MachairWind Offshore Windfarm

Appendix 20.1 Climate Projection Data

This page is intentionally blank

TABLE OF CONTENTS

List of Tables

List of Plates

Glossary of Acronyms

Term	Definition
CCR	Climate Change Resilience
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
GHG	Greenhouse Gases
IEMA	Institute of Environmental Management and Assessment
IPCC	Intergovernmental Panel on Climate Change
km	Kilometres
ms^{-1}	Metres per second
RCP	Representative Concentration Pathways
SSP	Shared Socioeconomic Pathways
UK	United Kingdom
WDA	Windfarm Development Area
W/m^2	Watts per square metre

Glossary of Terms

Term	Definition
Climate Variable	Climate variable is defined as a measurable, monitorable aspect of the weather or climate such as temperature or wind speed.
Climate Hazard	Climate Hazard is defined as a weather or climate-related event or trend in climate variable, such as storms or heatwaves, which has potential to do harm to receptors.
Climate Change Impact	Climate Change Impact is defined as an impact from a climate hazard, such as asset damage or failure, which affects the ability of the receptor to maintain its function or purpose.
Climate Mitigation	Climate mitigation comprises measures designed to avoid, reduce or offset greenhouse gas emissions in order to limit the magnitude and rate of long-term climate change. This includes actions that reduce emissions at source, improve energy efficiency, substitute low-carbon energy sources, or increase the removal of greenhouse gases from the atmosphere.
Development Area	Application boundary for consenting purposes which, for the Project, consists of a Windfarm Development Area, Offshore Export Cable Corridor, and Onshore Transmission Development Area. Separate consent and marine licence applications will be submitted for each Development Area where applicable.
Embedded mitigation measure	Mitigation measures, including industry good practice measures, that are directly incorporated into the design for the MachairWind Windfarm Development Area to avoid or reduce environmental effects.
Environmental Impact Assessment (EIA) Regulations	A collective term referring to The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017 and The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017.
Environmental Impact Assessment (EIA)	The process of evaluating the likely significant environmental effects of a proposed development over and above the existing circumstances (or 'baseline').
Greenhouse gas	A gas in the Earth's atmosphere that traps heat by absorbing and emitting infrared radiation, a process known as the greenhouse effect. Also known by the collective shorthand "carbon".
Landfall	The area from Mean Low Water Springs to a transition bay(s), where the offshore export cable(s) come ashore.
Machair Wind Offshore Windfarm	An offshore windfarm capable of exporting around 2 GW of renewable energy to the National Electricity Transmission System. MachairWind Offshore Windfarm comprises three Development Areas: • The WDA – located on the west coast of Scotland to the northwest of Islay and west of Colonsay; • The Offshore Export Cable Corridor – a preliminary boundary extending from the WDA to mean high water springs at a landfall location near Girvan, South Ayrshire; and • The Onshore Transmission Development Area – a preliminary boundary which extends landward from mean low water springs and includes the land required for the landfall of the offshore export cables and their route up to but not including the proposed high voltage direct current switching station which will be developed and constructed by Transmission Owner, ScottishPower Transmission. Separate consent and licence applications will be submitted for each Development Area.
Mean sea level	The average level of the sea taking account of all tidal effects but excluding surge events.
The Applicant	The legal entity submitting consent applications for the MachairWind Offshore Windfarm, namely MachairWind Limited.
The Project	MachairWind Offshore Windfarm including all its Development Areas and associated infrastructure.

Term	Definition
Windfarm Development Area (WDA)	The application boundary within the OAA where consent will be sought for the proposed WDA infrastructure. The WDA infrastructure is subject to Section 36 consent and marine licence applications (generation and transmission) which are being applied for separately from the Offshore ECC infrastructure and OnTDA infrastructure.

1 INTRODUCTION

1. This Climate Projection Data is an appendix to **Chapter 20 Climate Change Risk Assessment** of the Machair Offshore Windfarm (WDA) Environmental Impact Assessment (EIA) Report (EIAR).

2. The purpose of this appendix is to present the climate projection data, which forms **Step 1** of the three-step Climate Change Risk (CCR) assessment (as detailed in **Chapter 20 Climate Change Risk Assessment**). **Chapter 20 Climate Change Risk Assessment** sets out the three-step methodology which has been adopted for the CCR assessment in line with industry good practice for assessment of climate change resilience.

3. Climate hazards which affect the ability of the receptor to achieve or maintain its functions or purpose have been identified in **Step 1** of the CCR assessment in **Chapter 20 Climate Change Risk Assessment**. The climate projection data is used to determine the exposure of those climate hazards. The exposure assessment identifies those hazards with a potential for likely significant effects, which are addressed in the detailed climate risk assessment.

1.1 Representative Concentration Pathways and Shared Socioeconomic Pathways

4. The Representative Concentration Pathways (RCP) scenarios cover a recent set of assumptions based upon future population dynamics, economic development, and account for international targets on reducing greenhouse gases (GHG) emissions. Each RCP scenario has a different climate outcome, given that they are based upon a different set of assumptions. Noting that the climate science guidance cautions against reliably placing probabilities on which scenario of GHG emissions is most likely, multiple RCP scenarios should be selected due to their relevance in presenting a range of possible outcomes over the phases of the WDA.

5. The 5th Assessment Report by the Intergovernmental Panel on Climate Change (IPCC, 2014) defines a range of RCP. These are different possible trajectories of atmospheric concentrations of GHG, based on socio-economic and policy assumptions used in climate change projection modelling.

6. RCP are used to predict future climate conditions. They help scientists and policymakers understand how different actions today can affect the climate in the future and help planners to develop strategies to make projects more resilient to climate change. The RCP scenarios provide the range of possible future climate conditions which might affect the WDA infrastructure.

7. The RCP scenarios are related to the concentrations of GHGs that would result in target amounts of radiative forcing (measured in watts per square meter (W/m^2)) at the top of the atmosphere by 2100, relative to pre-industrial levels. Radiative forcing is a measure of the influence of factors (like GHGs) on the energy balance of the Earth's atmosphere. The RCP scenarios are:

   - RCP2.6: Pathway where radiative forcing peaks at approximately 3 W/m^2 mid-century and then declines to 2.6 W/m^2 by 2100. This would require significant reductions in GHGs emissions and aims to limit global warming to below 2°C.
   - RCP4.5: Represents a stabilization of radiative forcing at 4.5 W/m^2 by 2100 without overshooting. It assumes that emissions will peak in around 2040 and then decline.
   - RCP6.0: Pathway stabilizes radiative forcing at 6 W/m^2 by 2100. Emissions peak in around 2080 and then decline.
   - RCP8.5: Radiative forcing reaches 8.5 W/m^2 by 2100. The pathway assumes continued increases in GHG emissions throughout the 21st century.

8. The more recent IPCC 6th Assessment Report (IPCC, 2021) uses different scenarios called Shared Socioeconomic Pathways (SSP). The SSPs are scenarios that describe different ways in which global society, demographics, and economics might evolve over the 21st century. They are used alongside the RCPs to explore how different socioeconomic futures could influence GHG emissions and climate change:

- SSP1: Pathway focused on sustainability, with low challenges to climate mitigation and adaptation. It can be aligned with lower RCPs (e.g. RCP2.6).
- SSP2: Scenario follows historical trends without significant changes in policy and can be aligned with intermediate RCPs (e.g. RCP4.5).
- SSP3: Pathway describes a fragmented world with many challenges to mitigation and adaptation. It is typically aligned with higher RCPs (e.g. RCP6.0 or RCP8.5).
- SSP4: Scenario envisions a world with high inequality, leading to challenges for adaptation. It can be associated with a range of RCPs depending on the level of emissions control achieved.
- SSP5: Pathway describes a world with rapid economic growth and high energy use, leading to many challenges for mitigation. It aligns with higher RCPs, e.g. RCP8.5.

9. RCP4.5 and RCP8.5 are often considered more relevant than RCP2.6 and RCP6.0 for the assessment of climate change risk and resilience due to their representation of more realistic and widely studied scenarios:

- RCP2.6: This pathway requires very stringent mitigation efforts to limit global warming to below 2°C. While desirable, it is considered less likely due to the significant global cooperation and rapid changes needed to achieve such low emissions.
- RCP4.5: This pathway assumes moderate mitigation efforts and is considered an intermediate scenario. It reflects a future where GHG emissions peak in around 2040 and then decline. This scenario is often used in climate modelling because it represents a plausible future with significant but achievable mitigation efforts.
- RCP6.0: This scenario assumes that emissions peak in around 2080 and then decline. It is less commonly used because it represents a less likely future compared to the more moderate RCP4.5 and the extreme RCP8.5.
- RCP8.5: Known as the "business-as-usual" scenario, RCP8.5 assumes no significant efforts to curb emissions, leading to continuous growth in GHG concentrations throughout the 21st century. This pathway is crucial for understanding the potential impacts of unmitigated climate change and is widely used to model worst-case scenarios.

10. Overall, RCP4.5 and RCP8.5 are more relevant for planning and policy-making as they provide a broader range of realistic outcomes, helping to understand and prepare for both moderate and severe impacts of climate change. These RCP scenarios are deemed most relevant for the lifecycle of the WDA infrastructure. Their relationship to the SSPs is summarised in **Table 1.1**.

Table 1.1 Representative concentration pathways and shared socioeconomic pathways scenarios

RCP Scenario	RCP Scenario Description	SSP Scenario	SSP Scenario Description	Increase in Global Surface Temperature by 2081-2100, Mean (Range)
RCP4.5	A stabilisation scenario, characterised by stabilisation of radiative forcing at approximately	SSP2-4.5	Middle of the Road, intermediate emissions	2.7°C (2.1°C to 3.5°C)

RCP Scenario	RCP Scenario Description	SSP Scenario	SSP Scenario Description	Increase in Global Surface Temperature by 2081-2100, Mean (Range)
	4.5 W/m² by 2100 without overshoot			
RCP8.5	High emissions scenario, leading to high GHG concentrations by 2100.	SSP5-8.5	Fossil-fuelled Development, very high emissions	4.4°C (3.3°C to 5.7°C)

11. RCP8.5 is used as a realistic worst-case scenario for climate change projection data relevant to the operation and decommissioning phases of the WDA Infrastructure, whilst RCP4.5 projection data is included to provide a comparison with the RCP8.5 data.

12. The UKCP18 probabilistic projection data used to define the Predicted Future Baseline for the WDA (see **Chapter 20 Climate Change Risk Assessment**) are available for the RCP emission scenarios but not the SSP scenarios. At the time of development of the UKCP18 database, only the IPCC's Fifth Assessment Report (focusing on RCP) had been published. The latest report (focusing on SSP) was published in 2021-2023. Updated, verified and authorised climate data modelled on the SSP scenarios is not yet available.

1.2 Projection Data

13. Temperature and precipitation anomaly data is available for a 25 km grid resolution for all RCP Scenarios. Temperature and precipitation data are available for the land-based grid cells only. These land-based projections have been extracted from the nearest grid cell for the WDA as shown in Figure 20.1 of **Chapter 20 Climate Change Risk Assessment**. The coordinates of the nearest grid cell are 137500.00, 662500.00.

14. Changes in the annual average temperature and precipitation rate anomalies compared to the 1981-2000 baseline are presented for the WDA Infrastructure in **Table 2.1** for the RCP4.5 (intermediate emission) scenario and in **Table 2.2** for the RCP8.5 (very high emission) scenario. These scenarios are considered the most likely to occur during the construction, operation and decommissioning phases of the WDA Infrastructure and present a range of outcomes in terms of climate change projection data.

15. Wind speed anomaly values (10 m above ground level) are available for a 12 km grid resolution for the RCP8.5 scenario only. This data has been extracted for the Administrative Region – 'West Scotland' under annual, winter and summer conditions for the period 1981-2081.

16. Some models and observations suggest that there has been an increase in the frequency of severe storms and in significant wave heights in UK waters since the 1950s (Marine Climate Change Impacts Partnership (MCCIP), 2020). However, Horsburgh et al. (2020) concluded that there is no observational evidence for long-term trends in either storminess across the UK or resultant storm surges. Simulations for storm surges over the 21st century suggest that there are likely to be no significant changes to storm surges in the UK. The Wolf et al. (2020) summary of future projections for storms and waves concluded that future projections for the waters surrounding the UK are sensitive to climate model projections for the North Atlantic storm track, which includes significant uncertainty. In the near future, natural variability dominates any climate-related trends in storms and

waves. Towards the end of the 21st century, there is some consensus that mean significant wave height is decreasing while the most extreme wave heights are increasing.

17. For the exposure assessment, climate change projection data was obtained from the UKCP18 database, and used to provide an understanding of trends in climate variables within the WDA over the construction, operation and decommissioning phases for the two RCP scenarios considered in the CCR assessment (RCP4.5 and RCP8.5).

18. For each RCP scenario, where relevant and available, climate change projection data was obtained for three probabilities: 10% (unlikely), 50% (central estimate of projections) and 90% (projections unlikely to be less than). This approach aligns with the requirements set out in the *Overarching National Policy Statement for Energy (EN- 1),* (Department for Energy Security & Net Zero, 2026), Institute of Environmental Management & Assessment's (IEMA) best practice guidance (IEMA, 2020), the *Scottish National Adaptation Plan* and *Adaptation Scotland* resources (Adaptation Scotland, 2025), Scottish Environment Protection Agency's (SEPA) *Climate Change Allowances for Flood Risk Assessment in Land Use Planning* (SEPA, 2025), and the *National Planning Framework 4 (NPF4) Planning Guidance: Policy 2 – Climate Mitigation and Adaptation* (Scottish Government, 2025) to confirm impacts are considered across a range of climate change scenarios.

19. UKCP18 probabilistic projections have been obtained for time periods which align with the construction, operation and decommissioning phases of the WDA Infrastructure, to represent the temporal scope of predicted future climate conditions within the WDA. The following 20-year time slices are used:

- Construction - 2030s (2020-2039);
- Operation - 2040s (2030-2049) and 2050s (2050-2069); and
- Decommissioning - 2070s (2070-2089).

20. The predicted future baseline is based on the anomaly relative to conditions for the baseline period of 1981-2000.

2 LAND-BASED CLIMATE PROJECTIONS1 – TEMPERATURE, PRECIPITATION AND WIND

Table 2.1 Temperature and precipitation projections for grid cells closest to the Machair WDA under RCP4.5 relative to the 1981 to 2000 baseline period

Climate Variable	Season	Unit	2020 – 2039			2030 – 2049			2050 - 2069			2070 - 2089		
			10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile
Air temperature anomaly	Annual mean	°C	0.25	0.70	1.19	0.28	0.81	1.39	0.41	1.10	1.85	0.73	1.58	2.51
	Annual maximum	°C	0.23	0.68	1.18	0.24	0.77	1.35	0.33	1.05	1.82	0.68	1.59	2.54
	Annual minimum	°C	0.24	0.74	1.28	0.31	0.88	1.54	0.33	1.05	1.82	0.72	1.64	2.69
	Summer maximum	°C	-0.11	0.58	1.29	-0.20	0.61	1.45	-0.18	0.94	2.09	0.27	1.65	3.12
	Summer minimum	°C	0.17	0.77	1.37	0.19	0.85	1.52	0.31	1.14	2.00	0.65	1.67	2.76
	Winter maximum	°C	-0.07	0.60	1.29	-0.01	0.74	1.49	0.14	0.99	1.93	0.31	1.35	2.47
	Winter minimum	°C	-0.08	0.70	1.54	-0.07	0.84	1.83	0.18	1.27	2.52	0.29	1.57	3.07

[1] Red cells show high anomaly; yellow cells show medium anomaly and green cells show low anomaly.

Climate Variable	Season	Unit	2020 – 2039			2030 – 2049			2050 - 2069			2070 - 2089		
			10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile
Precipitation rate anomaly	Annual	%	-2.27	4.88	12.32	-1.58	6.73	15.45	-2.87	7.22	17.85	-3.25	7.10	18.58
	Summer	%	-14.28	-1.97	10.77	-14.33	-1.92	10.79	-18.00	-5.54	7.04	-23.47	-9.97	4.17
	Winter	%	-5.18	9.98	26.02	-3.79	12.28	29.71	-4.52	13.39	34.14	2.53	23.43	47.37

Table 2.2 Temperature and precipitation projections for grid cells closest to the Machair WDA under RCP8.5 relative to the 1981 to 2000 baseline period

Climate Variable	Season	Unit	2020 – 2039			2030 – 2049			2050 - 2069			2070 - 2089		
			10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile
Air temperature anomaly	Annual mean	°C	0.33	0.81	1.33	0.43	1.02	1.66	0.76	1.61	2.52	1.39	2.56	3.83
	Annual maximum	°C	0.31	0.80	1.32	0.39	0.99	1.61	0.66	1.56	2.50	1.31	2.55	3.86
	Annual minimum	°C	0.31	0.85	1.42	0.44	1.11	1.80	0.66	1.56	2.50	1.37	2.67	4.09
	Summer maximum	°C	-0.02	0.71	1.47	-0.07	0.85	1.77	0.06	1.47	2.90	0.66	2.66	4.65
	Summer minimum	°C	0.26	0.89	1.52	0.35	1.08	1.82	0.67	1.68	2.75	1.29	2.74	4.21
	Winter maximum	°C	0.00	0.68	1.40	0.11	0.89	1.71	0.37	1.41	2.52	0.72	2.16	3.67
	Winter minimum	°C	-0.02	0.81	1.68	0.03	1.03	2.13	0.39	1.76	3.30	0.67	2.54	4.65

Climate Variable	Season	Unit	2020 – 2039			2030 – 2049			2050 - 2069			2070 - 2089		
			10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile
Precipitation rate anomaly	Annual	%	-2.22	5.18	13.31	-1.68	7.46	17.07	-2.96	8.84	21.68	-4.01	10.14	26.62
	Summer	%	-15.11	-2.78	10.67	-15.87	-3.26	9.91	-23.22	-8.47	6.16	-32.91	-15.24	2.39
	Winter	%	-4.69	10.97	27.53	-2.66	14.13	32.88	-2.57	18.30	43.80	4.52	33.53	68.47

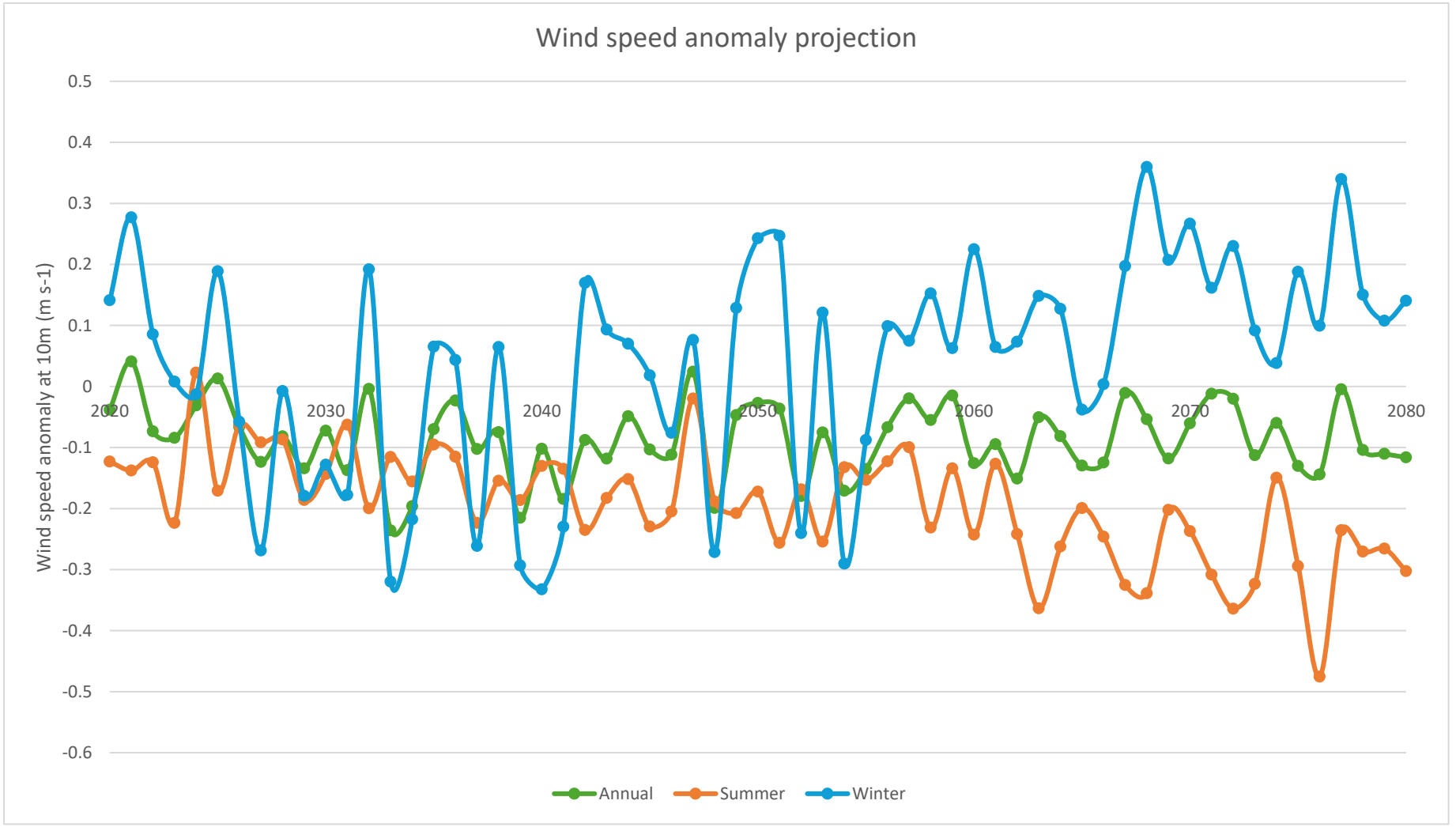

Plate 2.1 Wind Speed Projection Data for Administrative Region - West Scotland under RCP8.5 Relative to the 1981 to 2000 Baseline Period

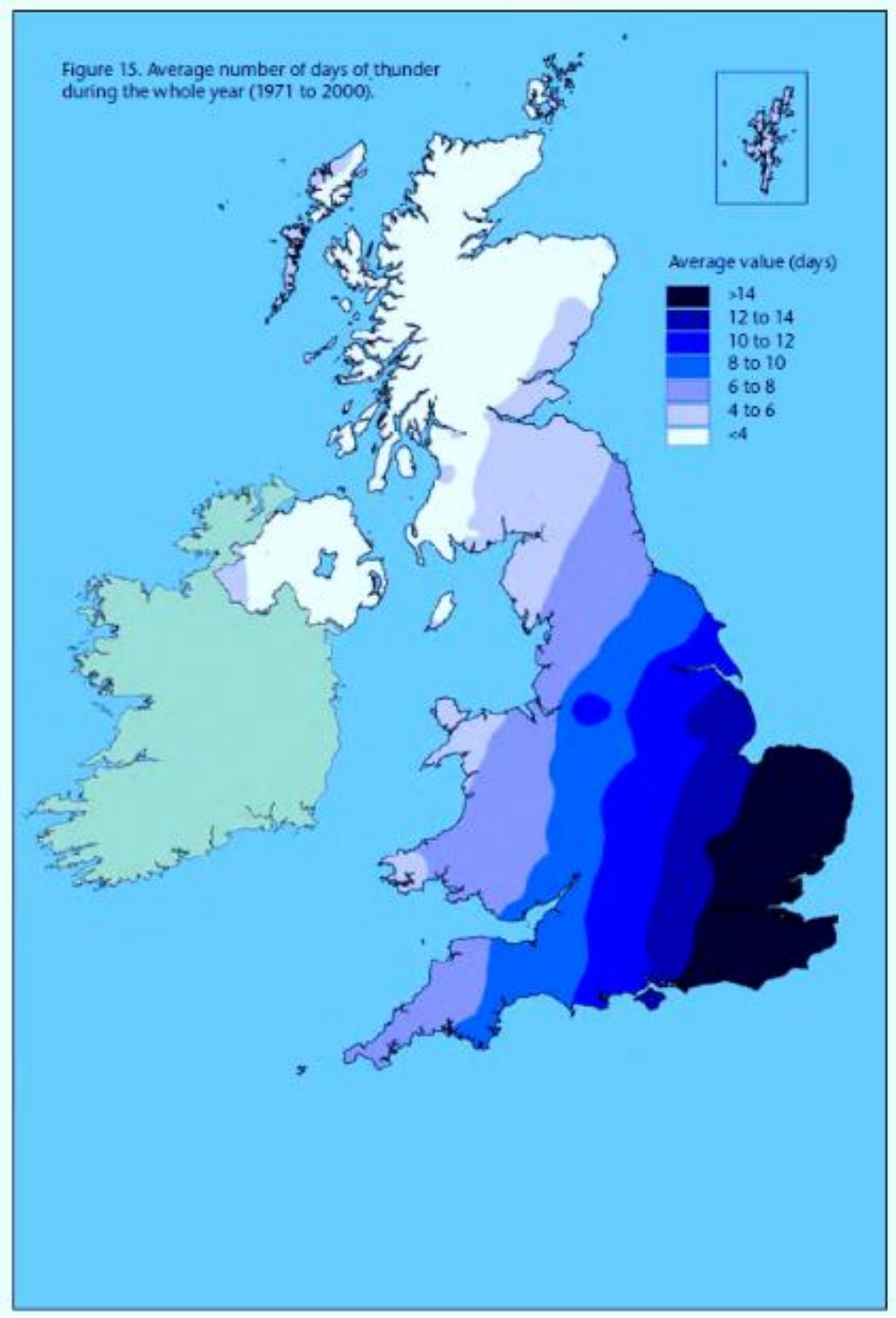

Plate 2.2 National Meteorological Library and Archive, Factsheet 2 – Thunderstorms, Met Office UK

References

Adaptation Scotland (2025) Adaptation Capability Framework and resources. Available at: https://adaptation.scot/ [Accessed 14 January 2026].

Department for Energy Security & Net Zero (2026) 'Overarching National Policy Statement for Energy (EN-1)', GOV.UK, published 6 January 2026. Ref: ISBN 978-1-5286-6066-2. Available at: https://www.gov.uk/government/publications/overarching-national-policy-statement-for-energy-en-1-2025 [Accessed 14 January 2026].

Horsburgh, K.J., Rennie, A. & Palmer, M.D. (2020) 'Impacts of climate change on sea-level rise relevant to the coastal and marine environment around the UK', in MCCIP Science Review 2020, pp. 116–131. doi: 10.14465/2020.arc06.slr.

Institute of Environmental Management & Assessment (IEMA) (2020) Environmental Impact Assessment Guide to: Climate Change Resilience and Adaptation. Available at: https://beta.evalforearth.org/resources/environmental-impact-assessment-guide-climate-change-resilience-adaptation [Accessed 28 November 2025].

IPCC (2014) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

IPCC (2021) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press. Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf [Accessed November 2025]. [ipcc.ch]

MCCIP (2020) Marine Climate Change Impacts Partnership Science Review 2020. Available at: https://www.mccip.org.uk [Accessed November 2025].

Met Office Hadley Centre (2018). UKCP18 Probabilistic Climate Projections. Centre for Environmental Data Analysis. Available at: http://catalogue.ceda.ac.uk/uuid/9842e395f2d04f48a177c3550756bf98 [Accessed August 2025].

Met Office Hadley Centre (2023). UKCP-18 Factsheet: Storms (Plate 2.2: Average number of days of thunder, 1971–2000) [PDF]. Centre for Environmental Data Analysis. Available at: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-factsheet-storms.pdf [metoffice.gov.uk]

Scottish Environment Protection Agency (SEPA) (2025) Climate change allowances for flood risk assessment in land use planning. Version 6, February 2025. Available at: climate-change-allowances-guidance_v6.pdf [Accessed 14 January 2026].

Scottish Government (2025) NPF4 Planning Guidance: Policy 2 – Climate Mitigation and Adaptation.

Wolf, J., Woolf, D. & Bricheno, L. (2020) 'Impacts of climate change on storms and waves relevant to the coastal and marine environment around the UK', MCCIP Science Review 2020, pp. 132–157. doi: 10.14465/2020.arc07.saw