polarized reflected light to guide them towards water to lay their eggs (Horvath et al. 2010; Farkas et al. 2016). Other invertebrate species have also been shown to be similarly attracted to highly polarized light (e.g. Egri et al., 2016) with concerns being raised that interference with egg-laying (oviposition) behaviour could have the potential to cause population-level impacts (Taylor et al., 2019). Although many other artificial surfaces can also cause misplaced egg-laying behaviour in invertebrates, the impact of solar panels could potentially be locally significant if located near diverse assemblages of aquatic insects. Horvath et al. (2010) advised consideration of the presence of important populations of aquatic invertebrates when deciding on the location of solar farms and employing white borders or grids on panels to break up the reflective areas making them less attractive to egg laying invertebrates. Subsequent work indicated that white non-polarizing grids of line width 1-5 mm were sufficient to deter ovipositing behaviour in all aquatic insect taxa tested (Black & Robertson, 2020). Penniman & Duffy (2021) raised the question of whether such measures might also usefully help reduce the likelihood that birds would similarly mistake panels for water, although there is little evidence to support this hypothesis. Anti-reflective coating has also been proposed as a means of creating less polarized light although more research is required as its effects varied amongst insect taxa and under different prevailing light conditions (Szaz et al., 2016). Subsequently, Fritz et al. (2020) have showed that a micro-textured cover layer was effective in reducing polarized light reflection and hence the attractiveness of solar panels to horse flies and mayflies. However, there is little field evidence to confirm any adverse effects of in-situ solar panels on oviposition behaviour in insects.

Experimental studies indicate that bats can mistake horizontal smooth surfaces for water and attempt to drink from them (Greif & Siemers 2010) whilst vertical smooth surfaces can be mistaken for clear flight paths (Greif et al. 2017). This has raised concerns that bats might accidentally collide with solar panels, or that their reflective properties could be disorientating to echolocating bats, thus causing them to avoid solar farms (see Harrison et al., 2017; Szabadi et al., 2023). However, the effects of solar panels on bat behaviour are not currently known and results from the few monitoring studies conducted to date have been mixed. Montag et al. (2016) recorded lower levels of bat activity on some solar farms than on adjacent undeveloped farmland, although bats did not avoid the former and species diversity was similar in both locations. Unpublished preliminary data from a study in south-west England indicated substantially reduced bat activity on solar farms compared to matched undeveloped areas (R. McDonald, Exeter University, unpublished data). The reasons for such effects are unclear and their magnitude may vary amongst species, as suggested by a recent UK study which showed that solar farms were frequented by bat species which typically use anthropogenic landscapes but were avoided by rarer species (Szabadi et al., 2023).

Despite the relatively high profile that adverse impacts on wildlife are afforded in the literature we reviewed, direct evidence is scant. Previous reviews have come to similar conclusions, including Taylor et al. (2019) who also stated that many concerns were based on evidence from studies that were not designed to assess impacts from ground-mounted solar panels.

6 Conclusions

There is insufficient empirical data on the impacts of solar farms to inform best-practice guidance on reducing adverse impacts and enhancing sites for certain species groups. Furthermore, there is insufficient evidence to determine whether measures are indeed required to mitigate putative impacts of solar panels on specific groups of species (e.g. bats, aquatic insects). Also, most of the existing recommendations for habitat restoration and creation on solar farms are based on generic principles, and so are not tailored to the specific ecological conditions that prevail on these sites such as the microclimate and soil conditions beneath arrays. Consequently, there are many clear knowledge gaps in the evidence base. Below we describe several research priorities informed by our review of the literature, although this list is not exhaustive.

- Experimental studies on how to optimise native plant diversity in the heterogenous environment beneath and between rows of solar panels.
- Experimental studies on the comparative value of different planting regimes for enhancing pollinator and pest-predating insect diversity and abundance on solar farms. This should include assessment of the role that grazing animals may play and the potential to export ecosystem services into adjacent farmland.
- Collection of in situ monitoring data to assess the risks of bat collisions with solar panels and impacts on bat foraging activity, abundance and species diversity (comparison with undeveloped adjacent habitat).
- Collection of in situ monitoring data to assess the attractiveness of solar panels to invertebrates, and in particular their role in altering oviposition behaviour.
- Collection of in situ monitoring data to assess the risks of bird collisions with solar panels and related infrastructure, including assessment of population-level effects.

It should be noted that what is ideally required in each instance is the collection of quantitative data from a range of different sites (i.e. replicated studies), before and after development and along a gradient into land adjacent to the solar farm. However, it is acknowledged that for practical reasons the number of sites and scale of individual studies may in some cases be limited. Nevertheless, the dearth of evidence currently available means that even small-scale studies may make important contributions to the development of best-practice, and could contribute to meta-analyses (e.g. Blaydes et al., 2022).

The availability of better evidence on the risks and opportunities for biodiversity on solar farms will improve our capacity for effective habitat management and mitigation of adverse impacts. But this knowledge is also important for informing the future design of solar farms so that maximising such benefits is considered from inception. Solar farms can be considered as 'engineered ecosystems' (Semeraro et al., 2020), where there is an opportunity to deliver a range of ecosystem services including enhanced biodiversity, pollination services, carbon storage and water retention, whilst also generating clean, renewable energy.

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8 Appendix A – List of articles

Item type	Authors	Title	Journal	Publication year	DOI	Species Group	Management	Negative Impact	Data Collection	Region
Journal Article	Armstrong, A., Ostle, N. J., & Whitaker, J.	Solar park microclimate and vegetation management effects on grassland carbon cycling	Environmental Research Letters	2016	10.1088/1748-9326/11/7/074016	Plants	No	No	Yes	Europe
Report	Beatty B, Macknick J, Mccall J, Braus G, & Buckner D	Native Vegetation Performance under a Solar PV Array at the National Wind Technology Center	Department of Energy	2017	10.2172/1357887	Plants	Yes	No	Yes	North America
Report	Bennun L, van Bochove J, Ng C, Fletcher C, Wilson D, Phair N, & Carbone G	Mitigating biodiversity impacts associated with solar and wind energy development: synthesis and key messages	IUCN	2021	10.2305/IUCN.CH.2021.06.en	Not specific	No	Yes	No	Global
Journal Article	Black, T.V., Robertson, B.A.	How to disguise evolutionary traps created by solar panels	Journal of Insect Conservation	2020	10.1007/s10841-019-00191-5	Insects	No	Yes	No	Europe
Journal Article	Blaydes H, Potts SG, Whyatt JD, & Armstrong A	Opportunities to enhance pollinator biodiversity in solar parks	Renewable and Sustainable	2021	10.1016/j.rser.2021.111065	Insects (Pollinators)	Yes	No	No	Europe

			Energy Reviews							
Journal Article	Blaydes, H., Gardner, E., Whyatt, J. D., Potts, S. G., & Armstrong, A.	Solar park management and design to boost bumble bee populations	Environmental Research Letters	2022	10.1088/1748-9326/ac5840	Insects	Yes	No	Yes	Europe
Journal Article	Choi, C. S., Cagle, A. E., Macknick, J., Bloom, D.E., Caplan, J. S. & Ravi, S.	Effects of Revegetation on Soil Physical and Chemical Properties in Solar Photovoltaic Infrastructure.	Frontiers in Environmental Science	2020	10.3389/fenvs.2020.00140	Soil	No	No	Yes	North America
Journal Article	Conkling TJ, Loss SR, Diffendorfer JE, Duerr AE, & Katzner TE	Limitations, lack of standardization, and recommended best practices in studies of renewable energy effects on birds and bats	Conservation Biology	2021	10.1111/cobi.13457	Birds, Bats	No	Yes	No	North America
Journal Article	Cypher BL, Boroski BB, Burton RK, Meade DE, Phillips SE, Leitner P, Kelly EC, Westall TL, & Dart J	Photovoltaic solar farms in California: can we have renewable electricity and our species, too?	California Fish and Wildlife Journal	2021	10.51492/cfwj.hwisi.6	Mammals, birds, reptiles	No	Yes	Yes	North America
Journal Article	Dhar A, Naeth MA, Jennings PD, & El-Din MG	Perspectives on environmental impacts and a land reclamation strategy for solar and wind energy systems	Science of the Total Environment	2020	10.1016/j.scitotenv.2019.134602	Not specific	No	Yes	No	Global

Journal Article	Dolezal AG, Torres J, & O'Neal M.E.	Can Solar Energy Fuel Pollinator Conservation?	Environmental Entomology	2021	10.1093/ee/nvab041	Insects (Pollinators)	No	No	No	North America
Report	Fox, J & Bennett, A	Overview of Pollinator-Friendly Solar Energy		2019		Insects (Pollinators)	No	No	No	North America
Journal Article	Fritz B, Horváth G, Hünig R, Pereszlényi Á, Egri Á, Guttmann M, Schneider M, Lemmer U, Kriska G, & Gomard G	Bioreplicated coatings for photovoltaic solar panels nearly eliminate light pollution that harms polarotactic insects	PLoS ONE	2020	10.1371/journal.pone.0243296	Insects	No	Yes	No	Europe
Conference Paper	Fthenakis V, Blunden J, Green T, Krueger L, & Turney D	Large photovoltaic power plants: Wildlife impacts and benefits		2011	10.1109/PVSC.2011.6186348	Not specific	No	Yes	No	North America
Journal Article	Gove B, Williams LJ, Beresford AE, Roddis P, Campbell C, Teuten E, Langston RH, & Bradbury RB	Reconciling biodiversity conservation and widespread deployment of renewable energy technologies in the UK	PLoS ONE	2016	10.1371/journal.pone.0150956	Not specific	No	No	No	Europe
Journal Article	Graham M, Ates S, Melathopoulos AP, Moldenke AR,	Partial shading by solar panels delays bloom, increases floral abundance during the late-	Scientific Reports	2021	10.1038/s41598-021-86756-4	Insects (Pollinators), plants	No	No	Yes	North America

	DeBano SJ, Best LR, & Higgins CW	season for pollinators in a dryland, agrivoltaic ecosystem								
Journal Article	Grippo M, Hayse JW, & O'Connor BL	Solar Energy Development and Aquatic Ecosystems in the Southwestern United States: Potential Impacts, Mitigation, and Research Needs	Environmental Management	2015	10.1007/s00267-014-0384-x	Insects, birds	No	Yes	No	North America
Journal Article	Hamed TA, & Alshare A	Environmental Impact of Solar and Wind energy-A Review	Journal of Sustainable Development of Energy, Water and Environment Systems	2022	10.13044/j.sdewes.d9.0387	Not specific	No	Yes	No	Global
Report	Harrison C, Lloyd H, & Field C	Evidence review of the impact of solar farms on birds, bats and general ecology		2017	10.13140/RG.2.2.24726.96325	Birds, bats	No	Yes	No	Europe
Journal Article	Hernandez, R. R., Easter, S. B., Murphy-Mariscal, M. L., Maestre, F. T., Tavassoli, M., Allen, E. B., Barrows, C. W., Belnap, J., Ochoa-Hueso, R., Ravi, S. & Allen, M. F.	Environmental impacts of utility-scale solar energy	Renewable and Sustainable Energy Reviews	2014	10.1016/j.rser.2013.08.041	Not specific	No	Yes	No	North America

Miscellaneous	Hathcock C	Literature review on impacts to avian species from solar energy collection and suggested mitigations		2018	10.3133/ofr20161087	Birds	No	Yes	No	North America
Miscellaneous	Horváth G, Blahó M, Egri Á, Kriska G, Seres I, & Robertson B	Reducing the maladaptive attractiveness of solar panels to polarotactic insects	Conservation Biology	2010	10.1111/j.1523-1739.2010.01518.x	Insects	No	Yes	No	Europe
Report	Huso M, Dietsch T, & Nicolai C	Mortality Monitoring Design for Utility-Scale Solar Power Facilities	U.S. Geological Survey	2016	10.3133/ofr20161087	Birds, bats	No	No	No	North America
Miscellaneous	Kagan, R.A., Viner, T.C., Trail, P.W. and Espinoza, E.O.	Avian mortality at solar energy facilities in southern California: a preliminary analysis	National Fish and Wildlife Forensics Laboratory	2014		Birds	No	Yes	Yes	North America
Journal Article	Kosciuch K, Riser-Espinoza D, Gerringer M, & Erickson W	A summary of bird mortality at photovoltaic utility scale solar facilities in the Southwestern U.S	PLoS ONE	2020	10.1371/journal.pone.0232034	Birds	No	Yes	No	North America
Journal Article	Lafitte A, Sordello R, de Billy VC, Froidevaux J, Gourdain P, Kerbiriou C, Langridge J, Marx G, Schatz B,	What evidence exists regarding the effects of photovoltaic panels on biodiversity? A critical systematic map protocol	Environmental Evidence	2022	10.1186/s13750-022-00291-x	Not specific	No	Yes	No	Global

	Thierry C, & Reyjol Y									
Journal Article	Lambert Q, Bischoff A, Cueff S, Cluchier A, & Gros R	Effects of solar park construction and solar panels on soil quality, microclimate, CO 2 effluxes, and vegetation under a Mediterranean climate	Land Degradation and Development	2021	10.1002/ldr.4101ï	Plants, soil microbes	No	Yes	Yes	Europe
Journal Article	Lambert Q, Gros R, & Bischoff A	Ecological restoration of solar park plant communities and the effect of solar panels	Ecological Engineering	2022	10.1016/j.ecoleng.2022.106722	Plants	Yes	No	Yes	Europe
Report	Lammerant L, Laureysens I, & Driesen K	Potential impacts of solar, geothermal and ocean energy on habitats and species protected under the Birds and Habitats Directives		2020	10.2779/784760	Not specific	No	Yes	No	Global
Masters Thesis	Martin J	Ecosystem Enriching and Efficient Solar Energy: Exploring the Effects of Pollinator-Friendly Solar Facilities on Ecosystem Function and Solar Panel Efficiency	Unpublished Masters of Science thesis	2022	10.21220/0mv9-9h84	Plants, insects	Yes	No	Yes	North America
Miscellaneous	Miller J	Biodiversity Enhancements for Solar Farms	RSPB Presentation	2013		Birds	No	Yes	No	Europe
Report	Montag H, Parker G, & Clarkson T	The Effects of Solar Farms on Local Biodiversity; A Comparative Study		2016		Plants, insects, birds, bats	Yes	No	Yes	Europe

Journal Article	Moscatelli MC, Marabottini R, Massaccesi L, & Marinari S	Soil properties changes after seven years of ground mounted photovoltaic panels in Central Italy coastal area	Geoderma Regional	2022	10.1016/j.geodrs.2022.e00500	Soil microbes	No	Yes	Yes	Europe
Journal Article	Nordberg EJ, Caley MJ, & Schwarzkopf L	Designing solar farms for synergistic commercial and conservation outcomes	Solar Energy	2021	10.1016/j.solener.2021.09.090	Not specific	No	Yes	No	Australasia
Report	BRE. Eds Parker G E and Green L	Biodiversity Guidance for Solar Developments		2014		Not specific	No	No	No	Europe
Report	Parker G, & Monkhouse J	Realising the Biodiversity Potential of Solar Farms		2022		Not specific	No	No	No	Europe
Report	Parker GE, & Mcqueen C	Can Solar Farms Deliver Significant Benefits for Biodiversity?		2013		Plants, insects	Yes	No	Yes	Europe
Report	Penniman, J. F. & Duffy, D. C.	Best Management Practices to Protect Endangered and Native Birds at Solar Installations in Hawaiʻi		2021		Birds	No	Yes	No	Global
Miscellaneous	RSPB	Solar Power RSPB Policy Briefing		2017		Birds	No	No	No	Europe
Report	Scurlock J	BRE Agricultural Good Practice Guidance for Solar Farms		2014		Not specific	No	No	No	Europe

Journal Article	Semeraro T, Aretano R, Barca A, Pomes A, Giudice C, Gatto E, Lenucci M, Buccolieri R, Emmanuel R, Gao Z, & Scognamiglio A	A conceptual framework to design green infrastructure: Ecosystem services as an opportunity for creating shared value in ground photovoltaic systems	Land	2020	10.3390/land9080238	Not specific	No	No	No	Europe
Journal Article	Semeraro T, Pomes A, Giudice C, Negro D, & Aretano R	Planning ground based utility scale solar energy as green infrastructure to enhance ecosystem services	Energy Policy	2018	10.1016/j.enpol.2018.01.050	Plants	No	No	No	Europe
Journal Article	Sinha P, Hoffman B, Sakers J, & Althouse L	Best practices in responsible land use for improving biodiversity at a utility-scale solar facility	Case Studies in the Environment	2018	10.1525/cse.2018.001123	Not specific	Yes	No	Yes	North America
Miscellaneous	Smit HA	Guidelines to minimise the impact of birds on Solar Facilities and Associated Infrastructure in South Africa		2018		Birds	No	Yes	No	Africa
Journal Article	Smith J & Dwyer J	Avian interactions with renewable energy infrastructure: An update	The Condor	2016	https://doi.org/10.1650/CONDOR-15-61.1	Birds	No	Yes	No	Global

Miscellaneous	Solar Energy UK	Natural Capital Best Practice Guidance Increasing biodiversity at all stages of a solar farm's lifecycle	Solar Energy UK	2022		Not specific	No	No	No	Europe
Report	Steinberger K	Native Plant Installation and Maintenance for Solar Sites	The Nature Conservancy	2021		Not specific	No	No	No	North America
Journal Article	Száz D, Mihályi D, Farkas A, Egri Á, Barta A, Kriska G, Robertson B, & Horváth G	Polarized light pollution of matte solar panels: anti-reflective photovoltaics reduce polarized light pollution but benefit only some aquatic insects	Journal of Insect Conservation	2016	10.1007/s10841-016-9897-3	Insects	No	Yes	No	Europe
Report	Taylor R, Conway J, Gabb O, & Gillespie J	Potential ecological impacts of ground-mounted photovoltaic solar panels		2019		Insects, birds, mammals (bats)	No	Yes	No	Europe
Journal Article	Tsafack N, Fang W, Wang X, Xie Y, Wang X, & Fattorini S	Influence of grazing and solar panel installation on tenebrionid beetles (Coleoptera Tenebrionidae) of a central Asian steppe	Journal of Environmental Management	2022	10.1016/j.jenvman.2022.115791	Insects	No	No	Yes	Asia
Journal Article	Turney, D. & Fthenakis, V.	Environmental impacts from the installation and operation of large-scale solar power plant	Renewable and Sustainable Energy Reviews	2011	10.1016/j.rser.2011.04.023	Not specific	No	Yes	No	North America

Journal Article	Uldrijan D,Černý M,Winkler J	Solar Park: Opportunity or Threat for Vegetation and Ecosystem	Journal of Ecological Engineering	2022	10.12911/22998993/153456	Plants	No	No	Yes	Europe
Miscellaneous	United States Department of Energy	Solar Impacts on Wildlife and Ecosystems Request for Information Response Summary	US Department of Energy	2021		Not specific	No	Yes	No	North America
Journal Article	Vervloesem J,Marcheggiani E,Choudhury MD,Muys B	Effects of Photovoltaic Solar Farms on Microclimate and Vegetation Diversity	Sustainability (Switzerland)	2022	10.3390/su14127493	Plants	No	Yes	Yes	Europe
Journal Article	Visser, E., Perold, V., Ralston-Paton, S., Cardenal, A.C. & Ryan, P.G.	Assessing the impacts of a utility-scale photovoltaic solar energy facility on birds in the Northern Cape, South Africa	Renewable Energy	2019	10.1016/j.renene.2018.08.106	Birds	No	Yes	Yes	Africa
Report	Walston LJ, Rollins KE, Smith KP, LaGory KE, Sinclair K, Turchi C, Wendelin T, & Souder H	A Review of Avian Monitoring and Mitigation Information at Existing Utility-Scale Solar Facilities	US Department of Energy	2015		Birds	No	Yes	No	North America
Journal Article	Walston, L. J., Rollins, K. E., LaGory, K. E., Smith, K. P. & Meyers, S. A.	A preliminary assessment of avian mortality at utility scale solar energy facilities in the United States	Renewable Energy	2016	http://dx.doi.org/10.1016/j.renene.2016.02.041	Birds	No	Yes	Yes	North America

Journal Article	Yu Liu, Rui-Qi Zhang, Ze Huang, Zhen Cheng, Manuel López-Vicente, Xiao-Rong Ma, & Gao-Lin Wu	Solar photovoltaic panels significantly promote vegetation recovery by modifying the soil surface microhabitats in an arid sandy ecosystem	Land Degradation and Development	2019	https://doi.org/10.1002/ldr.3408	Plants	No	No	Yes	Asia