CASE STUDY FACT SHEET

ELECTRICITY
SECTOR
CLIMATE
INFORMATION
PROJECT

Bushfire risk affecting electricity distribution: Approaches to determine feasibility of Stand-Alone Power Systems

Introduction

The increasing frequency and intensity of bushfire weather associated with climate change may have implications for the safe and efficient operation of Australia's electricity networks. These risks can be assessed, and strategies for mitigation and adaptation should be integrated within ongoing planning and operational decision-making frameworks.

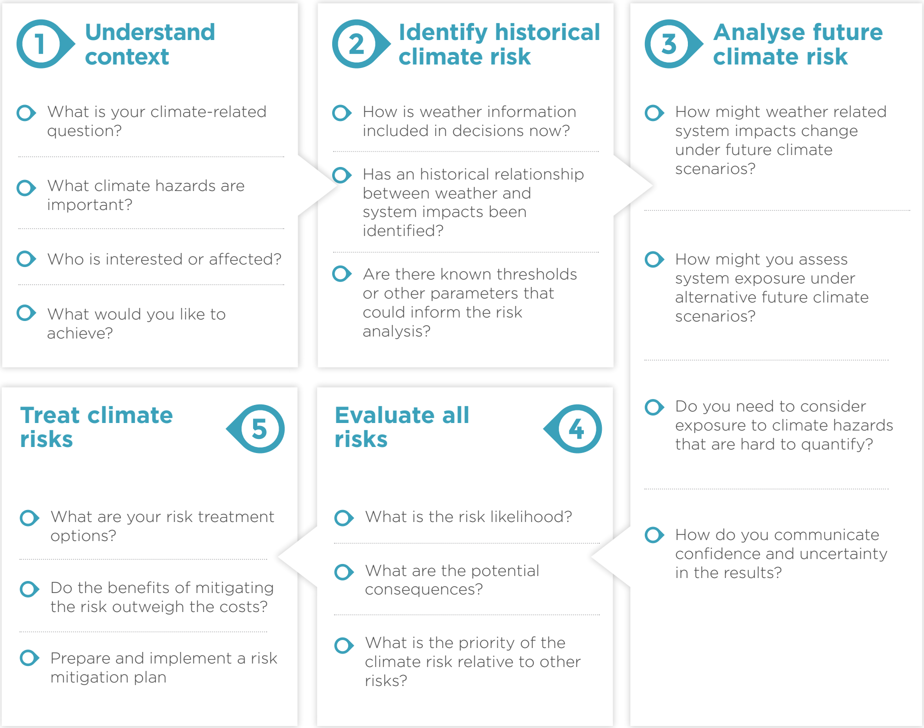
This Electricity Sector Climate Information (ESCI) case study, undertaken in collaboration with Energy Networks Australia (ENA) and the Total Environment Centre (TEC), explores the potential implications of projected changes to bushfire weather on the feasibility for introduction of stand-alone power systems (SAPS) to isolated townships in eastern Australia.

The case studies are designed to demonstrate the selection and application of appropriate climate information for long-term decision-making for the sector, and the use of the ESCI Climate Risk Assessment Framework.

This case study and other case studies from the project can be found at: www.climatechangeinaustralia.gov.au/en/projects/esci/esci-case-studies

Overview

The reliability of power supply to isolated townships is essential, however under changing climate conditions, the high voltage lines that supply isolated communities are likely to be increasingly exposed to bushfire hazard.



1 Understand context

- What is your climate-related question?
- What climate hazards are important?
- Who is interested or affected?
- What would you like to achieve?

2 Identify historical climate risk

- How is weather information included in decisions now?
- Has an historical relationship between weather and system impacts been identified?
- Are there known thresholds or other parameters that could inform the risk analysis?

3 Analyse future climate risk

- How might weather related system impacts change under future climate scenarios?
- How might you assess system exposure under alternative future climate scenarios?
- Do you need to consider exposure to climate hazards that are hard to quantify?
- How do you communicate confidence and uncertainty in the results?

4 Evaluate all risks

- What is the risk likelihood?
- What are the potential consequences?
- What is the priority of the climate risk relative to other risks?

5 Treat climate risks

- What are your risk treatment options?
- Do the benefits of mitigating the risk outweigh the costs?
- Prepare and implement a risk mitigation plan

Figure 1 ESCI Climate Risk Assessment Framework, based on International Standard ISO 31000 'Risk Management' and Australian Standard AS 5334 'Climate change adaptation for settlements and infrastructure'.

The Electricity Sector Climate Information (ESCI) project was funded by the Department of Industry, Science, Energy and Resources (DISER) and was a collaboration between the Bureau of Meteorology (BOM), the Commonwealth Scientific & Industrial Research Organisation (CSIRO) and the Australian Energy Market Operator (AEMO). The ESCI website is at: www.climatechangeinaustralia.gov.au/esci

Australian Government
Department of Industry, Science, Energy and Resources

Australian Government
Bureau of Meteorology

CSIRO

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

DISCLAIMER: This case study is intended as a guide for conducting a climate change risk assessment, not to provide information for use in operational decision-making as every organisation, location, and portfolio of risks is different and should be assessed in that context.

This case study demonstrates how to apply the ESCI Climate Risk Framework (Figure 1) to analyse the hazard associated with bushfire weather for the electricity distribution network. We assess future bushfire weather hazard using the Forest Fire Danger Index (FFDI) projections.

Understand context

Distribution networks, managed and operated by Distribution Network Service Providers (DNSPs), connect customers and households to the wider electricity system. Essential Energy, just one of three DNSPs in New South Wales (NSW), owns and operates over 183,000 km of powerlines, with over 163,000 km in bushfire-prone areas.[1] By comparison, the Transmission Network Service Provider (TNSP) in NSW, TransGrid, owns and operates 13,000 km of powerlines, with much lower exposure to natural hazards. Due to the distribution network's much larger exposure, over 94 per cent[2] of all power outages are the result of failures of distribution of various types, whereas failures from transmission networks represent less than 1 per cent of outages.

In this case study, we employ the ESCI Risk Assessment Framework for using climate information and data to improve the understanding of the magnitude of current and projected changes in frequency and duration of bushfire weather risk, based on the FFDI.

There are four 'switches' for fire activity: (1) ignition source, (2) fuel load, (3) fuel dryness and (4) suitable weather conditions for fire spread derived using daily temperature, humidity, windspeed and rainfall (Bradstock 2010). The FFDI incorporates two of the switches: fire weather and fuel dryness (in the FFDI Drought Factor). The Fire Danger Rating system used by emergency services is based on the FFDI, where FFDI > 50 is classed as 'severe' fire danger and FFDI > 25 is classed as 'very high' fire danger (BOM 2021).

It is important to note at the outset that the other components contributing to fire activity, that is, ignition source and fuel load, would also need to be considered when evaluating the results of the assessment.

Stakeholders

It is important to maintain reliability of supply of electricity to customers into the future, particularly those in rural communities who are likely to be reliant on electricity for cooling, communication, fuel supply, road transport and water supply. Bushfires can directly affect electricity reliability through the burning of power poles, with trees and debris also falling onto lines.

To maintain customer access to electricity, distribution network operators and asset managers and regulators will be required to consider and manage changing bushfire risk levels. Related to this is the frequency or timing of scheduled fuel management for the maintenance of powerline infrastructure. This may also be affected by changes to the duration of the bushfire season.

Identify historical climate risk

In cases where power lines are burned down during a bushfire, a community's electricity supply reliability can become affected, sometimes for protracted periods, particularly when there is only one high voltage (HV) distribution line feeding into the community. Subject to location-specific hazards, the longer the distribution line, the higher the risk of bushfire damage. It follows that communities and towns at the end of these lines are more vulnerable to being disconnected from electricity supply due to bushfire events.

The vulnerability of electricity networks to bushfires has been demonstrated on many occasions, including the Canberra fires in 2003, Victorian fires in 2009, Blue Mountains fires in 2013 and the widespread fires in 2019–2020. During 2019–2020, bushfires in Australia resulted in over 280,000 customers losing power for periods ranging from 1 to 10 days (Royal Commission on National Natural Disaster Arrangements 2020, p.229). These outages had a greater impact on rural communities where the loss of electricity not only means no refrigeration or air conditioning (extreme heat being the natural hazard of significance for mortality (Nairn and Williams 2020)) but also means the loss of mobile communications, transport disruption, the inability to charge a phone or computer, the inability to pump fuel and the inability to pump water to drink or to wash or fight fires.

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[1] Essential Energy (2017–2018). Annual report 2017–18: Empowering Communities. https://www.essentialenergy.com.au/-/media/Project/EssentialEnergy/Website/Files/About-Us/AnnualReport2017-2018.pdf?la=en&hash=FCF22A93C7F8C199A21E71185F28961D96C28E46

[2] Australian Energy Market Commission (2019). Consultation Paper: Definition of Unreserved Energy. https://www.aemc.gov.au/sites/default/files/2019-04/Consultation%20paper.pdf

This case study identified six locations where single, relatively long distribution lines pass through forested areas, potentially prone to bushfires, to selected isolated towns located on the east coast of Australia (Figure 2).

Figure 2 Key locations in study (green circles), transmission lines (purple lines). Distribution line map not available.

Observational records indicate that for the study sites there is a large variation in exposure to very high fire danger days (FFDI > 25) with Coonabarabran, NSW, having more than double the number of days than other sites, and Strahan, in Western Tasmania, having the fewest (Figure 3). Regional variation in vegetation prohibits direct comparison between regions, however of note is the increase in the number of high fire risk days across all the study sites from the 1960–1979 period (grey) compared to 1980–1999 (orange) and 2000–2020 (blue).

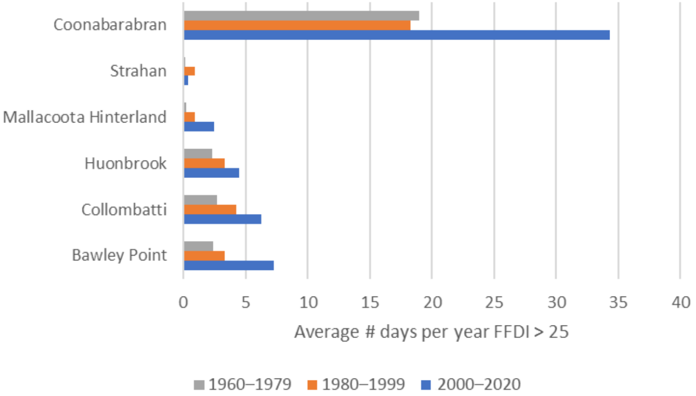

Figure 3 Average annual days FFDI > 25 for the 1960–1979, 1980–1999 and 2000–2020 periods for selected case study sites (Data source: Dowdy 2018).

Fire season length is found to be increasing over large areas of Australia (Dowdy 2018), with similar trends reported in North America, especially in eastern Canada and the south-western United States, which is consistent with an earlier fire season start and a later fire season end (Jain et al. 2017). In Collombatti, one of our case study sites, the fire season (defined here as first day with FFDI > 25) is currently commencing, on average, around 15 days earlier in the season than in 1950 (Figure 4).

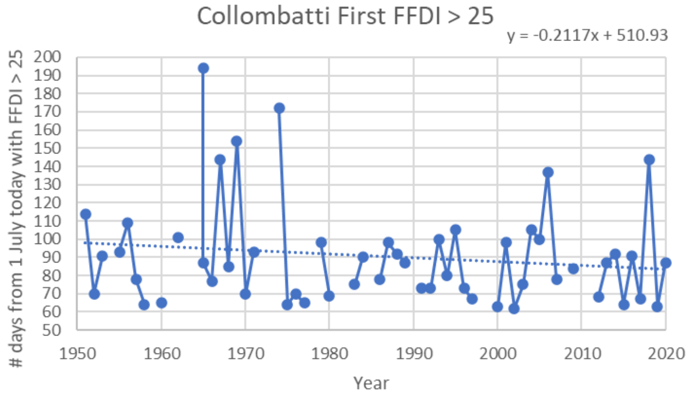

Figure 4 Number of days from 1 July to first occurrence of FFDI > 25 for Collombatti (NSW) for the period 1950–2020. Years are defined from July to June. (Data source: Dowdy 2018)

Past FFDI related exposure to power outages

DNSPs proactively manage bushfire risk through operational processes such as cutting back vegetation near power lines, reducing electricity flows (or de-energising) on windy or smoky days, and planning other maintenance so that it does not coincide with high bushfire risk or high temperature (therefore high demand) days. Despite this, a bad bushfire season, such as the 2019–2020 season can have a significant impact on network performance.

Severe rainfall deficiencies leading up to the spring and summer of 2019–2020 exacerbated bushfire hazard through increased fuel availability; the accumulated FFDI indices for spring 2019 were the highest on record for Australia as a whole (based on all years since 1950) (Figure 5). In the spring and summer of 2019–2020, known as the 'Black Summer', Australia faced severe and extensive bushfires over a drawn-out period.

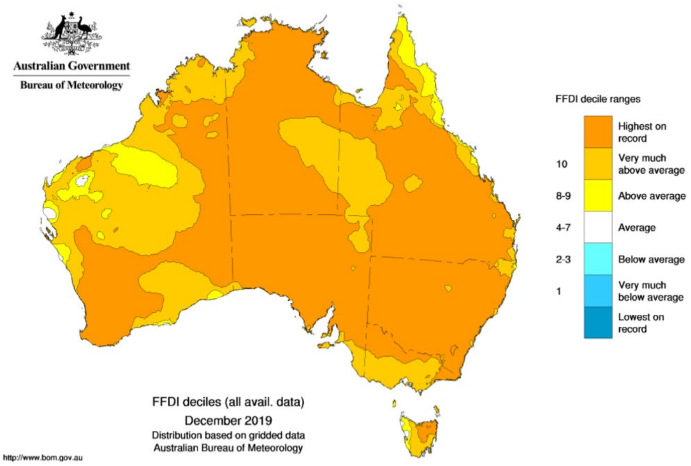

Figure 5 Accumulated FFDI deciles for December 2019 (based on all years since 1950). (Source: BOM, using the data set as described in Dowdy 2018)

The outcome for the electricity sector was that in the period from November 2019 to March 2020 the number of unplanned outages was significantly higher than in the previous summer, particularly in NSW, with the increase mainly due to bushfires between November 2019 and January 2020 (Figure 6).

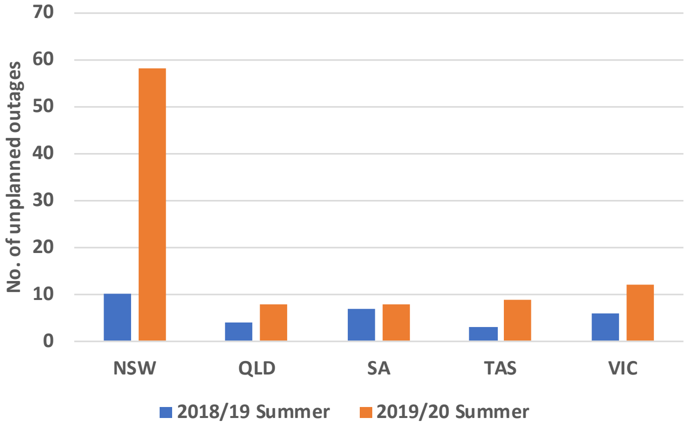

Figure 6 Number of unplanned transmission outages in NEM regions, summer 2019–2020 vs summer 2018–2019. (Data source: AEMO Summer 2019–20 NEM Operations Review)[3]

Analyse future climate risk

Projections indicate that bushfire risk will continue to increase over the coming decades due to greenhouse gas-induced climate change (Dowdy et al. 2019), with future energy supply reliability also potentially reduced. The following assessments explore projected changes in frequency and duration of bushfire weather risk for the case study locations.

Assessment locations

For this case study, we have identified six sites (Table 1) that fit the following criteria:

- Single HV distribution line passing through forested region
- 'Smaller' towns, villages or localities at the end of the line[4]
- Offer geographical and climatic diversity for ESCI case study demonstration

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[3] Australian Energy Market Operator (2020). 2019–20 NEM Summer Operations Review Report. https://www.aemo.com.au/-/media/files/electricity/nem/system-operations/summer-operations/2019-20/summer-2019-20-nem-operations-review.pdf?la=en

[4] CutlerMerz (2020). Opportunities for stand-alone power systems to enhance network resilience. https://www.energynetworks.com.au/resources/reports/2020-reports-and-publications/opportunities-for-saps-to-enhance-network-resilience/

Table 1 Selected locations for this distribution network case study (see Figure 2)

Study site or nearby town	Reason for selection (where relevant)	Latitude (°S)	Longitude (°E)
Huonbrook	Tyalgum is northern NSW representative.	28.54	153.36
Collombatti	Smaller town with a feeder close to large forest.	30.95	152.80
Coonabarabran	~150 km of feeder from Beryl to Coonabarabran	31.52	149.25
Bawley Point	middle of the two lines from Termeil to Bawley Point	35.49	150.36
Mallacoota hinterland	Middle of Noorinbee to Gipsy Point line	37.47	149.40
Strahan	45 km 22 kV feeder from Queenstown	42.14	145.46

Analysis period

Daily time-series of FFDI data are available for the 1980–2099 period, based on output from climate models.[5]

It is noted that the historic modelled and observational data have the similar statistical properties, however daily and annual sequences are not expected to be the same.

Future climate scenarios

Future climate scenarios are influenced by three main sources of uncertainty:

1. Future greenhouse gas emissions pathways
2. Regional climate model responses to a given emission scenario
3. Natural variability at timescales ranging from hours to decades

It is important to consider a range of greenhouse gas emission pathways and also a range of plausible regional responses simulated by different modelling groups from around the world.

Greenhouse gas concentration pathways

For this case study, a high emissions pathway (RCP8.5) was assessed to explore the changes to bushfire weather risk for DNSPs, noting that for a more thorough assessment it is strongly recommended a range of emission pathways are explored to assess potential best and worst cases (see ESCI Key Concept—Choosing emissions pathways (RCPs).

Climate models

Of the 40 global climate models available for assessing projected climate changes, each provides a different simulation of future weather and climate at a given location. There is not a single 'best' model for all applications so it is important to consider results from a range of models that sample the range of uncertainty.

The following climate models have been selected for exploring the potential range of future climate response:

- Greatest increase in FFDI or 'worst case' (GFDL-ESM2M)
- Mid-range increase in FFDI, with greater increase in the east than the west (CNRM-CM5)
- Mid-range increase in FFDI, with greater increase in the west than the east (ACCESS1.0)
- Least increase in FFDI or 'best case' (MIROC5)

For this case study projections for FFDI are produced using the Quantile Matching for Extremes (QME) methodology (Dowdy 2020), which ensures a good match between simulated and observed data.

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[5] See ESCI Key Concept—Climate models and downscaling.

Future fire weather risk

Given that very high and severe fire weather is measured at a daily timescale we explored daily FFDI time-series for the period 1980–2099, extracted for the locations of interest. Comparing the current and future fire weather risk provides an indication of changes in asset exposure and vulnerability, and so averages for a 20-year period centred on 1990 (1981–2000), and 20-year periods centred on 2050, 2070 and 2090 have been calculated and presented here. Timing of first and last day of year with FFDI > 25, used here to help indicate fire season duration, was also explored.

FFDI intensity

For the period 1979–2099 the number of days per year of 'FFDI between 25 and 50 (very high fire risk)' and 'FFDI > 50 (severe fire risk)' for Coonabarabran (a warmer site) and Mallacoota (a cooler site) are presented for the 'worst case' model under a high emissions pathway (Figure 7). The absolute number of very high and severe fire risk days is greater at Coonabarabran than at Mallacoota, and while large variability is evident from year to year at both sites, the frequency is increasing over the time period.

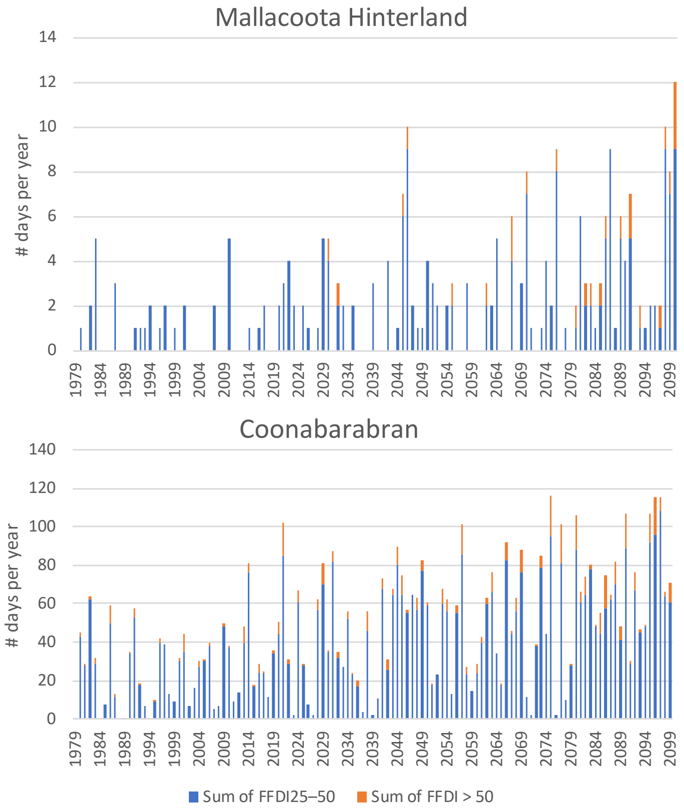

Figure 7 Number of days per year (June–July) 1979–2099 FFDI is between 25 and 50 (blue) and FFDI > 50 (orange) for Mallacoota Hinterland (top) and Coonabarabran (bottom) (GFDL_ESM2M climate model, RCP8.5). Note: different vertical scale.

FFDI frequency

For all sites, there is an increase in the mean number of days with FFDI > 25, on average, from the historic compared to the future periods. The range of uncertainty (due to regional climate model differences) increases after 2060 (Figure 8).

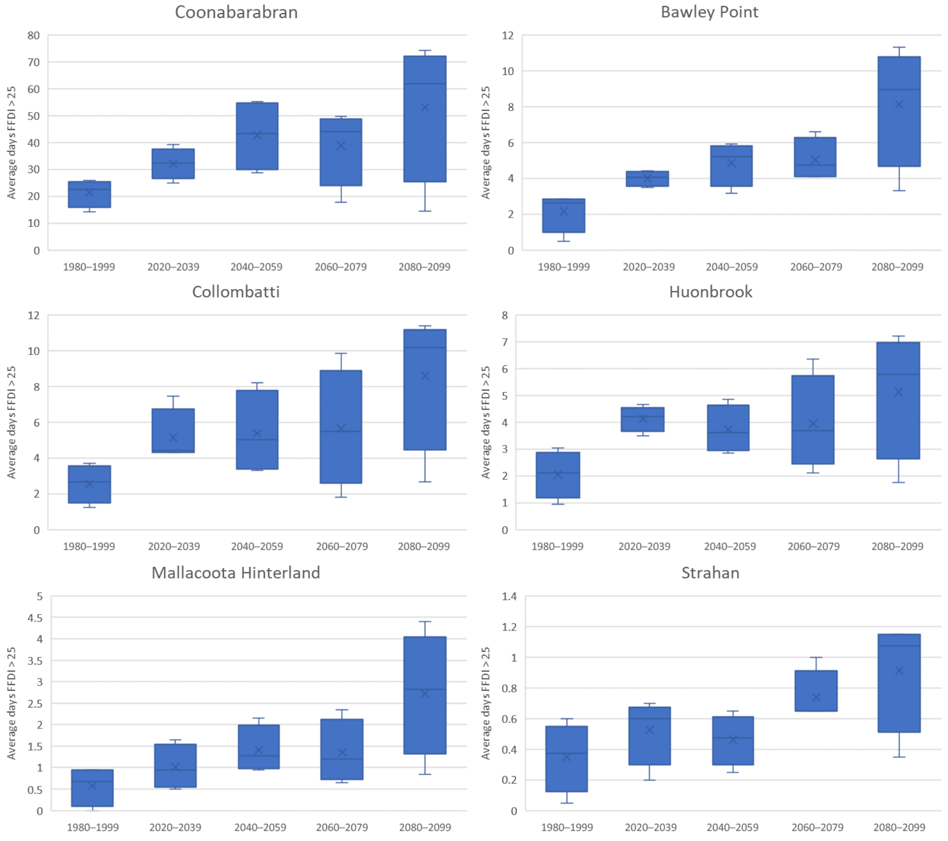

Figure 8 Modelled (RCP8.5) historical and future annual average (July–June) number of days with FFDI >25 for Coonabarabran (top left), Bawley Point (top right), Collombatti (mid left), Huonbrook (mid right), Mallacoota hinterland (bottom left), Strahan (Bottom right) across five 20-year periods. Blue box indicates 25th–75th percentile of the model range, with the mean indicated by 'X'. Note: Different vertical axis scales.

FFDI Duration

The duration of the fire season is defined here as the number of days per year (1 July–30 June) counted from the first day with FFDI > 25 to the last day with FFDI > 25. The current (1980–1999) number of days ranges from around five days for Strahan to around 100 days for Coonabarabran (Figure 10).

For all sites, the 'worst case' scenario, indicated by the top of the box-plots, shows a large increase in fire season duration from the historic (1980–1999) into the future periods. For example, Coonabarabran may see more than a doubling of the fire season duration by the end of the century under the high emissions scenario explored in this case study. The mean value across the four models (indicated by 'X' in the box-plot) also increases at all sites from earlier to later time periods. However, the 'best case' scenario (bottom of box-plot) for Coonabarabran, Collombatti and Strahan indicates a slight decrease in duration by the end of the century (Figure 9).

While the FFDI values vary greatly from Strahan in Tasmania to Coonabarabran in central western NSW, the potential for an increase in the frequency and duration of bushfire weather hazard is more consistent across all sites when considering changes in locally defined extremes (e.g. based on the number of days exceeding the historical 10-year return period values, as detailed in the ESCI Technical Report covering bushfires and other extremes).

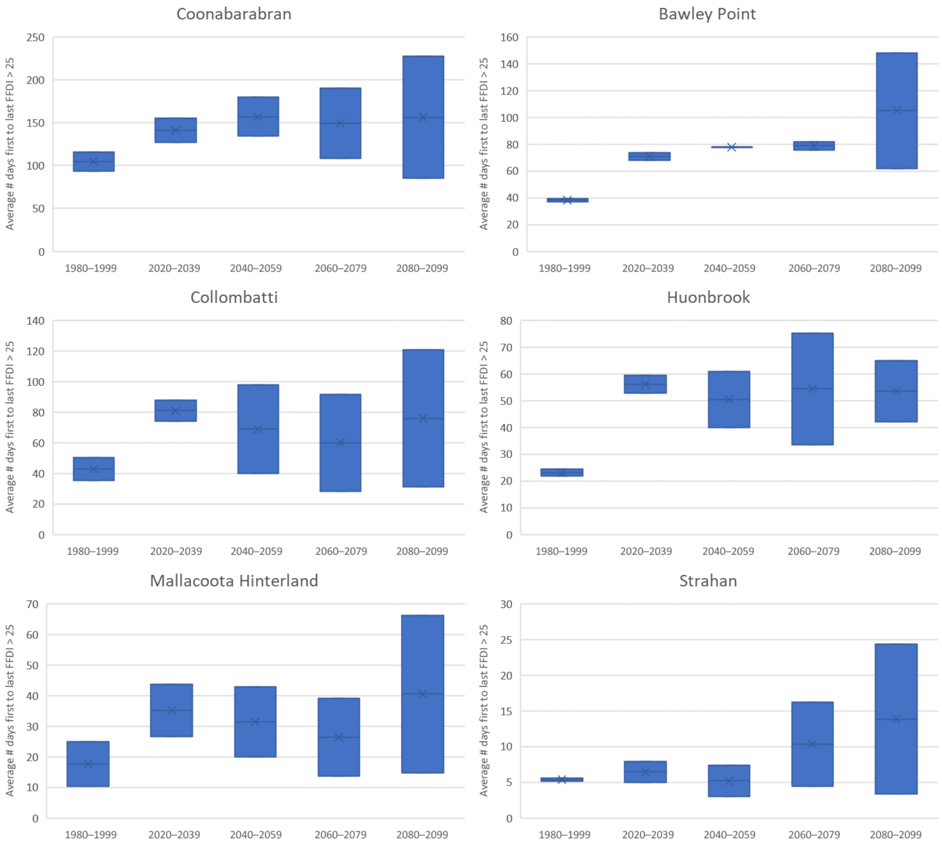

Figure 9 Fire season duration defined by the average number of days from first to last FFDI > 25 in the period 1 July–30 June for Coonabarabran (top left), Bawley Point (top right), Collombati (mid left), Huonbrook (mid right), Mallacoota Hinterland (bottom left), Strahan (Bottom right) across five 20-year periods from the worst case (GFDL_ESM2M) and best case (MIROC5) models (RCP8.5). Blue box indicates 25th–75th percentile of the model range, with the mean indicated by 'X'. NB: Different vertical axis scales.

Evaluate climate risk

DNSPs need to assess the future risk from bushfires in order to determine whether to replace damaged assets with like for like, or build back better or different, to ensure that customers have a resilient electricity supply. In the recent 2019–2020 bushfires, where large sections of network were lost, affected distribution network asset managers are considering whether to reinstate the line subject to the same risks, or explore other options. This may mean reducing the number of powerlines and taking communities off the grid, either permanently or in a way that allows a community to be 'islanded' (independent of the electricity network), or deploying key assets with other networks to support defensibility when required.

This type of decision-making is supported by a recent modelling assessment undertaken by Energy Networks Australia (ENA) (CutlerMerz 2020). The project explored feasibility of introduction of SAPS into a community to reduce electricity outages due to bushfires.

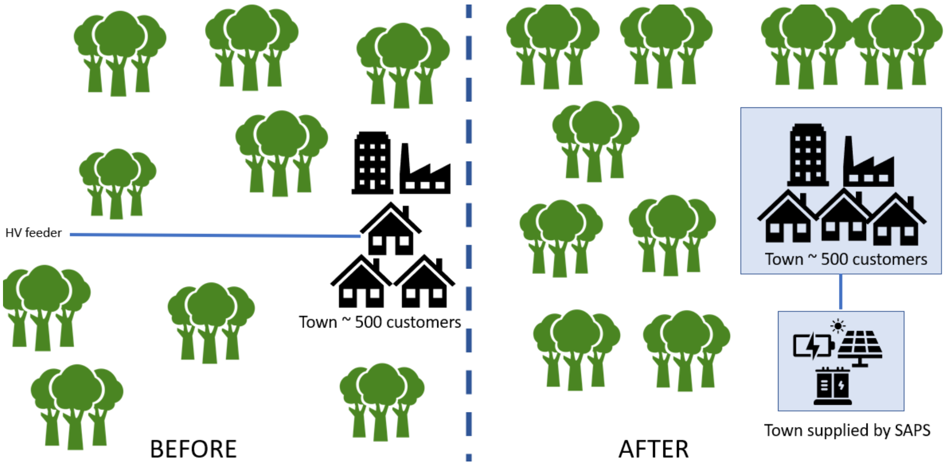

Figure 10 Concept diagram illustrating introduction of isolated SAPS to a remote town; one of the three case studies explored by CutlerMerz (2020). (Source: https://www.energynetworks.com.au/resources/reports/2020-reports-and-publications/opportunities-for-saps-to-enhance-network-resilience/)

The CutlerMerz (2020) study undertook a cost–benefit analysis considering both the costs (e.g. cost of SAPS system: PV, batteries, inverter, backup generator, etc.) and benefits (e.g. avoided network repairs, avoided bushfire unserved energy, avoided wholesale energy costs, avoided standard network maintenance, avoided forest management costs). In addition, an associated sensitivity analysis indicated how the feasibility might change with based on the current bushfire hazard (Zhang et al. 2016).

It is well understood by DNSPs that where distribution lines are removed, there are significant savings in the elimination of vegetation maintenance, a major part of the maintenance budget for both distribution and transmission line operators each year. Furthermore, if SAPS or undergrounding are introduced, customers no longer experience long duration outages when the line is damaged or destroyed during a natural hazard event. Understanding how bushfire weather may change across different sites around Australia (e.g. Table 2) can inform feasibility studies such as that described by CutlerMerz.

Table 2 Mean percent change (cf. 1980–1999) in average days per year with FFDI > 25 for two 20-year periods for RCP8.5 indicating the range for the 'best case' (MIROC5) and 'worst case' (GFDL_ESM2M) climate models.

Location	2040-2059	2060-2079
Coonabarabran	79 (37-120) %	46 (15-106) %
Bawley Point	84 (71-96) %	89 (46-132) %
Collombatti	93 (64-122) %	74 (-18-166) %
Huonbrook	81 (50-111) %	94 (11-176) %
Mallacoota Hinterland	69 (11-126) %	58 (-32-147) %
Strahan	11 (8-13) %	65 (63-67) %

For the 2050 (2040–2059) period, the 'worst case' model (under high emissions, RCP8.5) indicates a possible doubling of bushfire weather frequency (i.e. up to 100 per cent increase) at all sites except Strahan (Table 2). For the 2070 (2060–2079) period, the 'worst case' model (under high emissions, RCP8.5) indicates increases of around 150 per cent at all sites except Strahan, while the 'best case' indicates a mixture of moderate increases and decreases.

Confidence in the climate projections and sources of uncertainty

When evaluating risk, it is important to consider the range of risk exposure, so while, on average, there is an increased frequency of bushfire weather risk (e.g. Table 2), the MIROC5 model, representing a wetter future climate, does not indicate increases for all sites (e.g. Figure 11). Decision-makers need to be made aware of the variability in model outputs, as climate scientists cannot indicate which model outcome is more likely. Decision-makers can use 'model agreement', that is, maximum consensus, as one method to guide decision making (e.g. Clarke et al. 2011), or consider models that present more unusual or extreme scenarios, depending upon organisational risk appetite or the type of decision that is being made.

Another factor to consider when assessing the results is that there are four 'switches' for fire activity: (1) ignition source, (2) fuel load, (3) fuel dryness and (4) suitable weather conditions for fire spread (Bradstock 2010). The Forest Fire Danger Index (FFDI) relates to only two of the switches: fire weather and fuel dryness (in the FFDI Drought Factor). The other components would need to be considered when evaluating the results of the hazards assessment, with exposure and vulnerability also needed to complete the risk assessment.

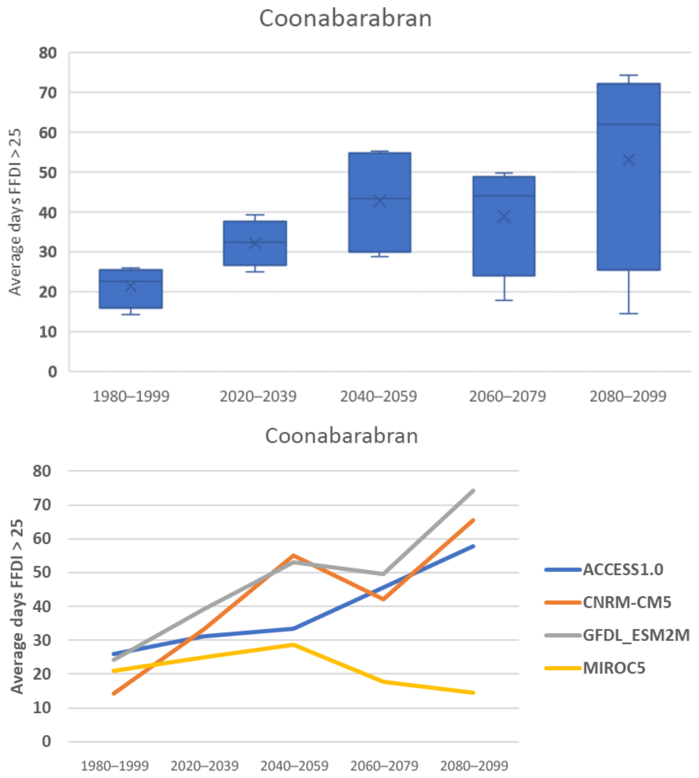

Figure 11 Range of change in FFDI frequency represented using box-plots (top) and line graphs (bottom).

Finally, as discussed earlier, RCPs range from low (RCP2.6), to medium (RCP4.5) to high (RCP 8.5). It is strongly recommended that a range of concentration pathways is used in climate risk assessments. For this risk assessment demonstration, only the high (RCP 8.5) pathway was explored. To complete the assessment thoroughly, other RCPs should be explored, or at least considered, in the decision-making process.

Risk treatment

As indicated above, the FFDI provides a partial measure of fire activity. Other factors will also determine future fire hazard such as changes in ignition, vegetation type/load, fire management practices/technology, planning regulations, population changes, opportunities for fuel reduction burning, and the level of community support for mitigation strategies (e.g. more fuel reduction burns and associated smoke, implementation of SAPS, underground cables).

In addition to the changing bushfire hazard in our warming world, exposure and vulnerability also form part of risk, and it is those factors that can be treated in some cases to help reduce risk. Reducing exposure or vulnerability to bushfires is a form of climate adaptation that could be used to help mitigate the increasing hazard due to climate change.

Potential adaptation options that might be considered from understanding the new bushfire risk probabilities could include those listed in the CutlerMerz study. These take into account a comparison of costs, with an appropriate discount rate, and wider regional, state, national, social, economic and environmental costs and benefits, for example:

- Installation of isolated SAPS
- Installation of islandable SAPS
- Community 'retreat' SAPS (significant community assets are part of a SAPS)
- Supporting customers to deploy rooftop solar PV that is islandable (e.g. with complementary batter storage)
- Business as usual (replace the line like-for-like)
- Replacing overhead networks with underground cables

Further Information

The goal of the ESCI project is to provide climate information to support risk analyses and decision making by electricity sector stakeholders. This case study provides an example of how this can be done. It is not intended to provide recommendations for risk mitigation options as every asset and location is different.

Maps of changes in FFDI and time-series of FFDI projections for multiple climate models and 168 locations around the NEM are accessible via the ESCI portal. The website also provides more general information on how to conduct a climate risk analysis and access to additional support materials.

The ESCI team would like to thank ENA, TEC, and Essential Energy for their involvement in this case study.

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