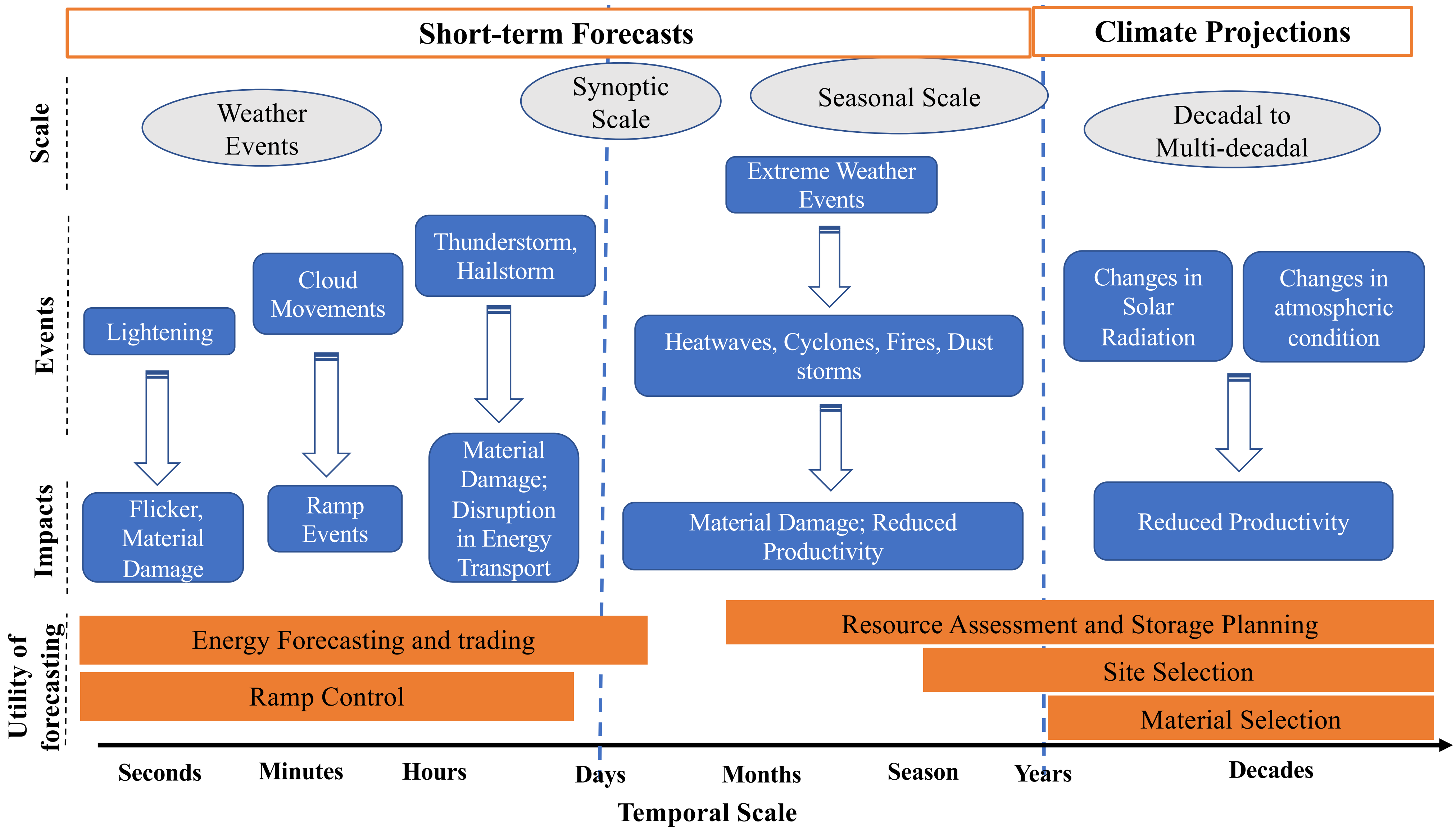
What does future of PV generation in Australia look like?: Risks and Challenges

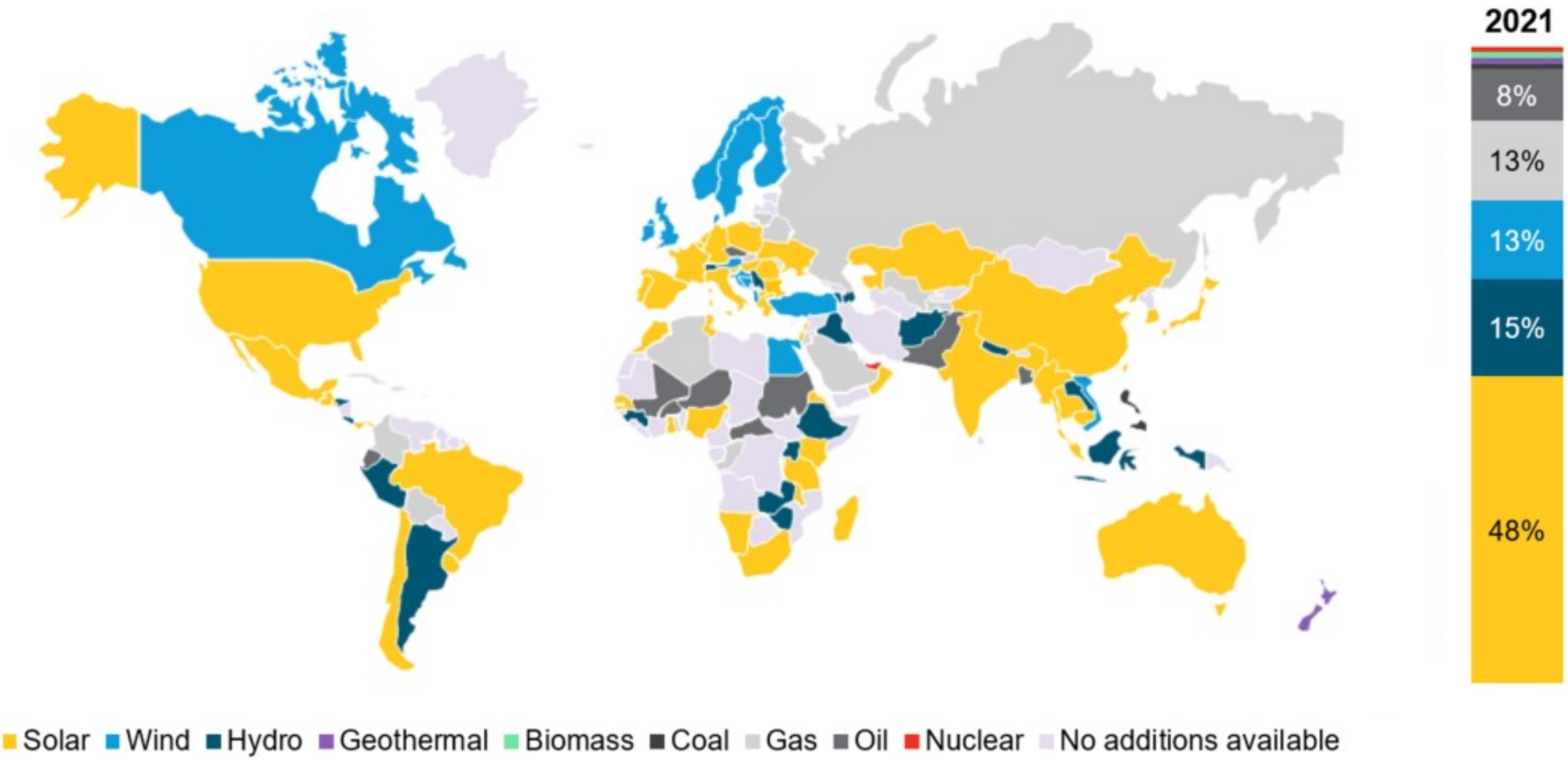
Predictions based on data science


September 2009
December 2019
October 2022
October 2020



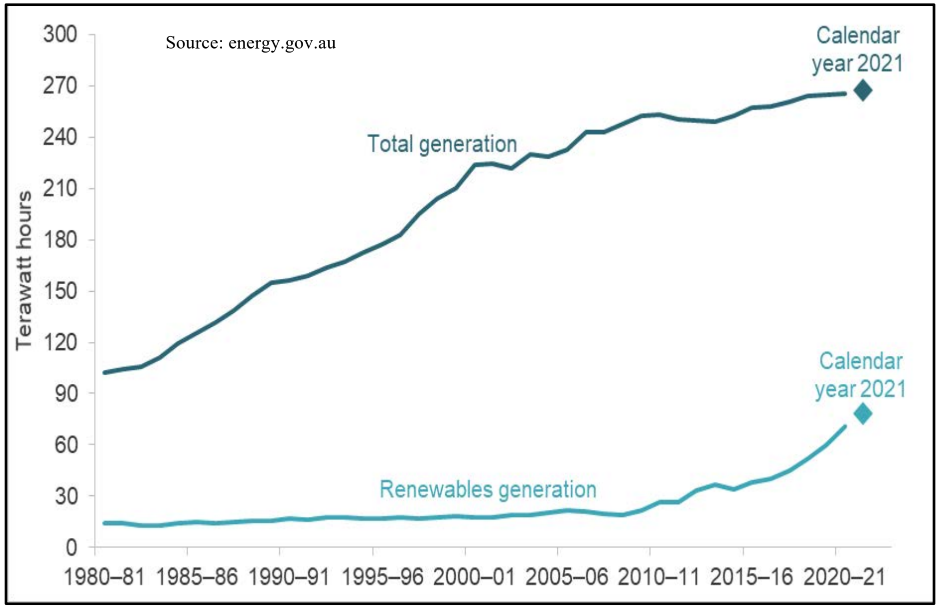
Short-term Forecasts
Climate Projections
Scale
Weather Events
Synoptic Scale
Seasonal Scale
Decadal to Multi-decadal
Events
Extreme Weather Events
Lightening
Cloud Movements
Thunderstorm, Hailstorm
Heatwaves, Cyclones, Fires, Dust storms
Changes in Solar Radiation
Changes in atmospheric condition
Impacts
Flicker, Material Damage
Ramp Events
Material Damage; Disruption in Energy Transport
Material Damage; Reduced Productivity
Reduced Productivity
Utility of forecasting
Energy Forecasting and trading
Ramp Control
Resource Assessment and Storage Planning
Site Selection
Material Selection
Seconds
Minutes
Hours
Days
Months
Season
Years
Decades
Temporal Scale

Figure 1: Most popular new power-generating technology installed, 2021

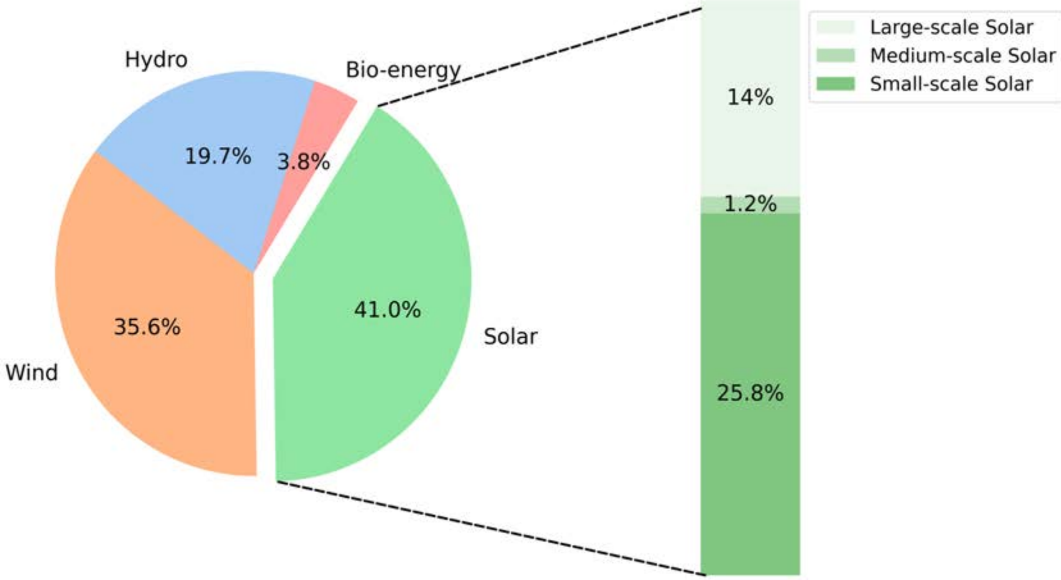


Source: BloombergNEF

Electricity generation in Australia



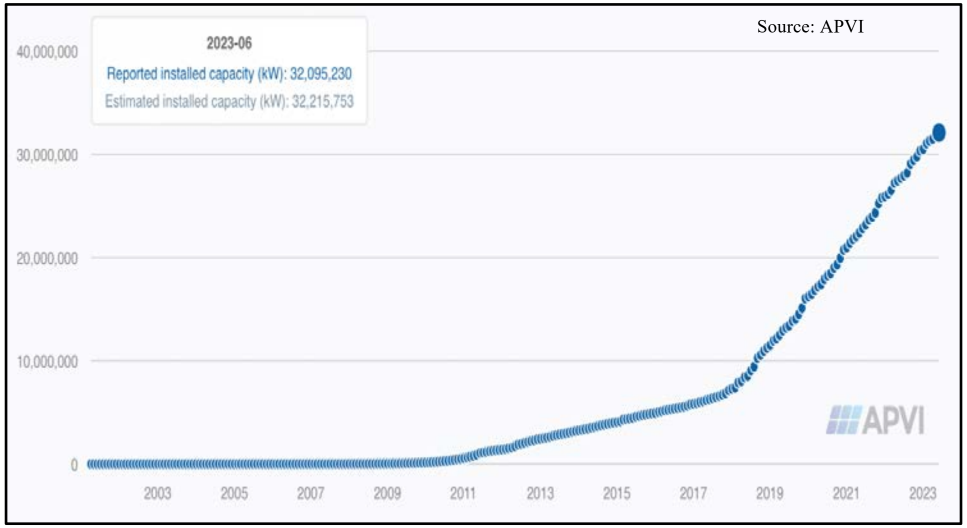
Annual electricity generation in Australia in 2022



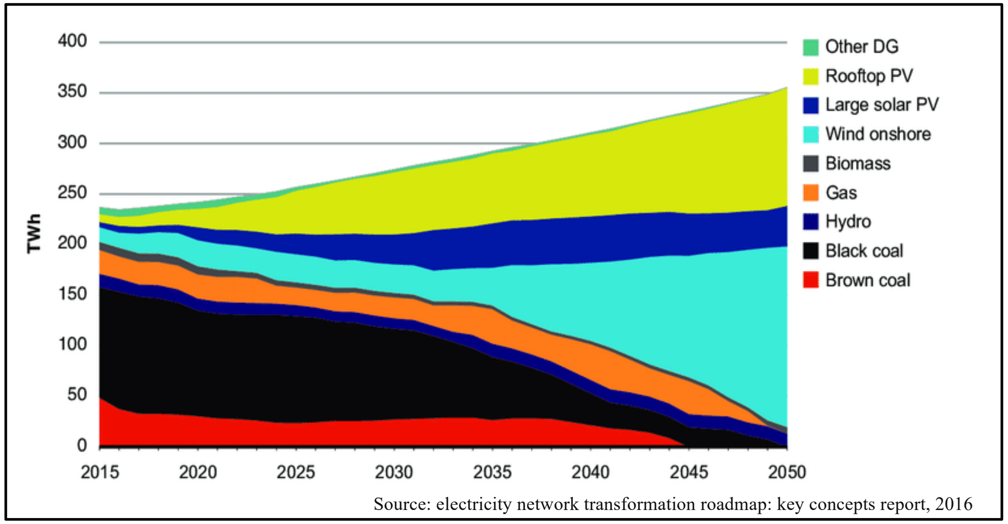
Source: Clean Energy Report 2023

- Out of the total electricity generated in 2022, about **36%** of the electricity was generated from the renewables.

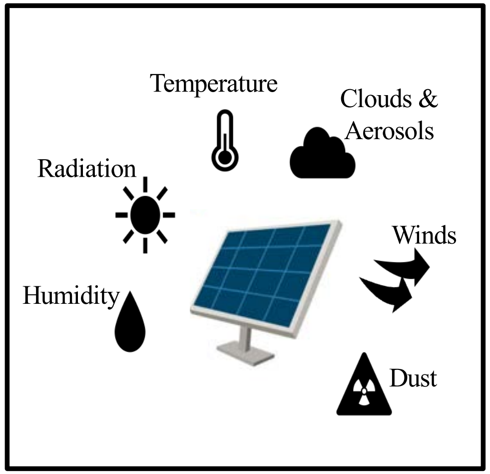
PV installations in Australia from 2001-2023



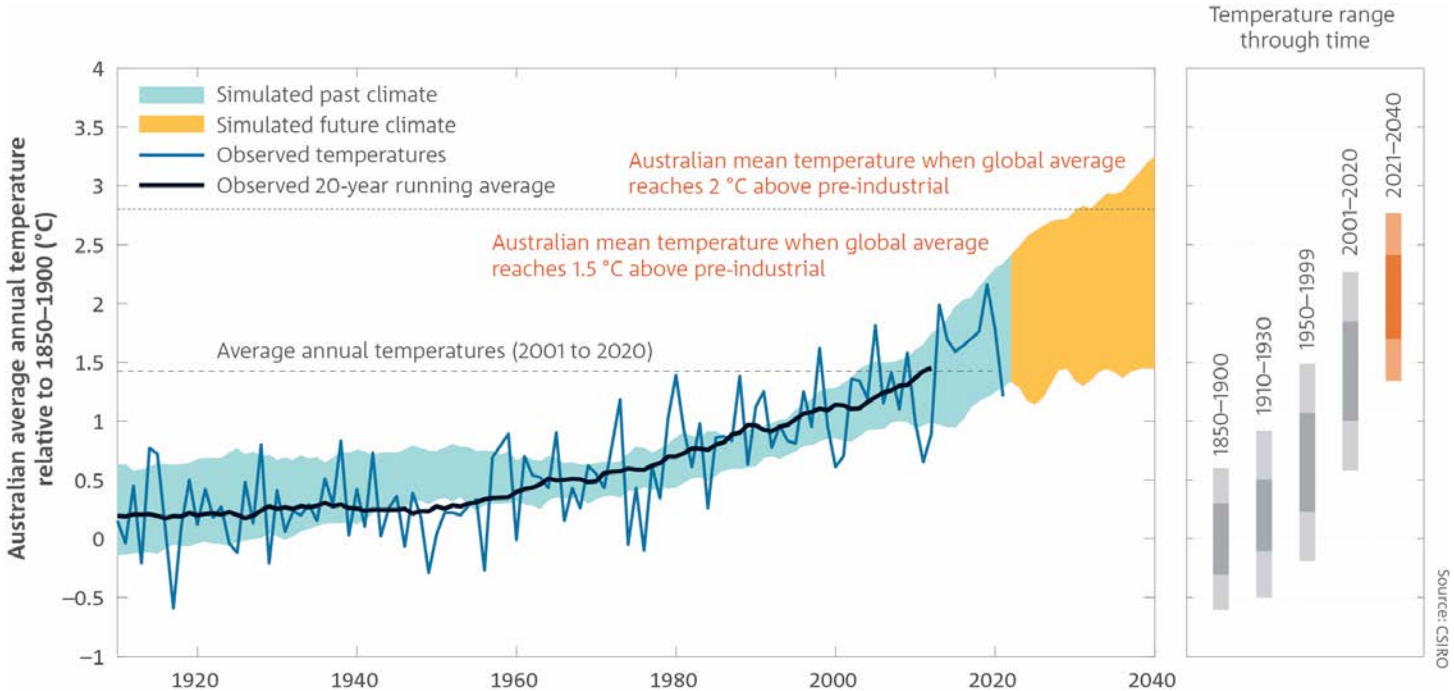
Estimated electricity output in future

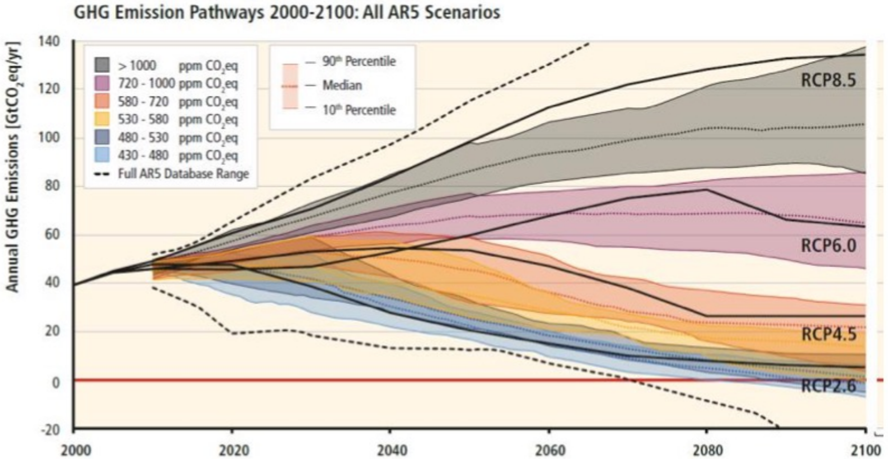


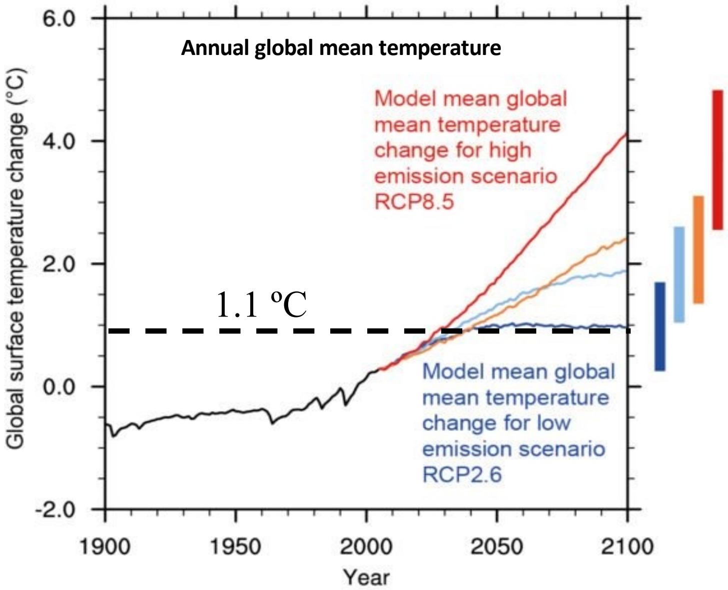
- Large-scale deployments and investments in solar PV have increased recently and it is expected to further increase in future.



Highly susceptible to changes in climate



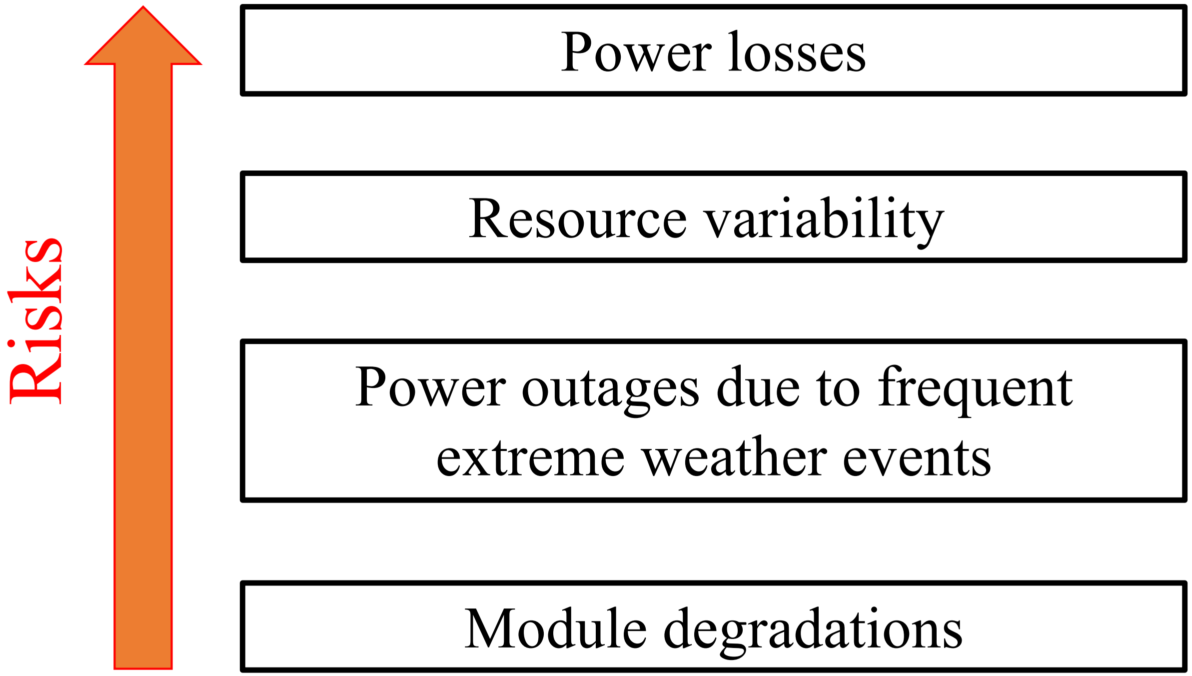




Future Scenarios

Scenario	RCP	Temperature
Low-Emission Scenario	RCP2.6	1ºC
Intermediate-Emission Scenario	RCP4.5	1.8 ºC
High-Emission Scenario	RCP8.5	3.7 ºC

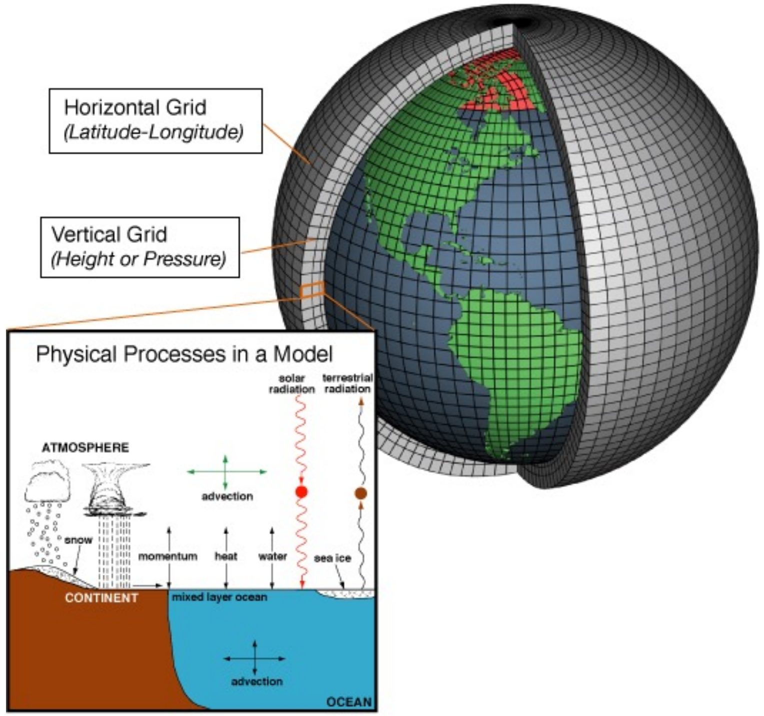
Source: IPCC 2014

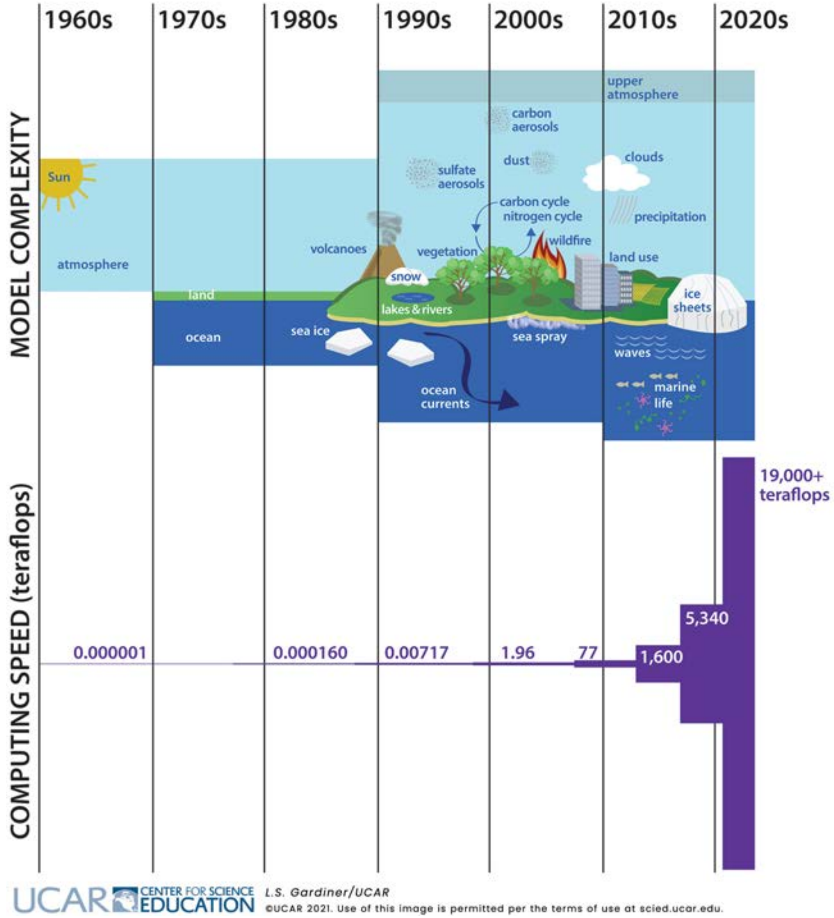

Risks
Power losses
Resource variability
Power outages due to frequent extreme weather events
Module degradations

What is the future of PV generation in Australia look like?

- **1 & 2** Weather-induced variability in the energy generation
- **3** Long-term PV potential and drivers
- **4** Role of climate in module degradation

Approach

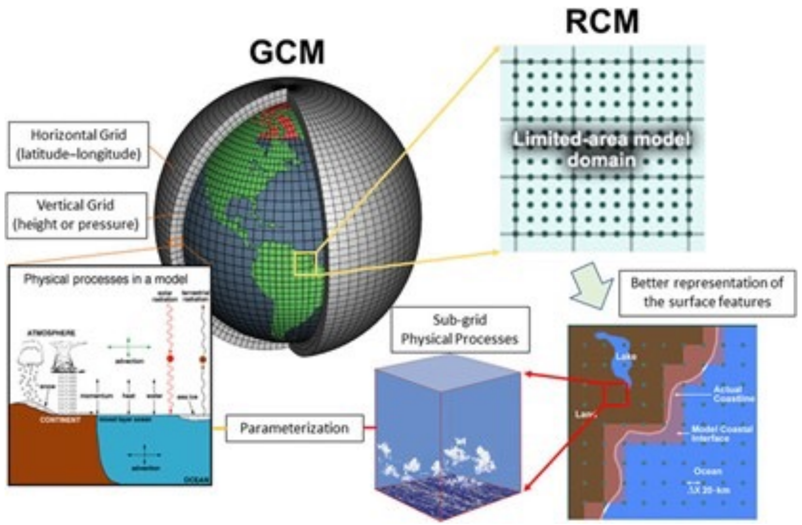




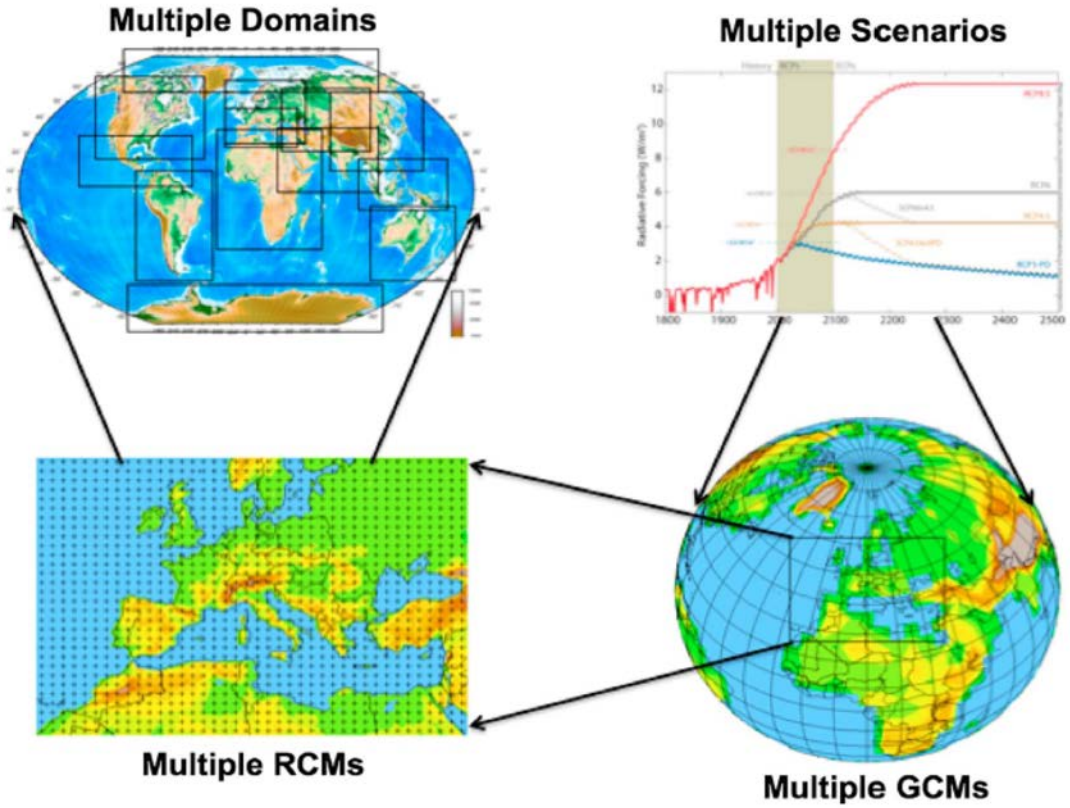
Climate models are a group of complex mathematical equations to characterize how energy and matter interact in different grid points.

$$A^{forecast} = Ainiti^{al} + F(A) \vartriangle t$$

Ambrizzi, T., M. Reboita, R. Rocha, and M. Llopart, 2018: The state-of-the-art and fundamental aspects of regional climate modeling in South America. *Annals of the New York Academy of Sciences*, 1436, https://doi.org/10.1111/nyas.13932.



CORDEX Framework

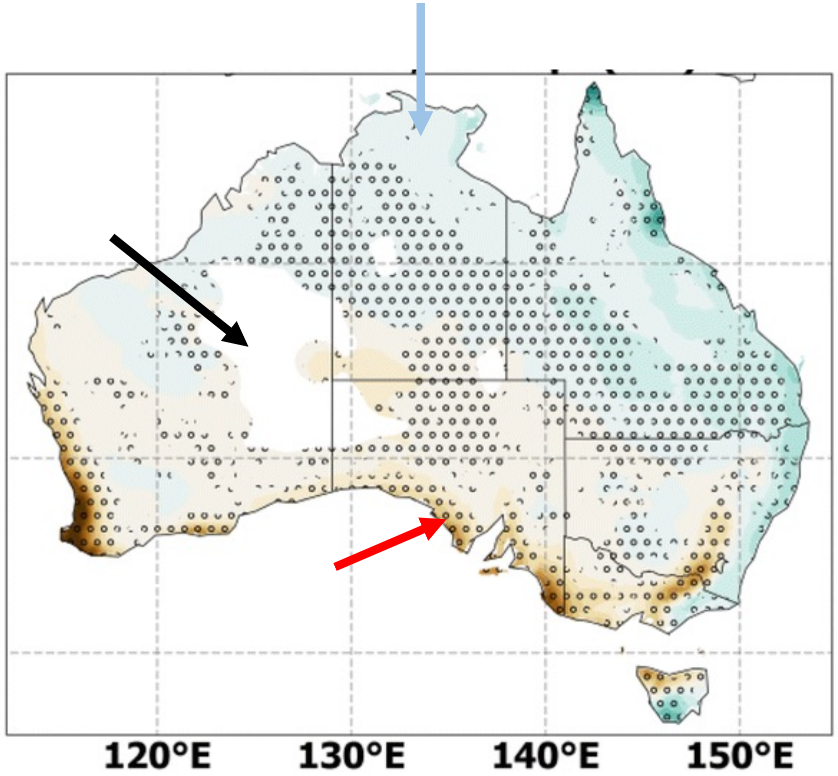


Confidence level on future projections

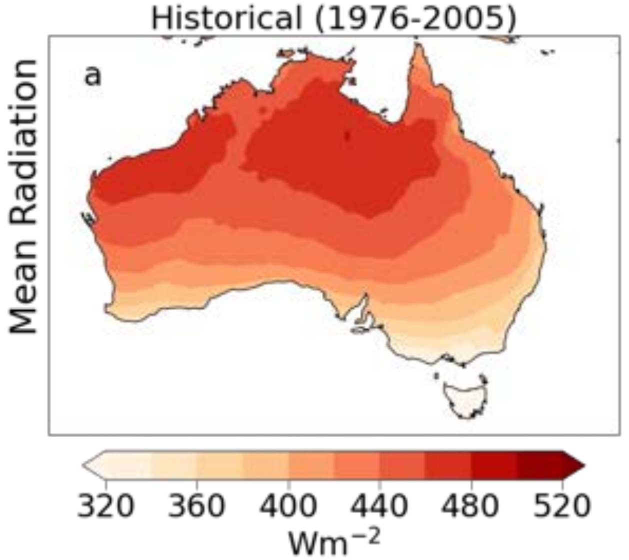
- **Significant change**: 50% or more of the models significant change, and at least 70% of them agree on the direction of change.

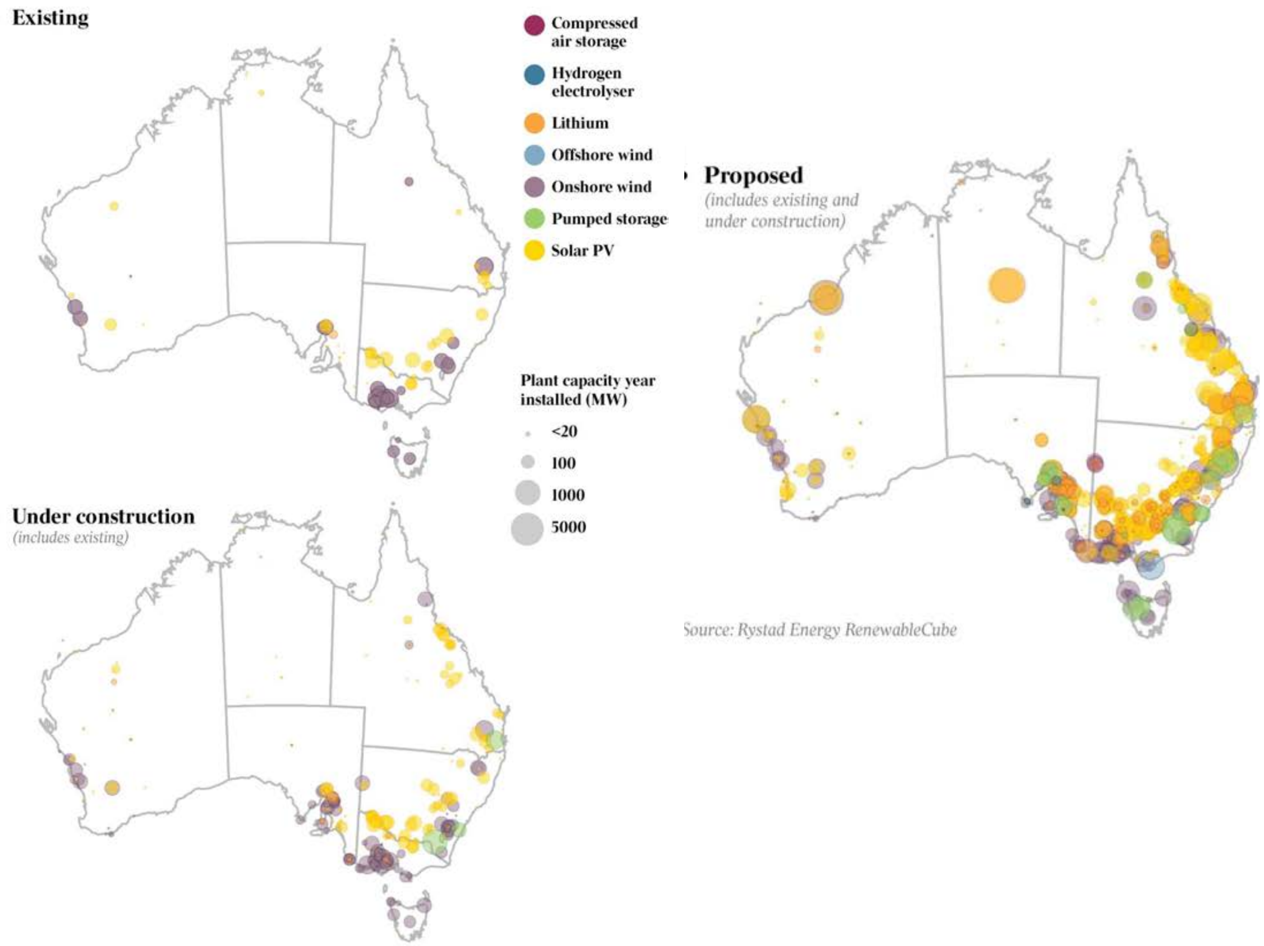
- **Insignificant agreement:** less than 50% of the models with significant change.

- **Significant disagreement:** at least 50% of the models with significant change, and less than 70% of them agree on the direction of change.



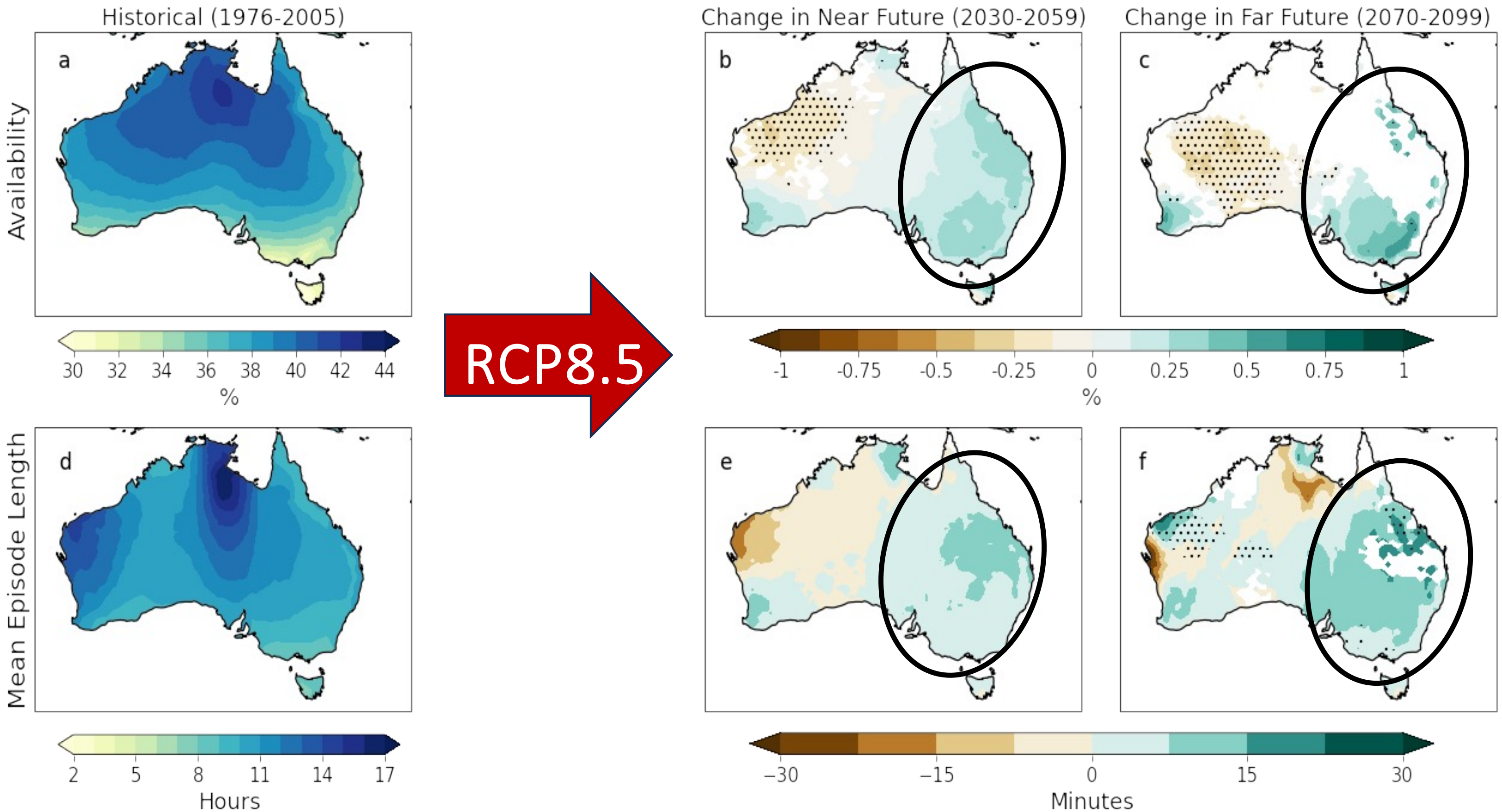
Resource Assessment : Solar PV viability





Data : CORDEX-Australasia model projections
Time periods: **Historical** (1976 to 2005), **Far Future** (2070 to 2099)
Scenarios: **RCP4.5**, **RCP8.5**

Solar Resource Reliability



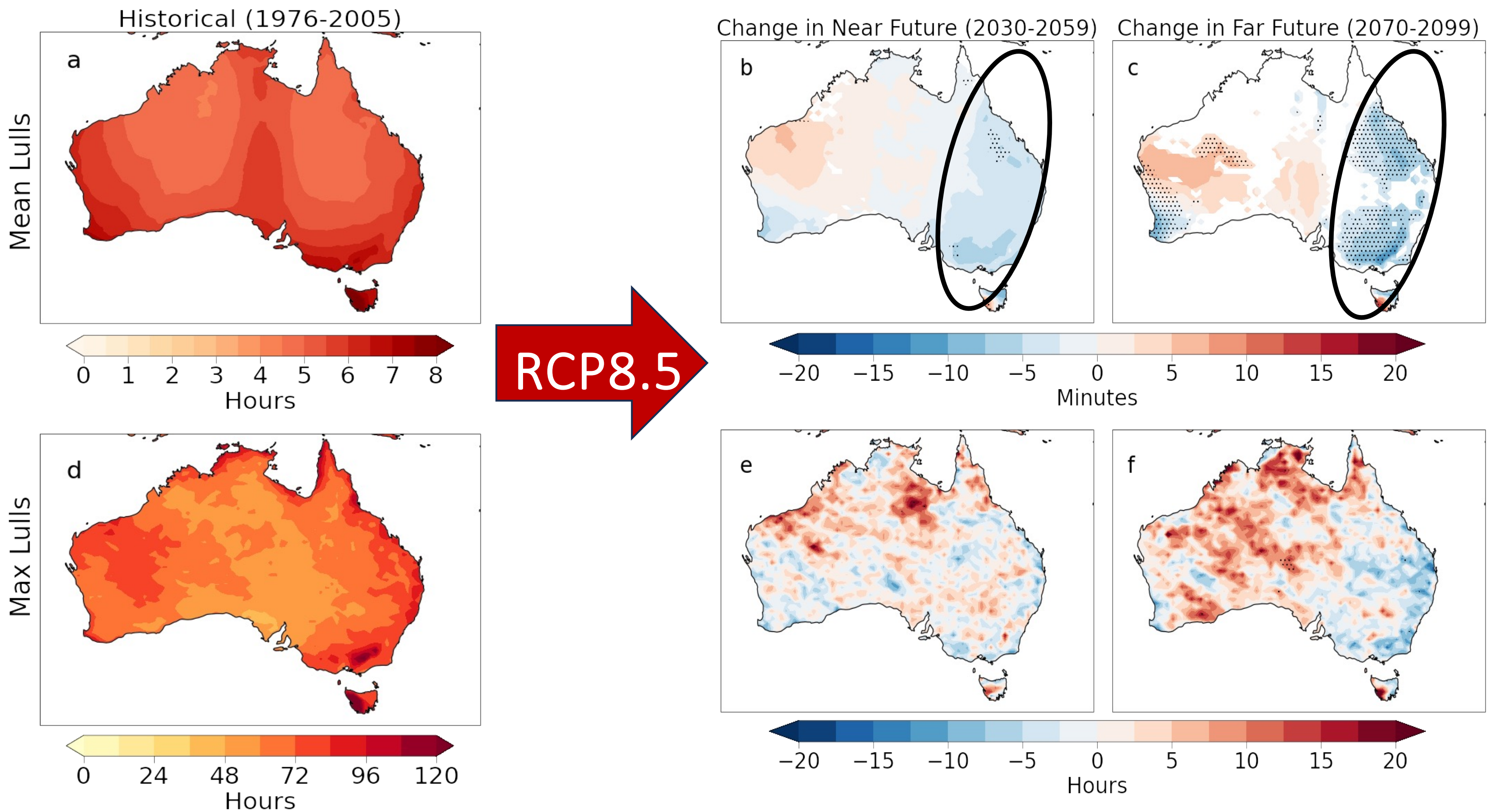
Availability : frequency of occurrences of efficient resources for solar power generation

Episode Length : period of time where solar power is usable for consecutive hours

↑ reliable power supply

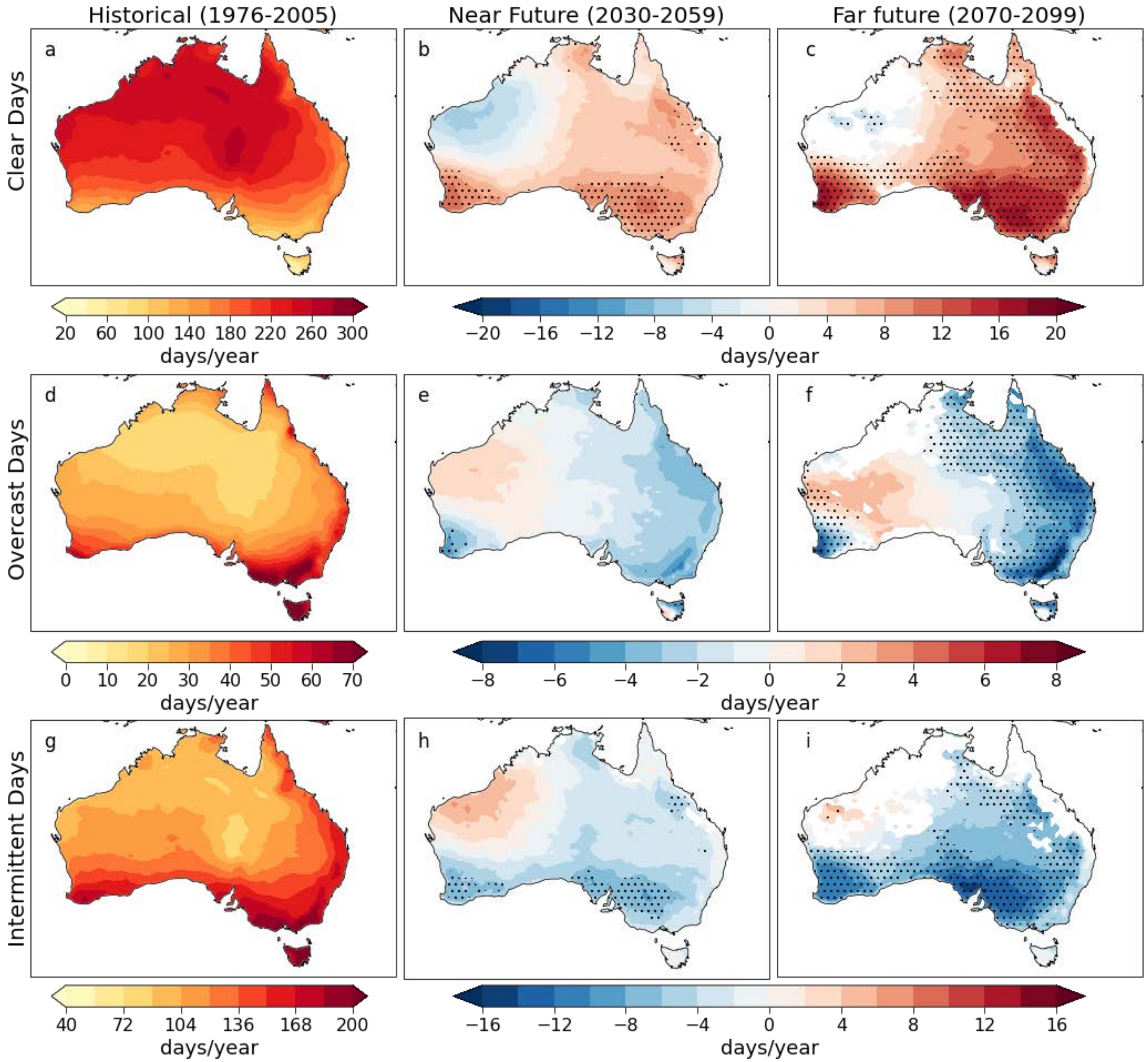
- Prasad AA, Taylor RA, Kay M. Assessment of solar and wind resource synergy in Australia. Appl Energy 2017;190:354–67. https://doi.org/https://doi.org/10.1016/j.apenergy.2016.12.135.
- Gunturu UB, Schlosser CA. Characterization of wind power resource in the United States. Atmos Chem Phys 2012;12:9687–702. https://doi.org/10.5194/acp-12-9687-2012.

Solar Resource Intermittency



Lulls: consecutive hours of almost no power generation during the day

↑ Stable Supply



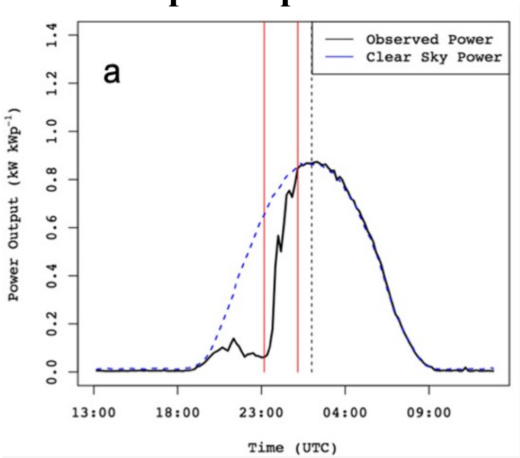
↑ Clear Days in the East

Poddar, S., Kay, M., Prasad, A., Evans, P. J. & Bremner, S. (2023). Changes in solar resource intermittency and reliability under Australia's future warmer climate. Solar Energy (under review).

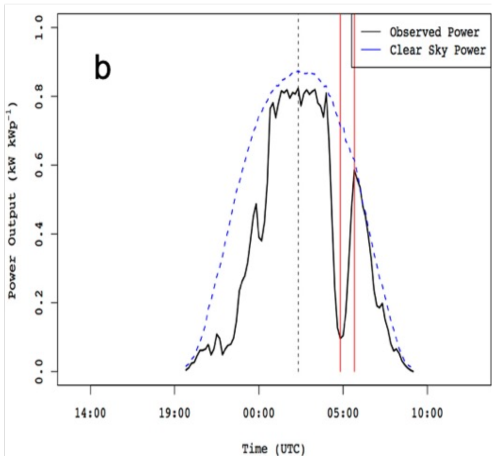
Solar Power Variability: Ramps

- On a clear sky day, PV power generated is expected to follow a diurnal curve similar to the GHI at that location
- Fluctuations in the amount of GHI during the day are responsible for intermittent periods of PV power output.

Up-Ramp Event



Down-Ramp Event



(Wellby and Engerer 2016)

Sudden increase or decrease in power output due to cloud movements is termed as called **ramps**.

- positive ramp event : ↑ in power output
- negative ramp event : ↓ in power output

Solar power ramps are estimated from the expected future power output using PVLIB energy modelling.

- Wellby SJ, Engerer NA. Categorizing the meteorological origins of critical ramp events in collective photovoltaic array output. J Appl Meteorol Climatol 2016;55:1323–44. https://doi.org/10.1175/JAMC-D-15-0107.1.

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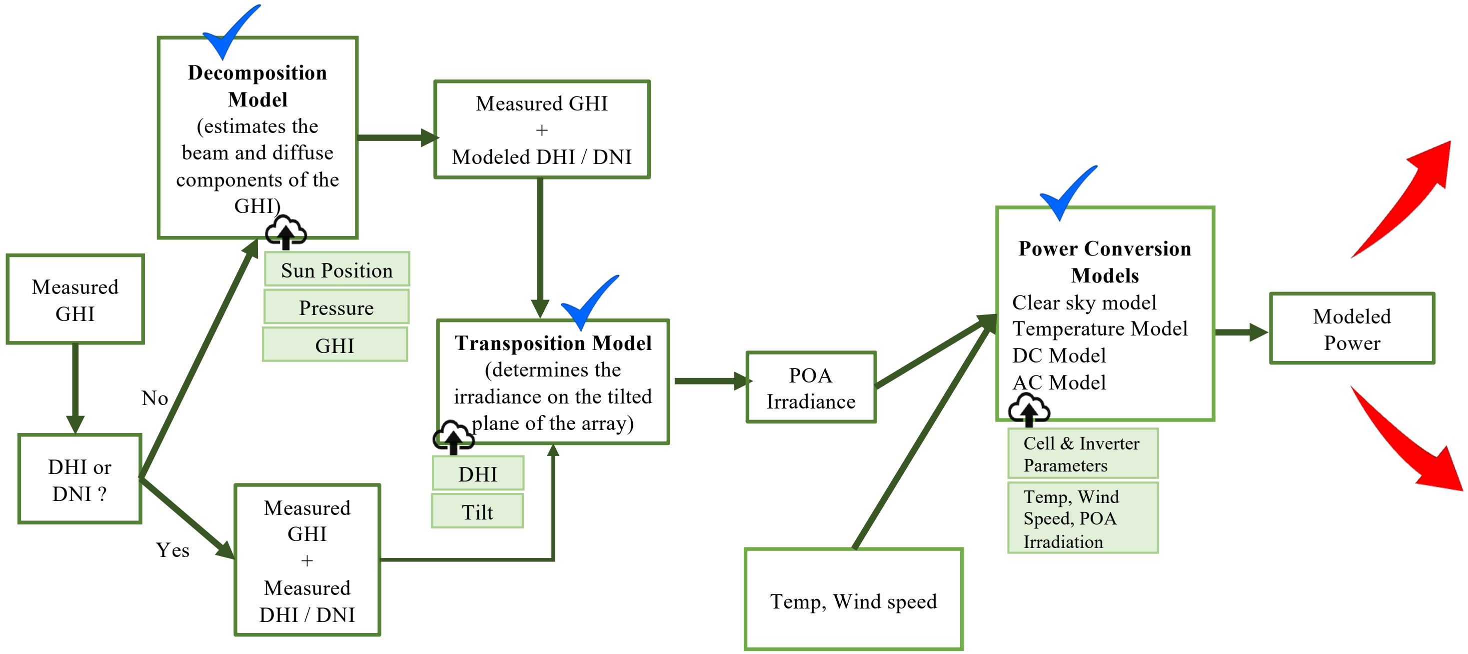
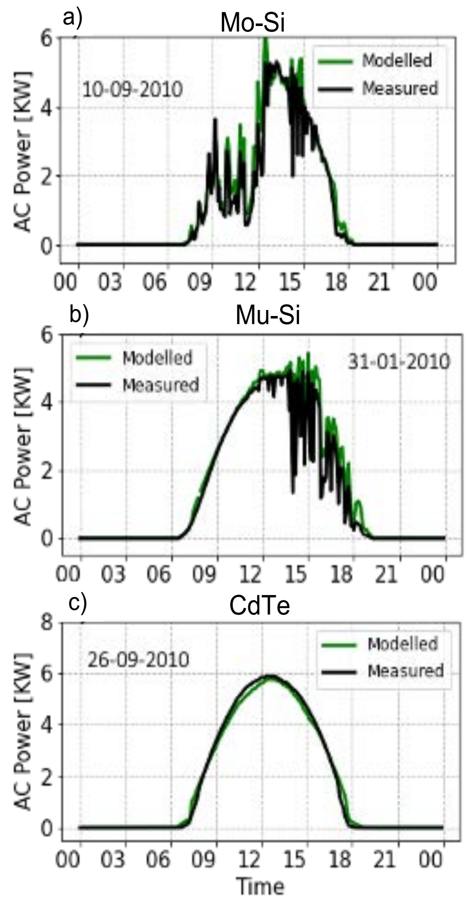
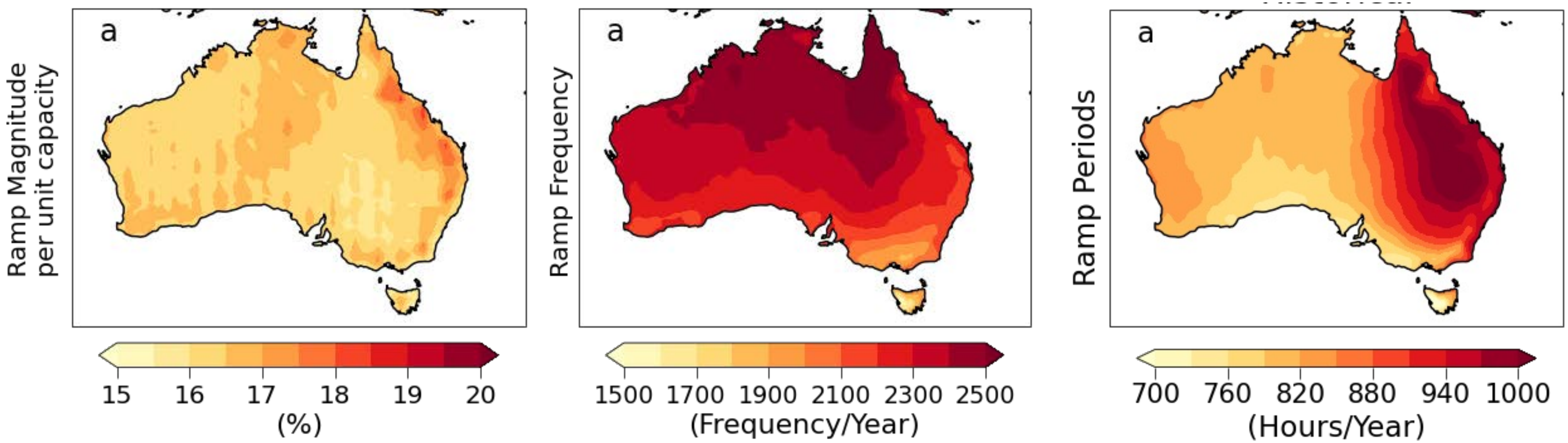
Power Simulations using PVLIB





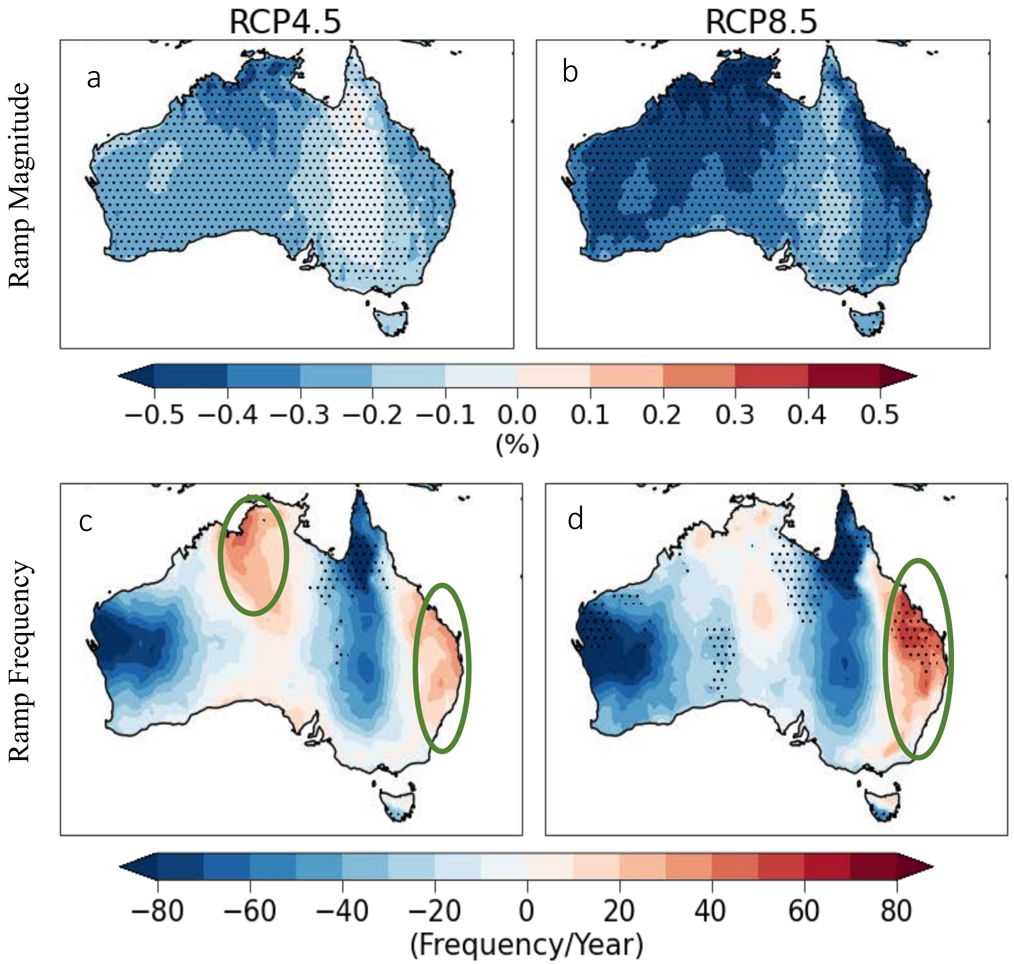
Solar Power Ramps : Historical Era



Data : CORDEX-Australasia model projections
Time periods: **Historical** (1976 to 2005), **Far Future** (2070 to 2099)
Scenarios: **Historical**, **RCP8.5**

Poddar, S., Evans, J.P., Kay, M. *et al.* Assessing Australia's future solar power ramps with climate projections. *Sci Rep* **13**, 11503 (2023). doi.org/10.1038/s41598-023-38566-z

How do ramps vary in future?



require more robust ramp control devices to avoid grid instability and voltage flicker issues

Poddar, S., Evans, J., Kay, M., Prasad, A., and Bremner., S (2023). Assessing Australia's future solar power ramps with climate projections. Scientific Reports

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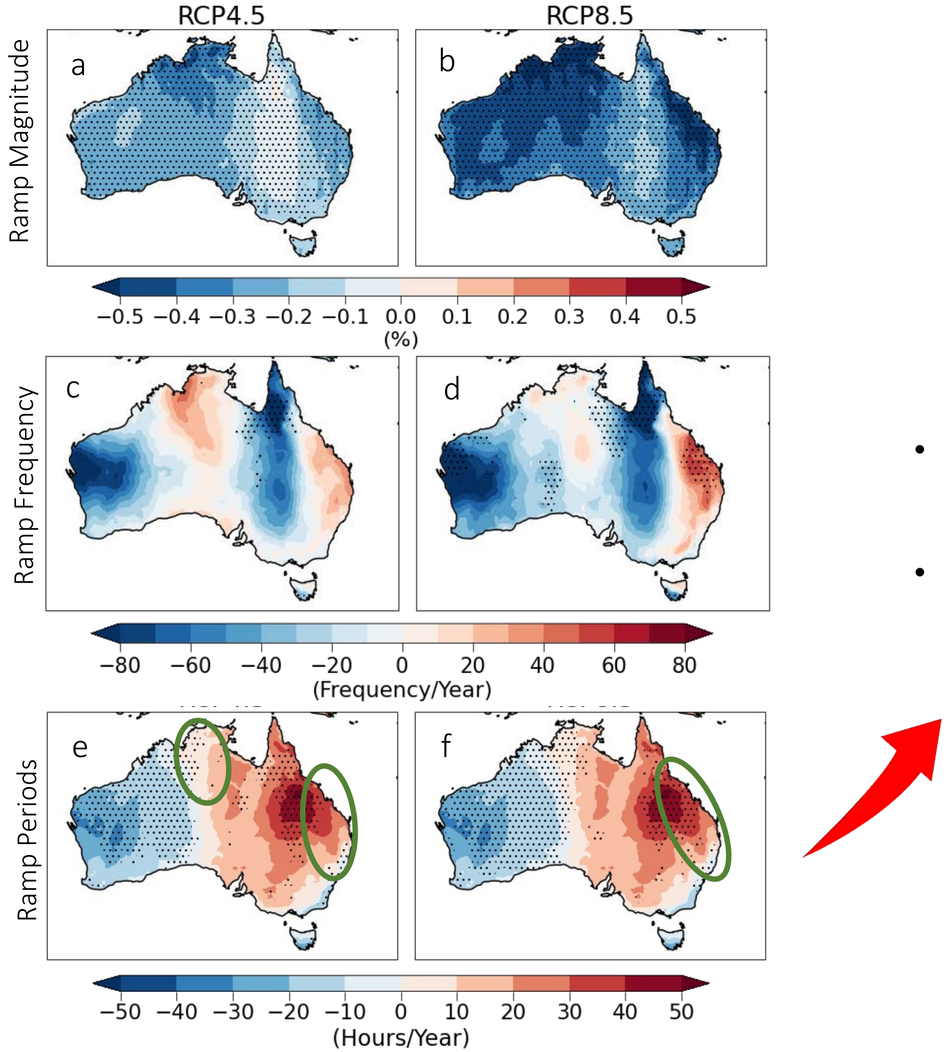
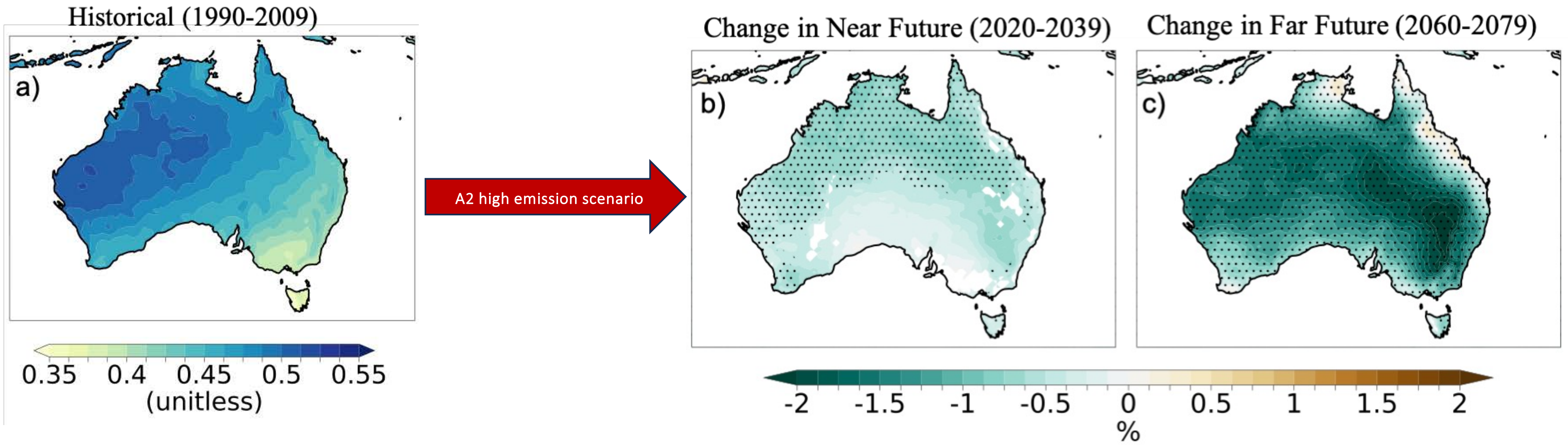
How do ramps vary in future?



- possibility of prolonged lower magnitude ramps with higher chances of occurrence.
- likely create extended periods of energy deficits

Long-term projections in PV potential



WHY?

PV Potential=f (r, t, w)

Data : NARCliM regional model projections
Time periods: **Historical** (1990 to 2009), **Near Future** (2020 to 2039), **Far Future** (2060 to 2079)

Poddar, S., Evans, P. J., Kay, M., Prasad, A. & Bremner, S. (2021). Estimation of future changes in photovoltaic potential in Australia due to climate change. Environmental Research Letters 16:114034. https://doi.org/10.1088/1748-9326/ac2a64.

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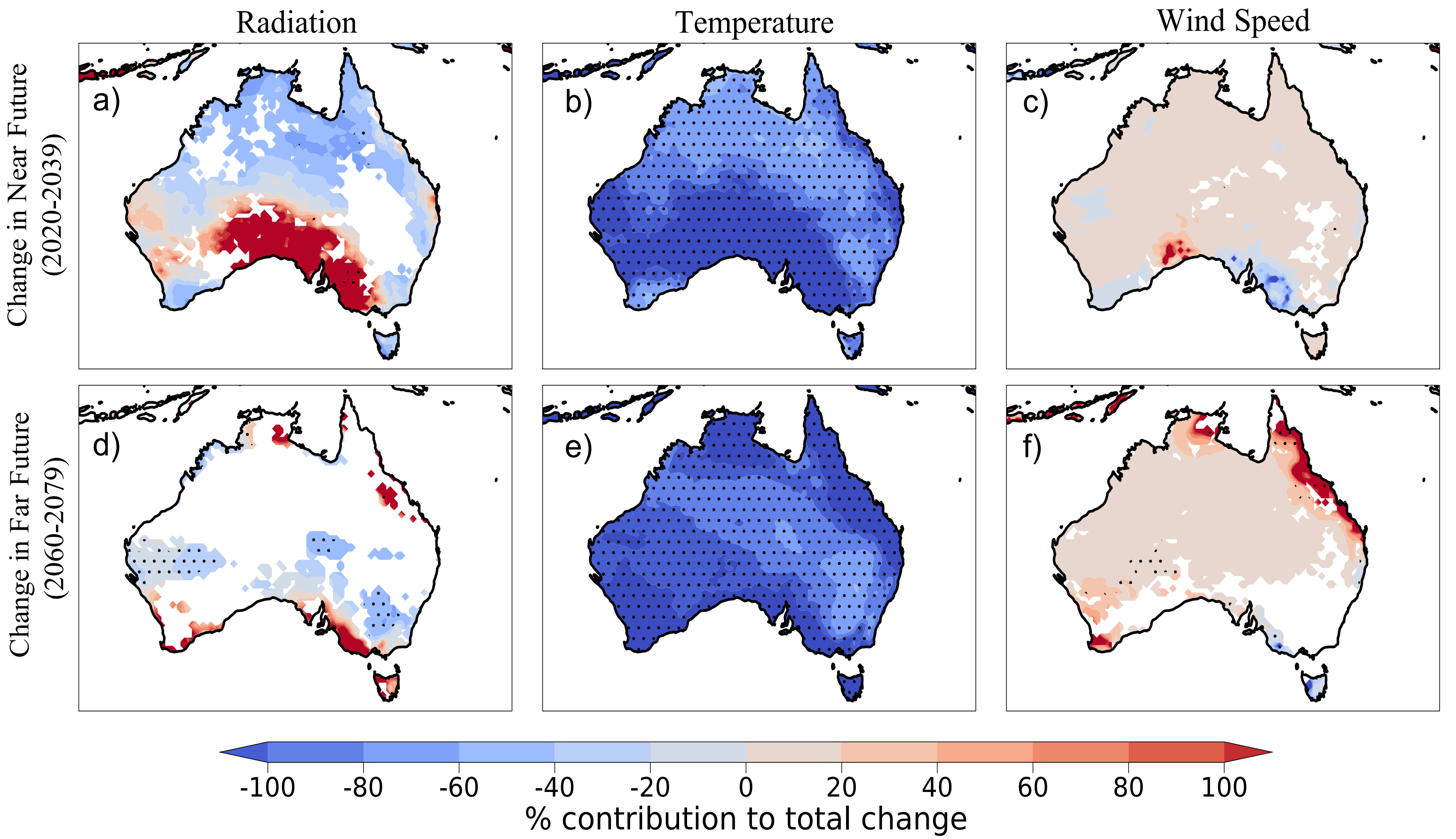
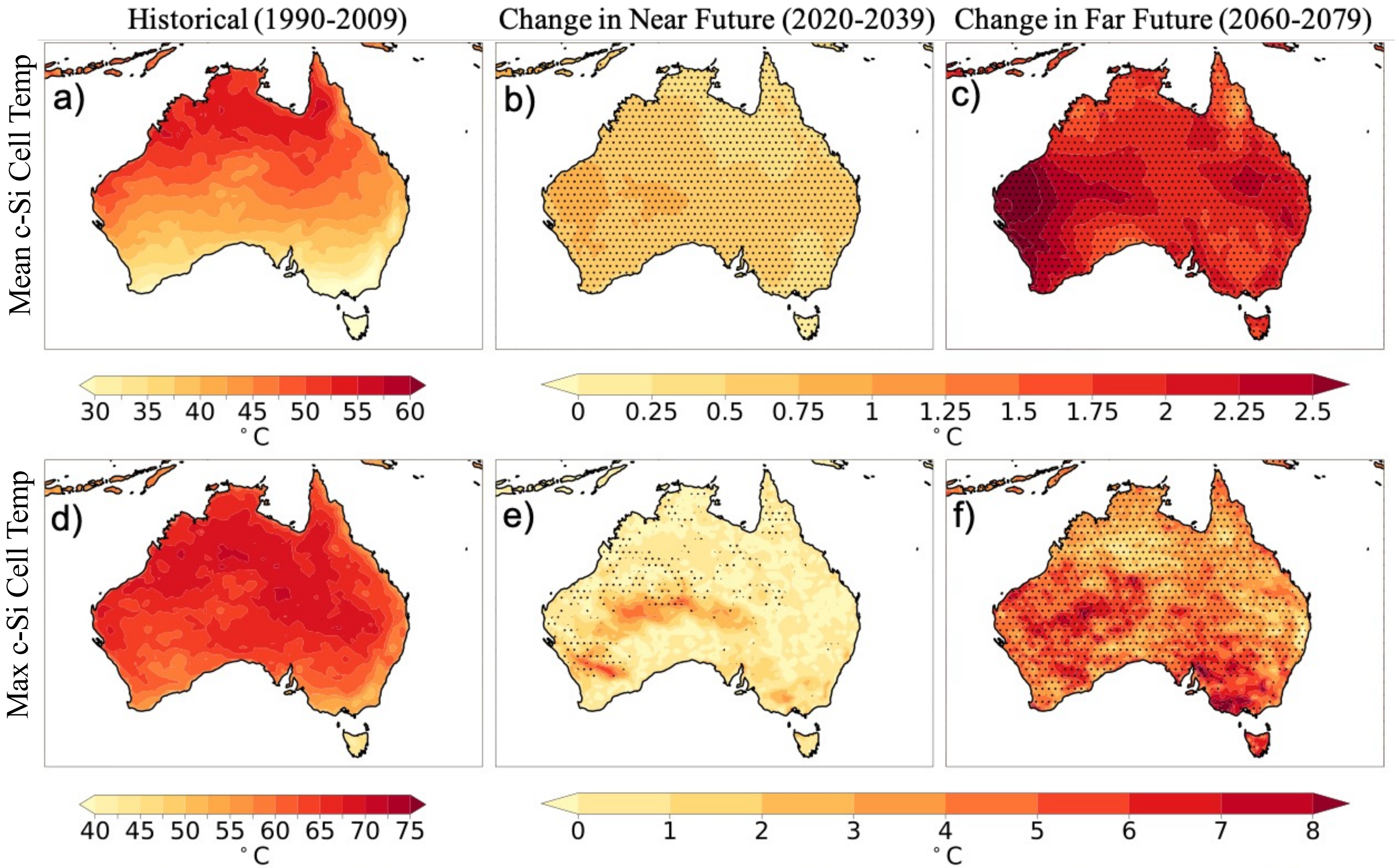
Net Contribution to PV potential change

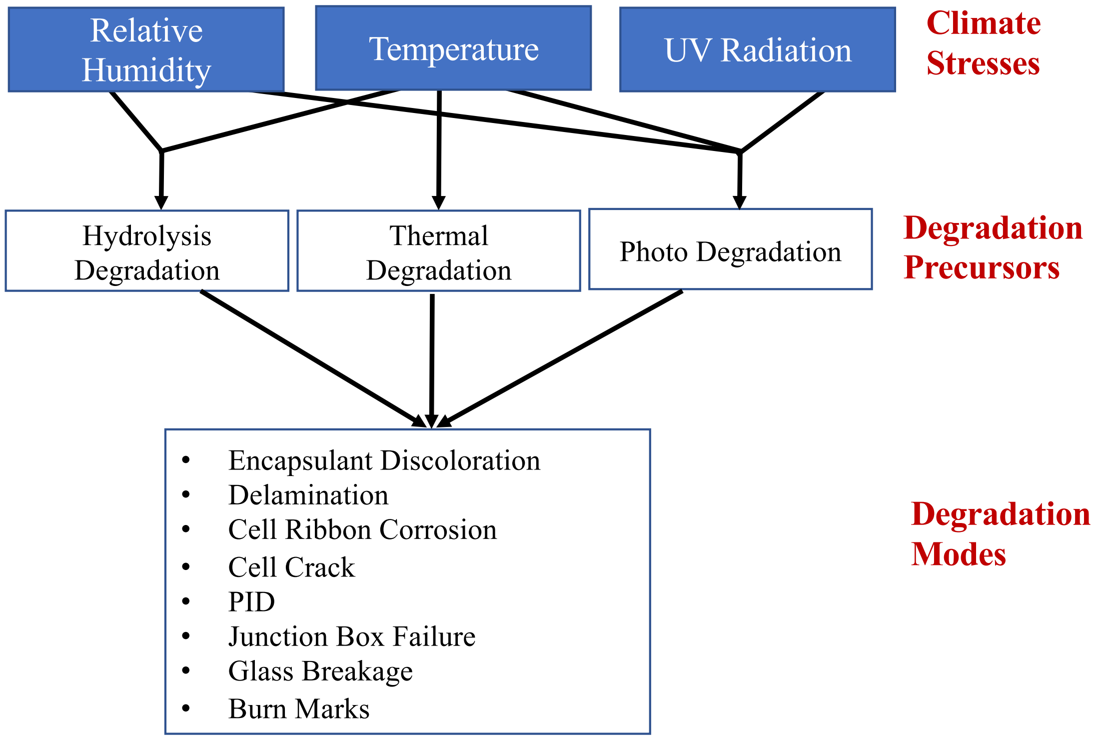


✓ Temperature contributes highest followed by radiation and wind.

Climate Change Impacts: Cell Temperature



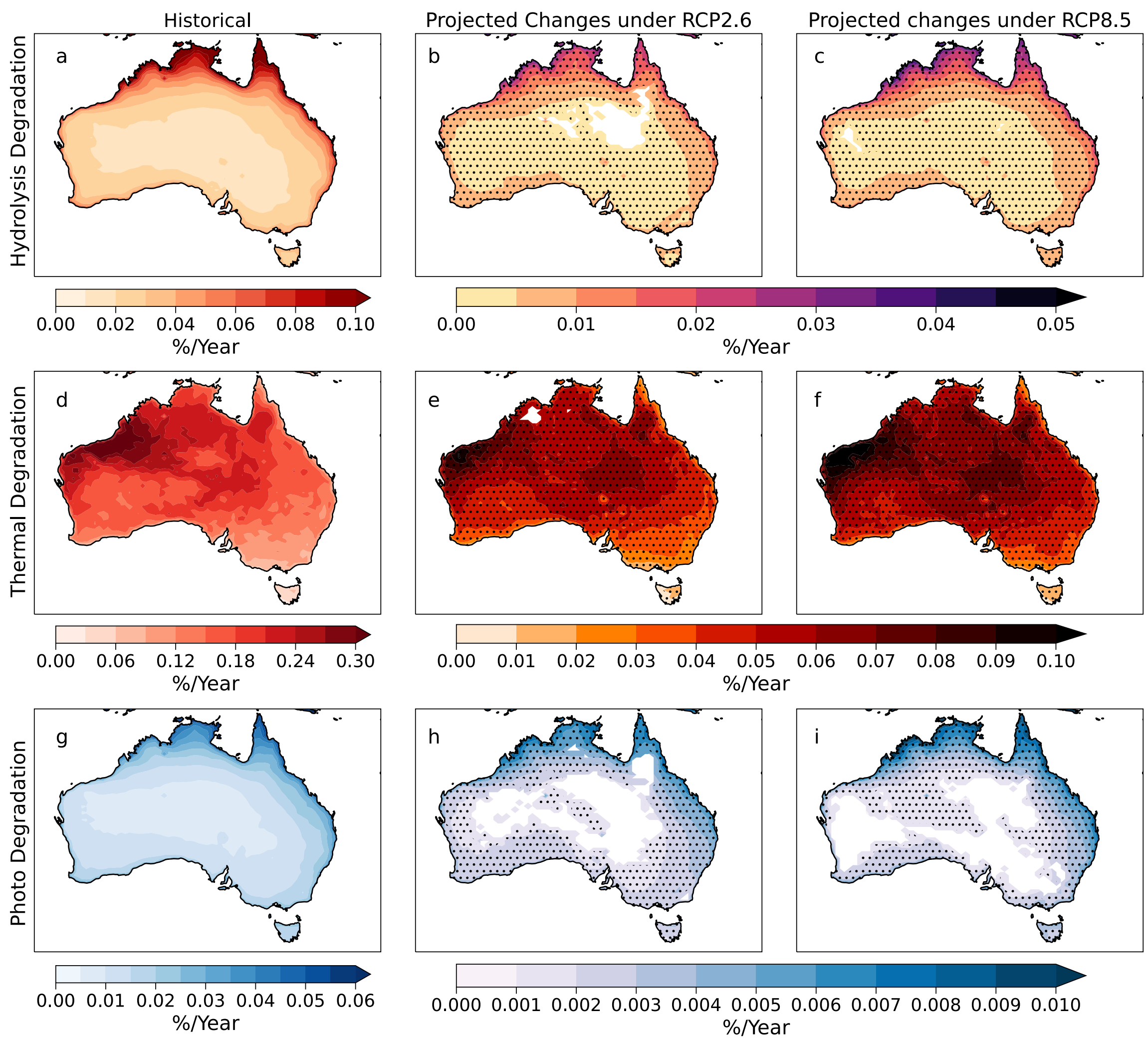
Degradation Modes and Role of Climate



- Relative humidity, temperature and UV radiation are major environmental parameters that causes PV module degradation.

- Future climate change can impact the degradation rates of the modules.

Degradation Mechanisms of mono-Si Modules



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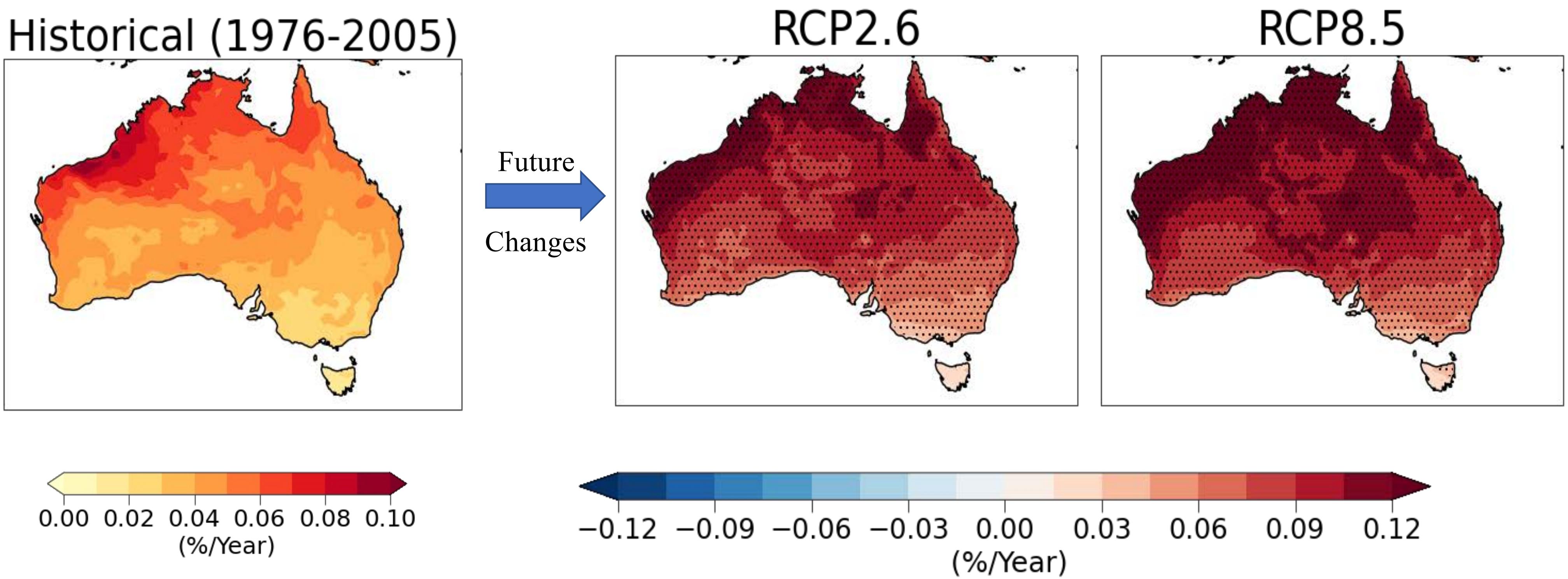
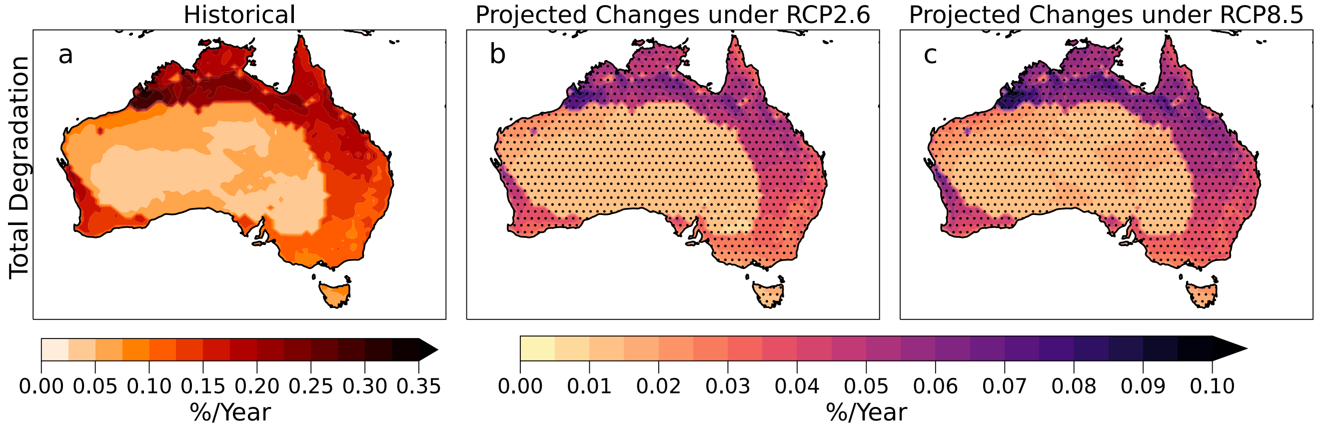
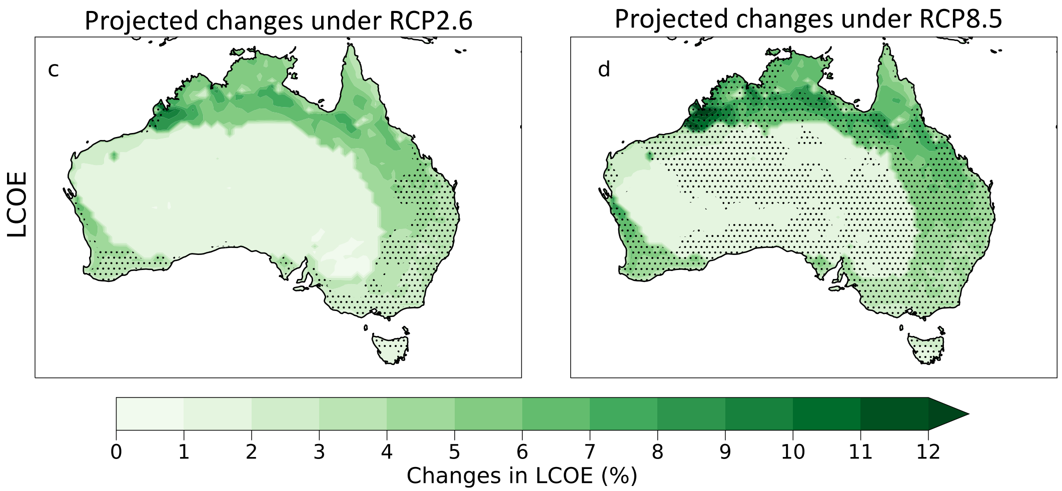
Delamination : Future Changes



Total degradation rate & its impact



- Depends on the POC of each mode



- LCOE is calculated assuming the costs don't change in the future.

↑ LCOE

Poddar, S., Rougieux, F., Evans, P. J., Kay, M., Prasad, A. & Bremner, S. (2023c). Accelerated degradation of photovoltaic modules under a future warmer climate. Progress in Photovoltaics: Research and Applications (under review).

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Current Challenges

- Uncertainty range
- High-temporal resolution climate model data
- POC of degradation modes would vary with the location and climate type
- Difficulty in empirical modelling of various modes that are completely dependent on either lab tests or field inspection
- String and cell level analysis of module degradation

Take Away Points

- Need site-assessment and material selections that incorporates climate change.
- We need to adapt mitigation strategies to manage weather-induced variability
- It will be interesting to do comparative analysis of different PV technologies to suggest climate-resilient technologies for different locations.
- Co-existence of multiple renewable technologies at the same farm

Future Directions

- Module Degradation Framework and Modelling
- Clear-sky classification scheme and variability metrics
- Extreme weather event impact on energy generation
- Co-located Solar and Wind farm: possibilities, challenges and risks

TEAM

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