Ausgrid Climate Impact Assessment

Letter to the Australian Energy Regulator

October 2022

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Dear Australian Energy Regulator,

About Risk Frontiers

Risk Frontiers has operated for 28 years and was established within Macquarie University, Sydney. We are a Partner Organisation of the ARC Centre of Excellence for Climate Extremes and were a Scientific Committee member of the Australian industry-led Climate Measurement Standards Initiative.

Risk Frontiers develops catastrophe loss models and natural hazard and climate datasets which are widely used in the (re)insurance sector as well as other sectors including banking, energy, government and infrastructure. Our products are used to understand and quantify the impacts of natural hazard and climate risks. Risk Frontiers' suite of five Australian probabilistic catastrophe loss models cover tropical cyclone, riverine flood, bush/grassfire, hail and earthquake.

About the project

Ausgrid has undertaken a physical climate risk assessment to better quantify risk under present day and future climate for a range of acute and chronic hazards including bushfire, flood, windstorm, heatwave, and coastal inundation. This report will help Ausgrid to plan for, manage and respond to the physical impacts of a warming world on people, assets and services.

Risk Frontiers has contributed to the Ausgrid physical climate risk assessment by providing catastrophe loss modelling and data derived from observations and regional climate model simulations. Risk Frontiers has also provided expert climate scientist advice on the use, interpretation and limitations of gridded weather and climate data products. The climate datasets and methodologies used in this project by Risk Frontiers have been described and evaluated in peer reviewed scientific literature such that they are currently considered the best available data for this purpose. Throughout this project uncertainties have been discussed with reference to published research, and wherever possible quantified.

The main conclusions from this work are that the hazards investigated pose a material risk to Ausgrid's assets and operations. Under a warming climate the frequency and/or intensity of bushfire, flood, windstorm, heatwave, and coastal inundation hazards will increase across Ausgrid's network area. These findings are consistent with existing published research and the latest IPCC report (IPCC AR6 2021). Without adaptation and/or mitigation measures the risks to Ausgrid's assets and operations will also increase. The results of this project should be used to guide Ausgrid's decision making on investments in adaptation and mitigation.

Climate data for Ausgrid network area

Information on historical weather and climate has been sourced from gridded data products produced by the Australian Bureau of Meteorology (BoM) and European Centre for Medium Range Weather Forecasting (ECMWF). These produces provide the most spatially complete historical weather information available, however they do have some limitations which are outlined in Appendix 1. Information about possible future climate has been sourced from regional climate model simulations produced by the CSIRO, NSW government, and other global research groups and are described in detail in Appendix 1.

Regional climate model simulations

The only evidence-based climate projections available are those produced by climate models which incorporate a physical understanding of how the climate system works. Climate model simulations produced as part of the Coupled Model Intercomparison Project (CMIP), including NARCliM1.5, provide the best available information on how climate might change in the future, however they are subject to a range of limitations (e.g., Alexander and Arblaster 2017, Remedio et al. 2019). Uncertainty in the skill of individual climate models is partially addressed by the ensemble approach, where output from at least three different models is considered. This uncertainty can be quantified in terms of the variability (standard deviation) between different models.

Evaluation

Evaluation of global climate models show that they are skillful in simulating the earth system. For example, climate extremes experienced in Australia, and globally during recent years are part of a continuing trend where each decade is hotter than the previous – this warming is entirely consistent with global climate model projections produced more than 20 years ago (Hausfather et al 2020).

Uncertainty

To help with communication to non-scientific audience, the Intergovernmental Panel on Climate Change (IPCC) created text-based definitions of uncertainty (confidence) using familiar terminology: low, medium, high. These text-based confidence definitions are based on the quantified variance (standard deviation) between model ensemble members as described above. The level of confidence varies across different climate variables.

Scenarios

Uncertainty about future climate change due to anthropogenic influences is partially encompassed by exploring low, moderate, and high greenhouse emission scenarios; these scenarios are called Representative Concentration Pathways (RCP2.6, RCP4.5, and RCP8.5). While RCP4.5 is now considered more likely than RCP2.6 or RCP8.5, all are possible, and it is important to understand the implications of a 'worst-case' scenario (Hausfather and Peters 2020).

For climate risk assessment the choice of scenario depends on the risk tolerance threshold. Over the past ~10 years global warming has been tracking equivalent to or higher than the worst-case scenarios. There is the possibility that the global geopolitical cooperation required to achieve even a RCP4.5 scenario will not eventuate. It is also possible that climate model simulations underestimate the full impact of a warming climate.

Climate thresholds

There is high uncertainty around the timing and magnitude of thresholds, tipping points and non-linear responses within the climate system. For example, it is currently not known whether events like the sudden stratospheric warming of 2019 will become more frequent in a warming world, or rapid ice sheet collapse will suddenly raise sea level by several meters. These changes may lead to abrupt, irreversible, and dangerous impacts with serious implications for humanity (McKay et al 2022). Due to high uncertainty these tipping points are mostly not simulated in the RCP scenarios, meaning that even the worst-case scenario could significantly underestimate real-world impacts of global warming.

Our understanding of the climate system response to warming and the skill of climate models is constantly improving. Future research and modelling projects will likely help to improve the accuracy and narrow the uncertainties seen in the current generation of models.

Appendix 1: Dataset descriptions

ERA-5 reanalysis

For this study, historical weather data are obtained from the European Centre for Medium Range Weather Forecasting (ECMWF) ERA5 and ERA5-Land reanalysis (Muñoz-Sabater et al 2019). ERA5-Land provides hourly weather variables on a 0.1x0.1 degree grid, which is approximately 9km spatial resolution. Reanalyses are a combination of weather model simulations and observations from satellites and weather stations. Reanalyses are used extensively in weather and climate research (https://reanalyses.org); although they have limitations, these are well understood. Reanalyses are used instead of weather station data for several important reasons, including:

- Weather station data coverage is not spatially continuous across NSW (or anywhere), whereas reanalyses provide modelled values (with assimilation) for all locations
- Reanalyses provide a more complete set of variables (windspeed, humidity, atmospheric pressure, etc) than are usually available from weather stations

Weather observations often have biases, missing data and quality issues; the Australian Bureau of Meteorology (BOM) carefully correct data for a limited number of high-quality stations (http://www.bom.gov.au/climate/data/acorn-sat/) which provides an excellent historical climate record with a wide range of variables, but unfortunately it is only for point locations and therefore not suitable for this type of analysis. Prior to assimilation in reanalyses, weather observations are rigorously quality controlled, and bias adjusted.

AWRA

The Australian Bureau of Meteorology (BOM) Australian Water Resources Assessment (AWRA) provides gridded hydrological and temperature data on a 0.05 degree grid (approximately 5km) for all of Australia. It is conceptually similar to the ERA5 reanalysis; however, it is produced by statistically interpolating weather station observations onto a regular grid, whereases reanalyses produce a regular grid of data by using weather observations to 'nudge' a dynamical weather forecast model.

ESCI-CORE

A recent report from the Energy Sector Climate Information (ESCI) Project evaluated a wide range of simulations from different RCM-GCM combinations. Simulations were bias corrected using Quantile Mapping for Extremes (QME) and evaluated for their suitability at representing rainfall and temperature for two scenarios: RCP4.5 and RCP8.5.

QME bias corrected simulations from three RCM-GCM combinations (CCAM-GFDL-ESM2M, CCAM-NORESM1-M, and NARCliMJ-CANESM2) were recommended as the most suitable ensemble for projections associated with rainfall, temperature, and FFDI: these three datasets will be referred to as the ESCI-CORE. An additional RCM-GCM combination, BARPA-ACCESS1-0, was also recommended in the ESCI report, but simulations were only produced for the period 1950 to 2060 and RCP8.5 scenario, so is not included in this study.

Ausgrid has requested the ESCI-CORE datasets be used for this analysis. The QME bias corrected temperature, precipitation and FFDI data were obtained from CSIRO for the three recommended RCM-GCM combinations, and the three NARCliM1.5 RCM-GCM combinations.

The ESCI-CORE datasets are used for evaluation of RCP4.5 and RCP8.5 scenarios for daily resolution rainfall and temperature hazards (riverine flood, drought, and heatwave). For aspects of the study where ESCI-CORE QME bias corrected data are not available alternative datasets are be used:

ESCI-CORE data is not available for RCP2.6. For this scenario all RCM data will be sourced from CORDEX-GERICS as outlined below.

NARCliM1.5

The NSW and ACT Regional Climate Model (NARCliM) climate model simulations version 1.5. NARCliM1.5 data are produced as part of a NSW government-led project providing high resolution climate change projections across NSW. NARCliM1.5 uses a regional climate model to dynamically downscale projections from three Coupled Model Intercomparison Project Phase 5 (CMIP5) models: CAN-ESM2, ACCESS1.0 and ACCESS1.3. These projections cover the 2006 to 2099 period at a spatial resolution of approximately 9km. Projections have been downscaled for two scenarios—RCP4.5 and RCP8.5. NARCliM1.5 was evaluated as part of the ESCI project, and NARCliM-CANESM2 was recommended as one of the ESCI-CORE models for evaluating temperature and rainfall.

CORDEX-GERICS

Data for the RCP2.6 scenario are sourced from RCM-GCM simulations developed by the Climate Service Center Germany (GERICS) as part of the Coordinated Regional Downscaling Project (CORDEX). The RCP2.6 scenario was not modelled as part of ESCI or NARCliM1.5.

CORDEX is a global framework for research organisations to develop and evaluate regional climate model simulations. Within the CORDEX-COmmon Regional Experiment (CORE) Framework global climate model simulations are dynamically downscaled for many regions of the global, including the Australia region. The resolution of the CORDEX-CORE domains is 0.22°x0.22° for an equatorial rotated coordinate system, resulting in a quasi-regular resolution of ~25km. There are 10 domains covering most global areas, and the Australian domain is called AUS-22. NARCliM1.5 is an example of a project that contributes to CORDEX. Several other organisations including the GERICS have used RCMs to produce downscaled simulations for the AUS region.

The driving CMIP5 models selected for the CORDEX-CORE ensemble offer a broad spread of equilibrium climate sensitivity (ECS) and were evaluated by McSweeney et al (2015) for their suitability for downscaling. Models were evaluated for their realism in simulating monsoon systems, storm tracks, teleconnections, annual cycle in temperature and precipitation for three continental-scale regions: Southeast Asia, Europe, and Africa. These models have not been evaluated for AUS-22, but the Southeast Asia domain includes parts of northern Australia.

Evaluation was by comparison against the observation-based ERA-40 reanalysis, and magnitude of projected change for 2070-2099 under rcp8.5. McSweeney et al (2015) recommended 9 models as suitable for downscaling. The three models used in the CORDEX simulation were chosen from this subset based on their range of equilibrium climate sensitivity (ECS):

- NCC-NORESM (low ECS)
- MPI-ESM-LR/MPI-ESM-MR (medium ECS)
- HadGEM-ES (high ECS)

The simulations used here were produced by GERICS using the REMO regional climate model. Simulations are available for rcp2.6, rcp8.5 (2006 to 2099), and historical (1950-2005).

Bias correction is required to ensure the RCM simulations are representative of observed climate. The CORDEX data are bias corrected against the AWRA gridded data and ERA5-Land reanalysis using the ESCI recommended Quantile Mapping for Extreme (QME) approach. QME also interpolates the GCM simulations to the same resolution as the historical data. The GERICS simulations are at a native resolution of ~25km and have been bias corrected and downscaled to AWRA data at ~5km resolution and the Era5-Land which is at a ~9km resolution.

Appendix 2: References

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Ausgrid Representative Concentration Pathway Weighting

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December 2022

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RISK FRONTIERS

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About Dr. Stuart Browning

Dr. Stuart Browning is Chief Climate Scientist at Risk Frontiers and has a PhD in multi-decadal climate variability. A former Lecturer in Climate Science at Macquarie University Stuart has a strong track record of publications in peer reviewed journals and over 15 years experience advising government and private sector on weather and climate risk.

Weighting of Representative Concentration Pathway Scenarios

Optimum climate scenario for cost benefit analysis of adaptation investments

The Ausgrid climate risk assessment has evaluated 3 possible climate futures as represented by Representative Concentration Pathways RCP2.6, RCP4.5, and RCP8.5. From an adaptation-risk perspective these can be viewed as low, medium, and high-risk futures. This is aligned with guidance from the Taskforce on Climate-Related Financial Disclosure (TCFD) and the Climate Measurement Standards Initiative (CMSI) which recommend at least 2 scenarios—a best and worst case to bracket possible future risk.

The climate scenarios were designed by the Intergovernmental Panel on Climate Change (IPCC) to span a range of possible climate futures, but they have intentionally avoided assigning probabilities to these scenarios, as the precise future is inherently unknowable. The TCFD and CMSI reports also do not provide guidance on assigning a specific scenario as the most likely or most suitable as a basis for financial disclosure or adaptation investments.

Attempting to determine which scenario is most likely has seen increased discussion recently in climate science literature. Current consensus follows that historical and anticipated future total CO_2 emissions to 2050 show more agreement with RCP8.5 than other scenarios (Schwalm et al

2020). However, beyond 2050 RCP8.5 is unlikely (Hausfather and Peters 2020; Huard et al 2022), with recent estimates of somewhere between RCP4.5 and SSP4-7.0 being our most likely future by 2100 (Burgess et al 2022). Noting that the current generation of climate scenario simulations do not simulate possible tipping points and threshold in the climate system (such as ice sheet collapse), the timing and magnitude of which are highly uncertain, but will significantly increase the impacts of global warming.

For organisations who wish to choose a single scenario to guide cost benefit analysis of adaptation investments, the decision around which scenario to use will be subjective, and should consider a range of factors including exposure, organisational risk tolerance, and cost-benefit of over or underinvestment in adaptation. For example, highly exposed entities with low risk tolerance (e.g. some agriculture and energy businesses) should use the worst-case scenario, while entities with low exposure and high risk tolerance (e.g. actuarial businesses) can afford to follow a best-case scenario.

In preparing a single-scenario recommendation for Ausgrid the following factors were taken into consideration:

- Exposure
- Expected impact on critical infrastructure
- Expected impact on communities
- Organisational risk tolerance
- Risk of over-investment
- Risk of under-investment
- Most likely future climate scenario, including possibility of tipping points and thresholds
    - There is high uncertainty around the timing and magnitude of thresholds, tipping points and non-linear responses within the climate system. For example, it is currently not known whether events like the sudden stratospheric warming of 2019 will become more frequent in a warming world, or rapid ice sheet collapse will suddenly raise sea level by several meters. These changes may lead to abrupt, irreversible, and dangerous impacts with serious implications for humanity (McKay et al 2022). Due to high uncertainty these tipping points are mostly not simulated in the RCP scenarios, meaning that even the worst-case scenario could significantly underestimate real-world impacts of global warming.
    - Our understanding of the climate system response to warming and the skill of climate models is constantly improving. Future research and modelling projects will likely help to improve the accuracy and narrow the uncertainties seen in the current generation of models.
-

For the purposes of future climate risk modelling for Ausgrid assets, a single scenario was calculated using a weighted average of the three modelled scenarios based on these factors:
RCP2.6 — 15%. A possible but increasingly unlikely best-case future
RCP4.5 — 70%. The most probable scenario post 2050, with significant risk and adaptation

challenges
RCP8.5 — 15%. A worst case, but still possible scenario, presenting very high risk and extreme adaptation challenges.

The weightings assigned to each scenario have been subjectively determined based off Ausgrid's discussions with expert climate scientists and their risk tolerance as a critical infrastructure provider, and should be reviewed periodically (~ every 5 years) as new evidence becomes available.

It is important to note that the weightings assigned by Ausgrid are more conservative on RCP8.5 than the view of Dr. Browning, who would weight the scenarios differently due to what has been historically demonstrated by society:

RCP2.6 — 0%.
RCP4.5 — 75%.
RCP8.5 — 25%.

Appendix : References

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