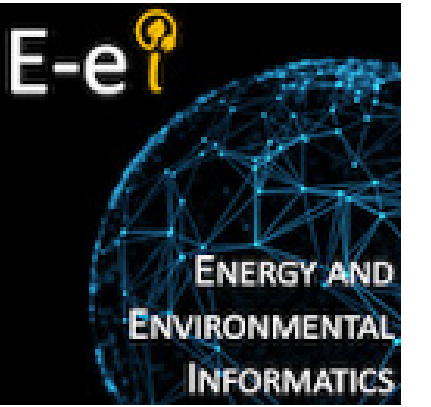


Grid Resilience in a Warming Climate: Wildfire Risk Management through Distributed Renewables

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Key takeaways

- Prototype Wildfire Energy Model (WEM) developed to assess power grid resilience during wildfire seasons in Victoria, Australia
- High-resolution Fire Weather Index (FWI) data calculated and integrated with power flow analysis
- Distributed wind generation (DG) investigated as a solution to enhance grid resilience
- Cost-benefit analysis conducted to determine the breakeven Value of Lost Load (VoLL) for renewable investment

Background

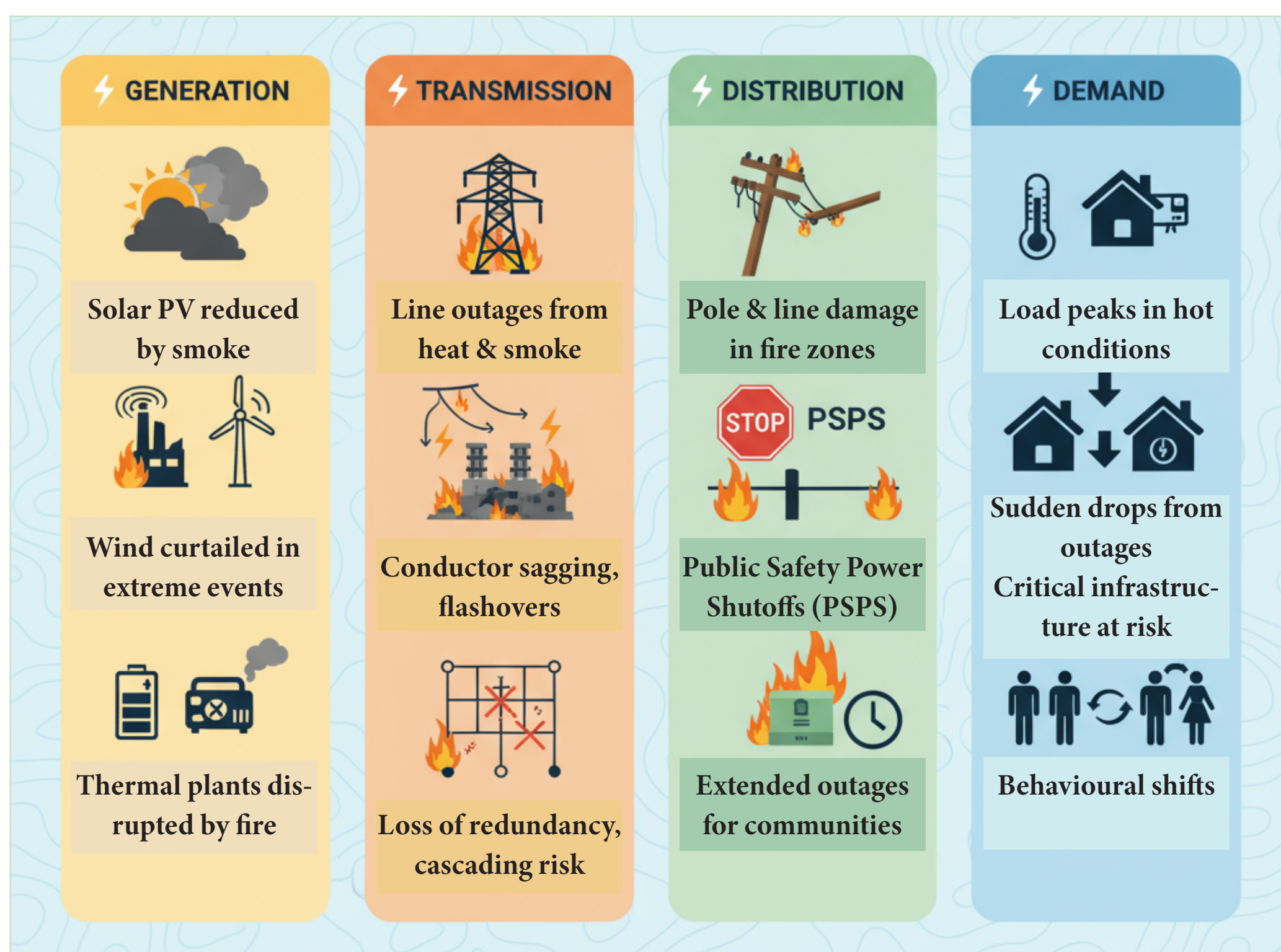


Figure 1. Wildfire impact on power systems - a multi-stage challenge

- Between 2000 and 2016, Californian wildfires caused network damages costing over \$700 million [1]
- Over 280,000 Australian customers lost power for days during the 2019–2020 Black Summer [2]

Research question

How to model and enhance power system resilience under extreme wildfire risks?

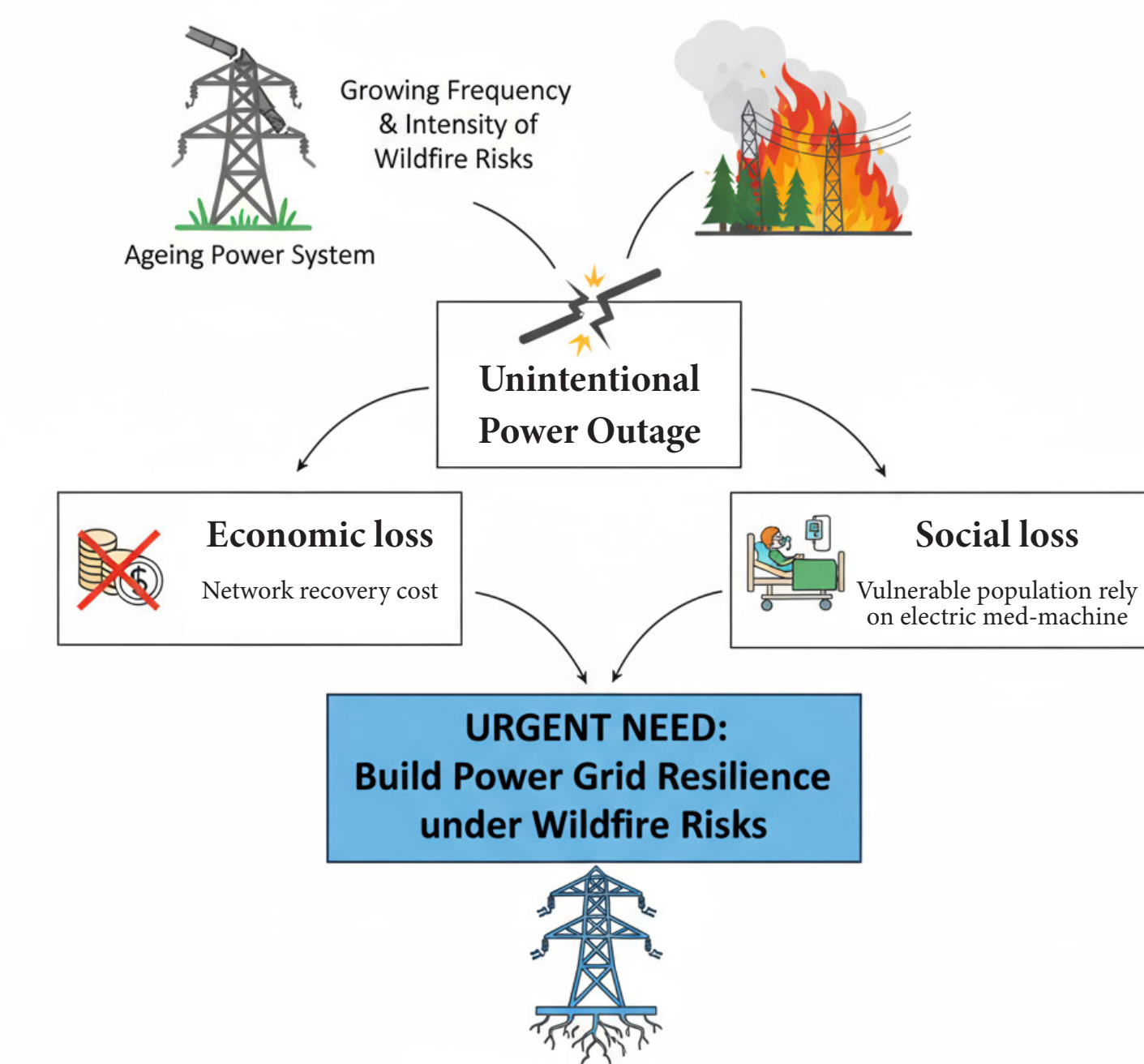


Figure 2. Motivation to enhance power grid resilience under wildfire risks

- A large portion of networks in developed economies like Europe and the US is over 40 years old [3]
- Extreme wildfire activity has more than doubled worldwide in the last two decades [4]

Power system

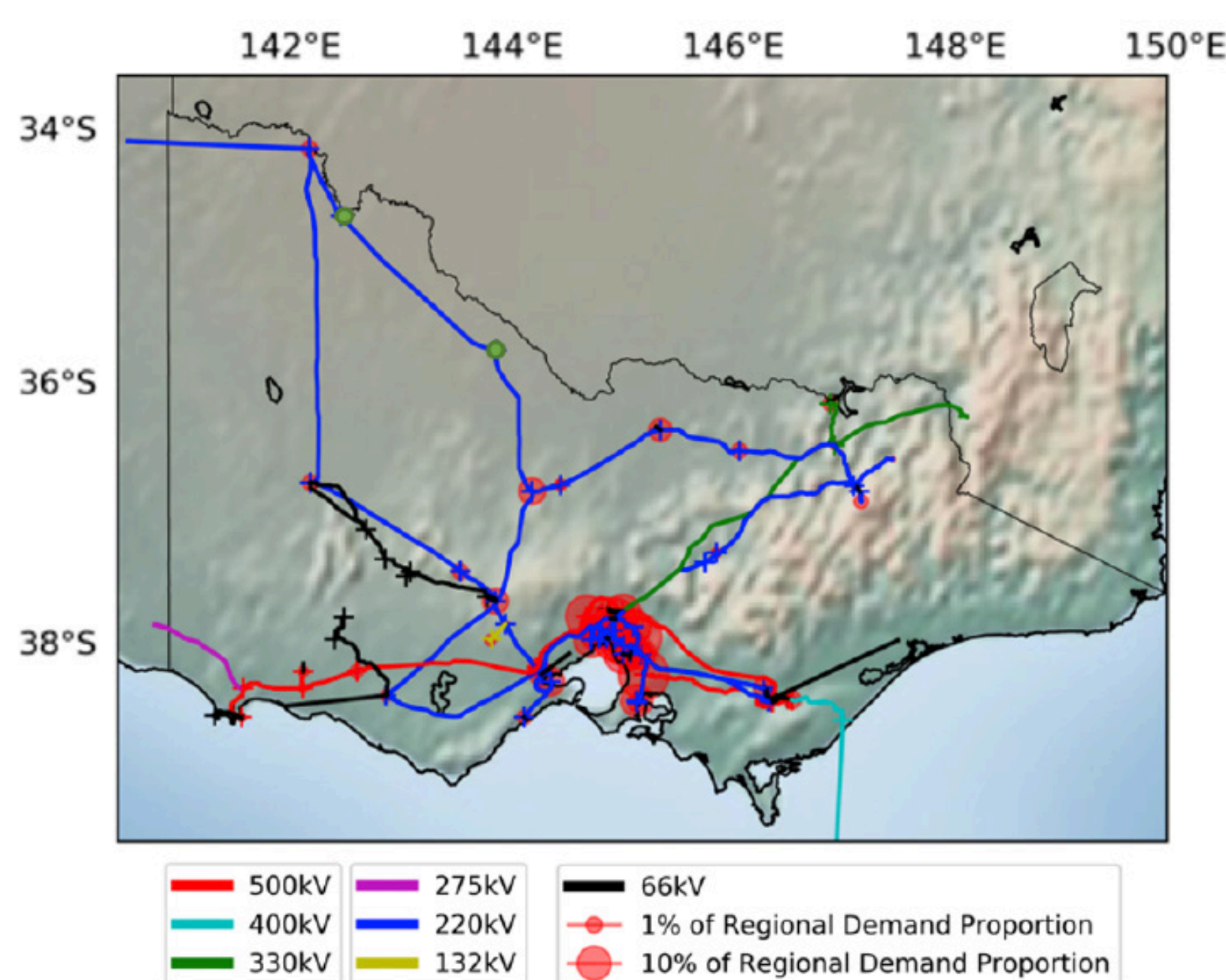


Figure 3. Transmission network in Victoria, Australia

- Network component: 72 buses, 122 transmission lines, and 84 power generators
- Power flow analysis - objective: minimise the overall system operational cost while satisfying all security constraints

Wildfire risk

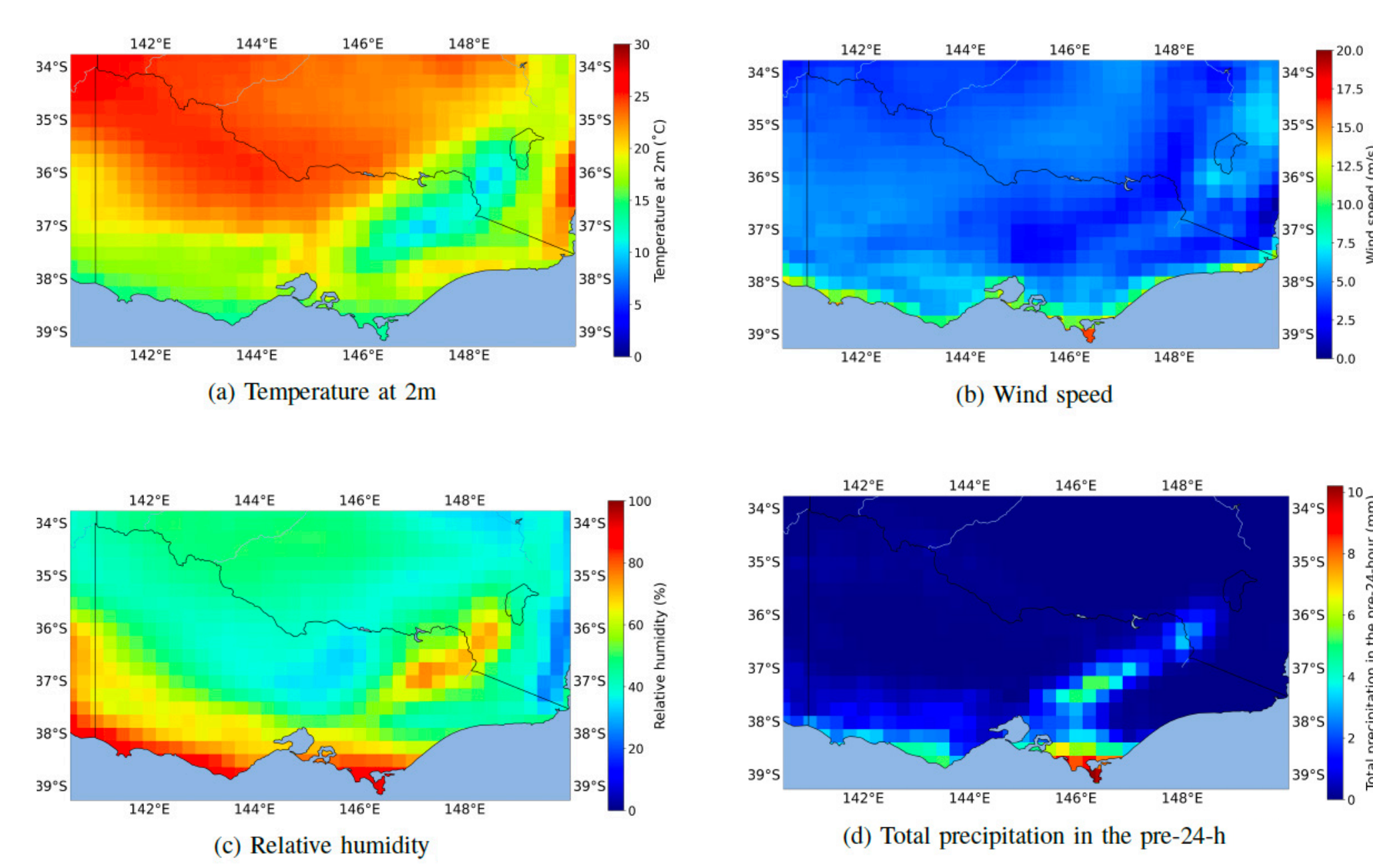


Figure 4. Climate variable heat maps at 4 pm on 3 Dec 2019 in Victoria, Australia

- Fire Weather Index (FWI) is calculated using temperature, wind speed, relative humidity and precipitation to represent fire risk in each grid cell
- Resolution: hourly, $0.25^\circ \times 0.25^\circ$

Nexus

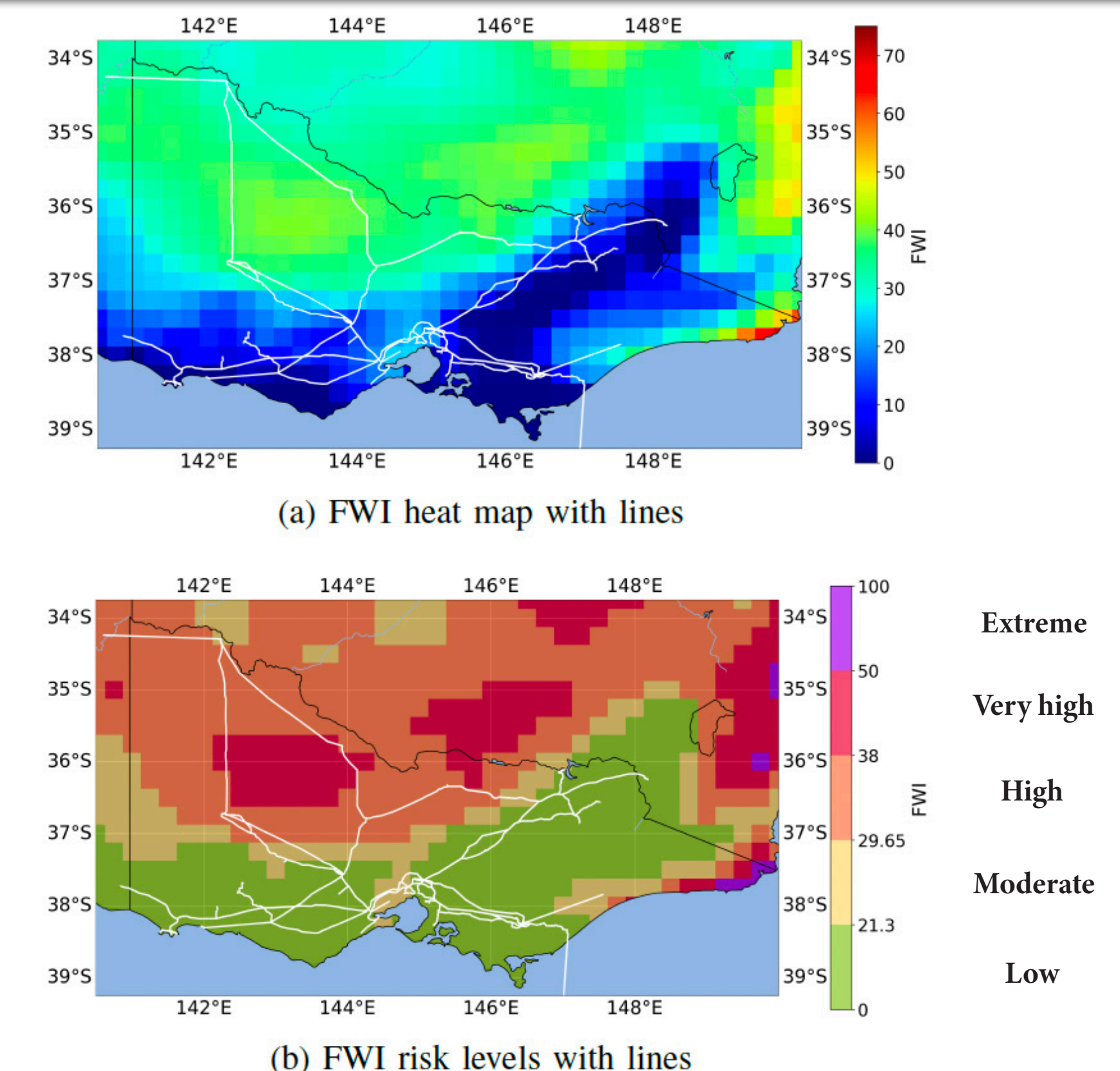


Figure 5. FWI heat maps at 4 pm on 3 Dec 2019 in Victoria, Australia, using different classification methods

Result & discussion

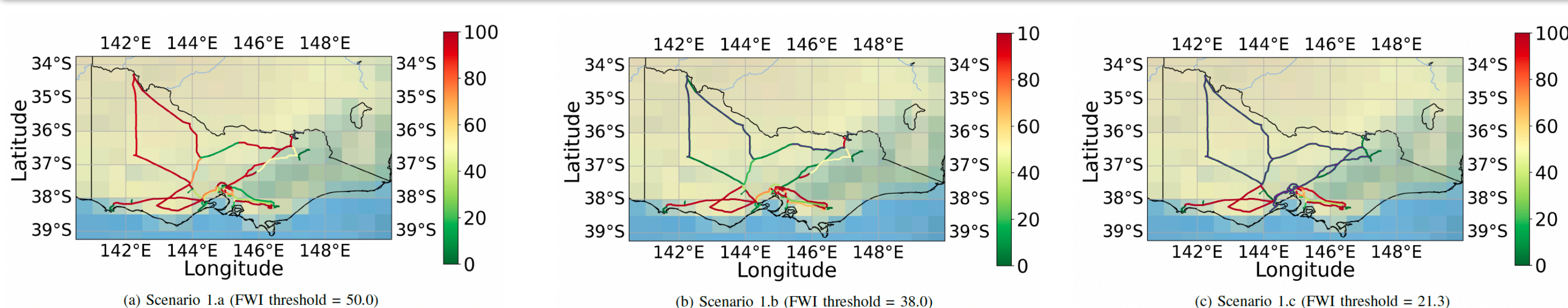


Figure 6. Scenario 1: Line loading maps for transmission networks with different FWI line disconnection thresholds (lines pre-disconnected due to the violation of the preset FWI risk thresholds are marked in dark purple)

Scenario 1		Scenario 2		Cost-benefit analysis	
Metrics	1.a	1.b	1.c	Unit	
Thresholds	50.0	38.0	21.3	N/A	
LL_{grid}^{ave}	46.15	40.73	33.68	%	
LS_{grid}	0	699.26	1,642.36	MWh	
$LS_{percent}$	0	15.32	35.98	%	
C_{grid}	283,832	290,825	300,253	AUS	
$C_{ave,grid}$	62.21	75.23	102.72	AU\$/MWh	
E_{grid}	269,812	270,210	275,210	kg	
$E_{ave,grid}$	59.11	71.20	94.18	kgCO _{2eq} /MWh	

Table 1. Scenario 1: grid resilience performances for the peak burning condition at 4 pm on 3 December 2019 in Victoria, Australia - various fire risk control levels

Scenario 2		Cost-benefit analysis	
Metrics	2.a	Unit	
LL_{grid}^{ave}	41.67	%	
LS_{grid}	0	MWh	
$LS_{percent}$	0	%	
C_{grid}	829,114	AUS	
$C_{ave,grid}$	181.64	AU\$/MWh	
E_{grid}	270,210	kg	
$E_{ave,grid}$	60.29	kgCO _{2eq} /MWh	

Table 2. Scenario 2: grid resilience performances for the peak burning condition at 4 pm on 3 December 2019 in Victoria, Australia - with distributed generation solutions (2.a is built on 1.b with FWI threshold = 38.0)

Scenario 1		Scenario 2		Cost-benefit analysis	
Scenarios	TS_{cost} AU\$	Load shed MWh	VoLL AU\$	SO_{cost} AU\$	
1.a	290,825	700	10,490,370	10,781,195	
2.a	829,114	0	0	829,114	

Table 3. Cost-benefit analysis - DG investment under fire risks

$$VoLL_{unit} = \frac{SO_{cost}^{ori} - SO_{cost}^{wind}}{LS}$$

- VoLL for Australian market: AU\$15,000/MWh
- Calculated breakeven VoLL to justify DG investment: AU\$14,217/MWh

Conclusion & future work

Conclusion

- Power system resilience was assessed in high-risk regions, with Victoria, Australia as a case study
 - Stricter fire control strategies increase grid stress in both economic and environmental aspects
 - Optimised intentional power shut-offs and DG deployment can enhance resilience cost-effectively
 - A method for calculating the breakeven VoLL for DG investment is presented for grid planning
- ### Future work
- Extend analysis from worst-case peak burning scenarios to longer operational periods
 - Apply the model to other fire-prone regions for broader generalisation
 - Integrate real-time control systems (e.g., SCADA) to enhance industrial applicability

References & relevant publications

- [1] Dale, L., Carnall, M., Wei, M., Fitts, G., & McDonald, S. L. (2018). Assessing the impact of wildfires on the California electricity grid. Lawrence Berkeley National Laboratory.
- [2] Electricity Sector Climate Information. (2021). Bushfire risk affecting electricity distribution: Approaches to determine feasibility of Stand-Alone Power Systems.
- [3] Perez, M. et al. (2025). From AI to Gen Z – how infrastructure is shaping our future. Allianz Global Investors.
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- [5] Yang, W., Sparrow, S.N. and Wallom, D.C.H. (2024). A comparative climate-resilient energy design: Wildfire resilient load forecasting model using multi-factor deep learning methods, Applied Energy, 368, p. 123365. 2024.123365.
- [6] Yang, W. et al. (2022). 'Resilient by design: Preventing wildfires and blackouts with microgrids', Applied Energy, 313, p. 118793.

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