Capturing storage and DER operation for resource adequacy in low-carbon power systems

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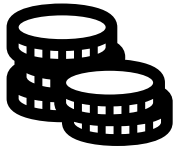
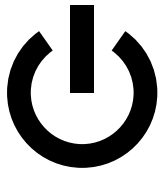
Motivation



Affordability

- Supplying power at lowest cost



Reliability

- Ensuring continuous power supply

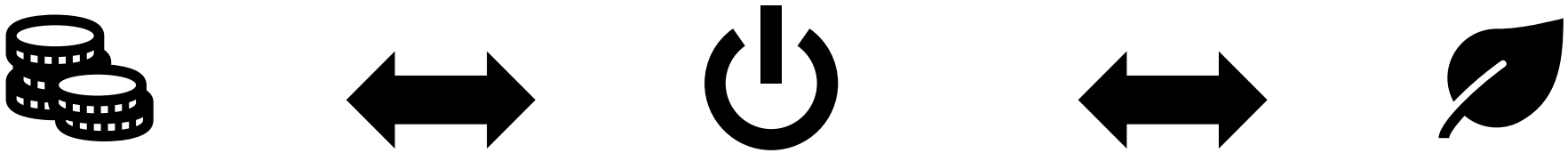
Sustainability

- Supplying power with low emissions

Three main objectives of power systems

ESIG: *Redefining Resource Adequacy for Modern Power Systems* (2021)

Motivation



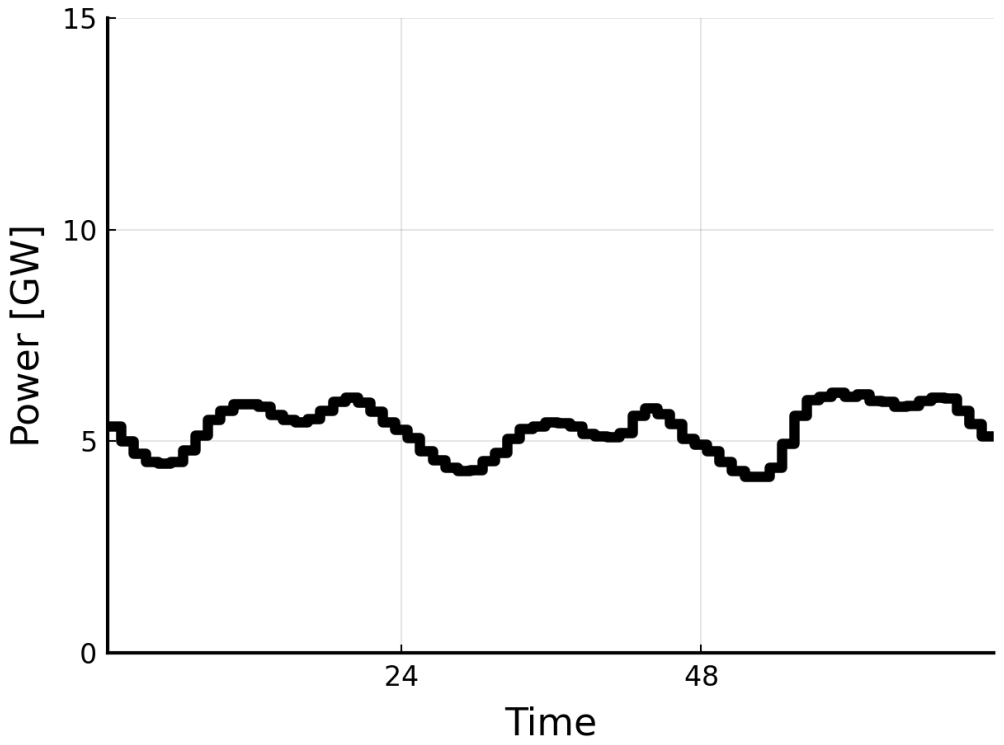
Affordability **Reliability** **Sustainability**

Resource Adequacy

Resource adequacy: Planning to ensure reliability

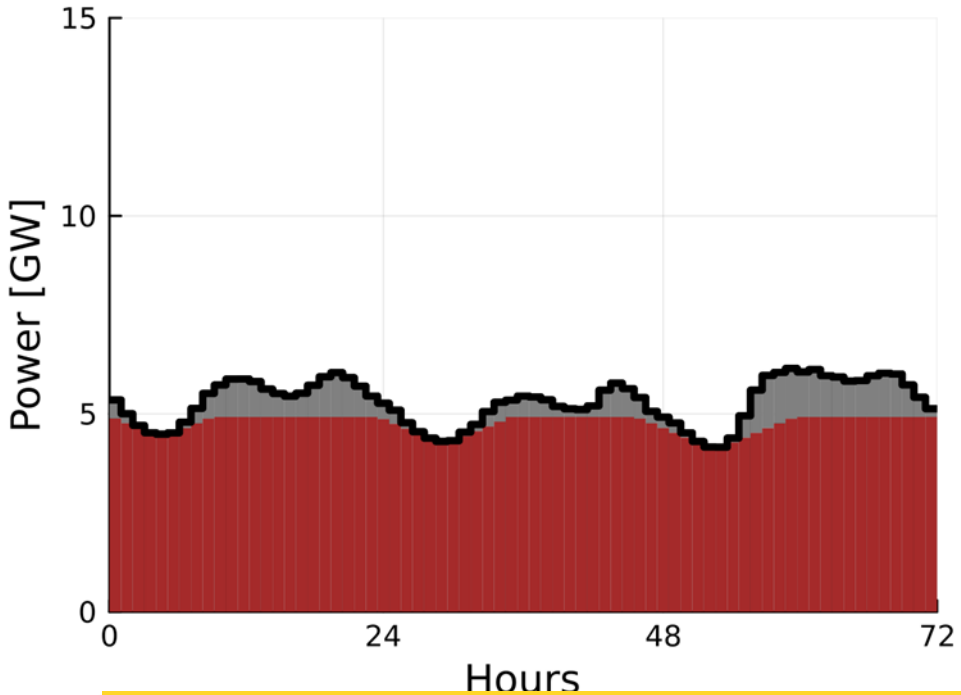
ESIG: *Redefining Resource Adequacy for Modern Power Systems* (2021)

Serving the demand

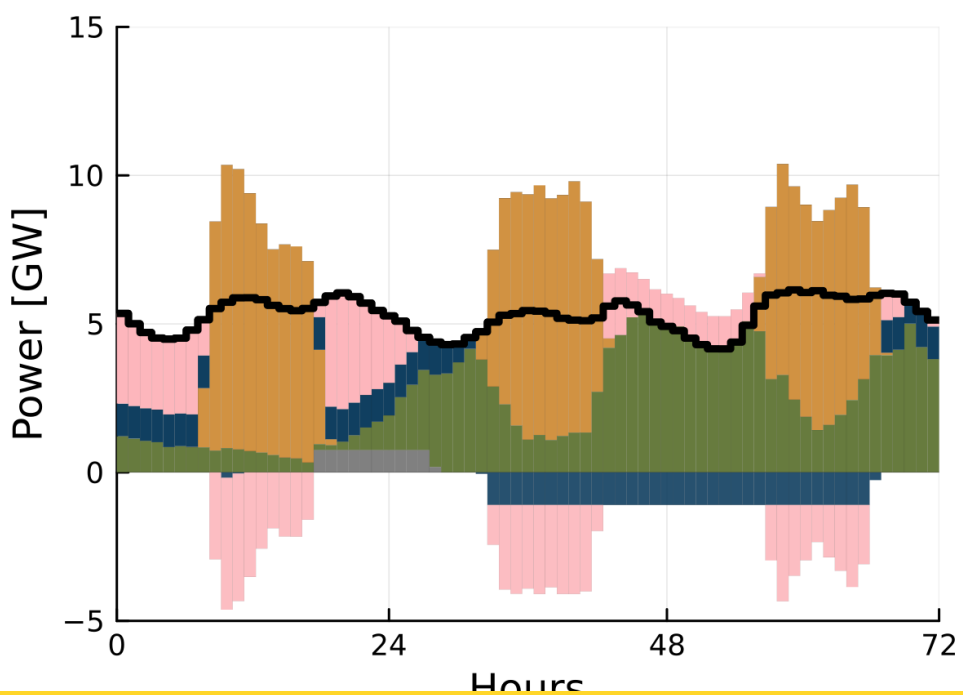


Serving the demand with least cost

Only thermal technologies



All technologies



Coal
OCGT
Solar PV
Wind
BESS (4h)
PHES (48h)

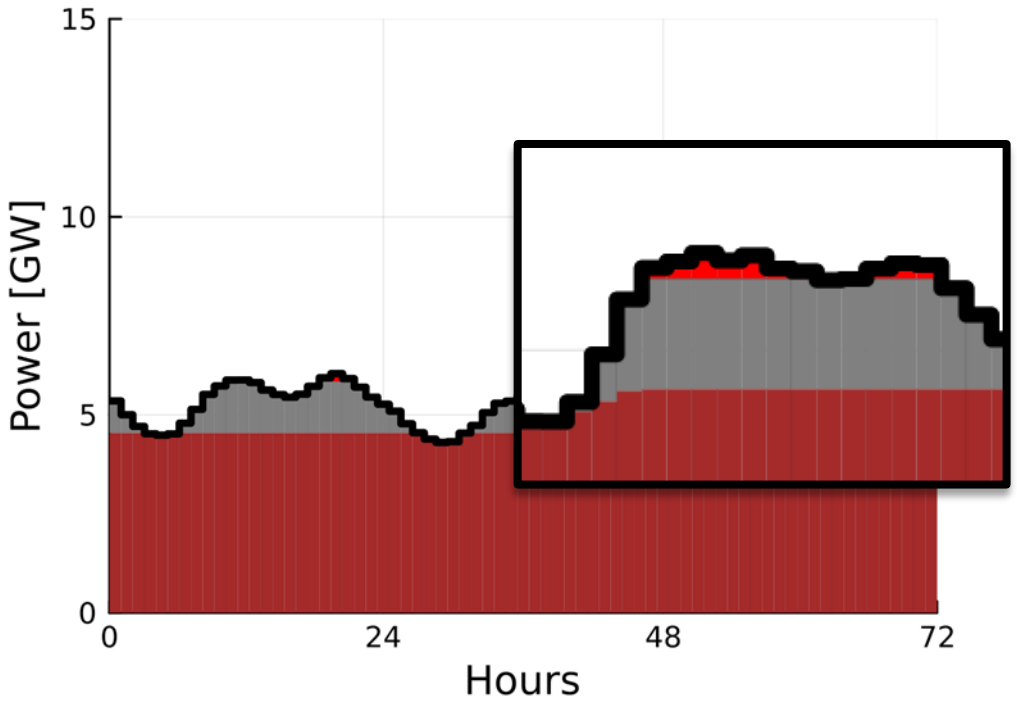
Low-carbon cost-optimal system is fundamentally different

OCGT: Op
VRE: Vari
DER: Dist
BESS (4h

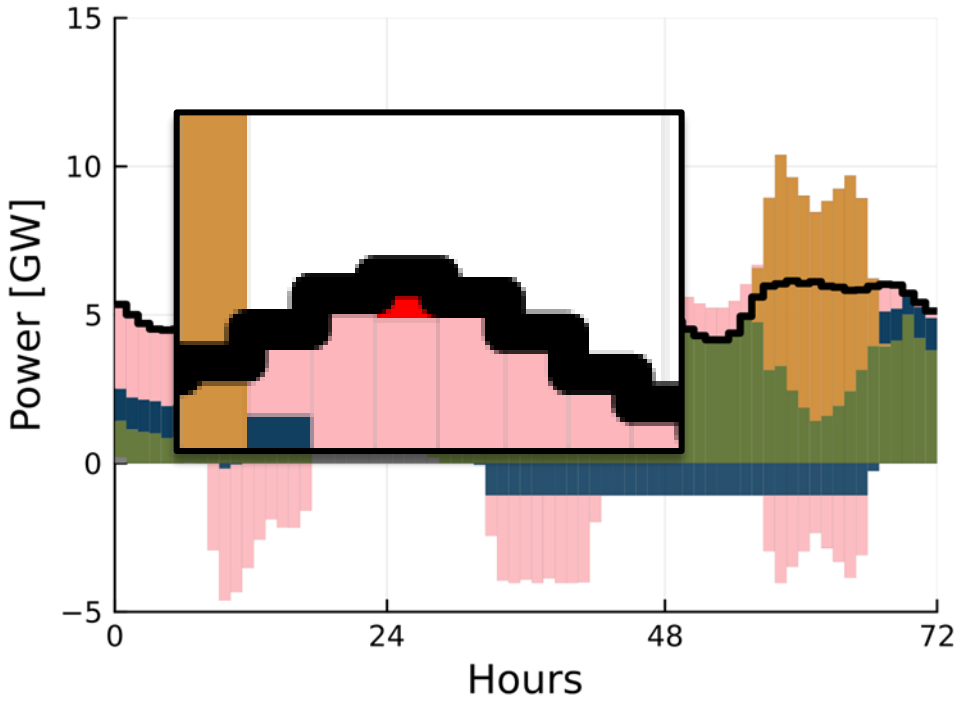
PHES (48h): Pumped Hydro Energy Storage
(Max discharge of 48h at maximum capacity)

Serving the demand + outages

Only thermal technologies



All technologies



Coal
OCGT
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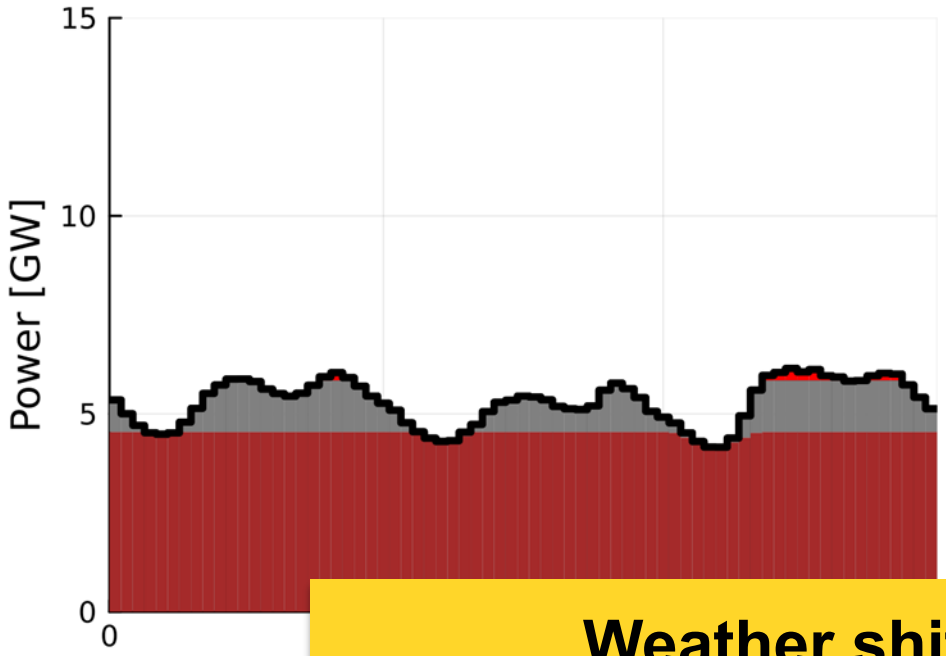
Wind
BESS (4h)
PHES (48h)

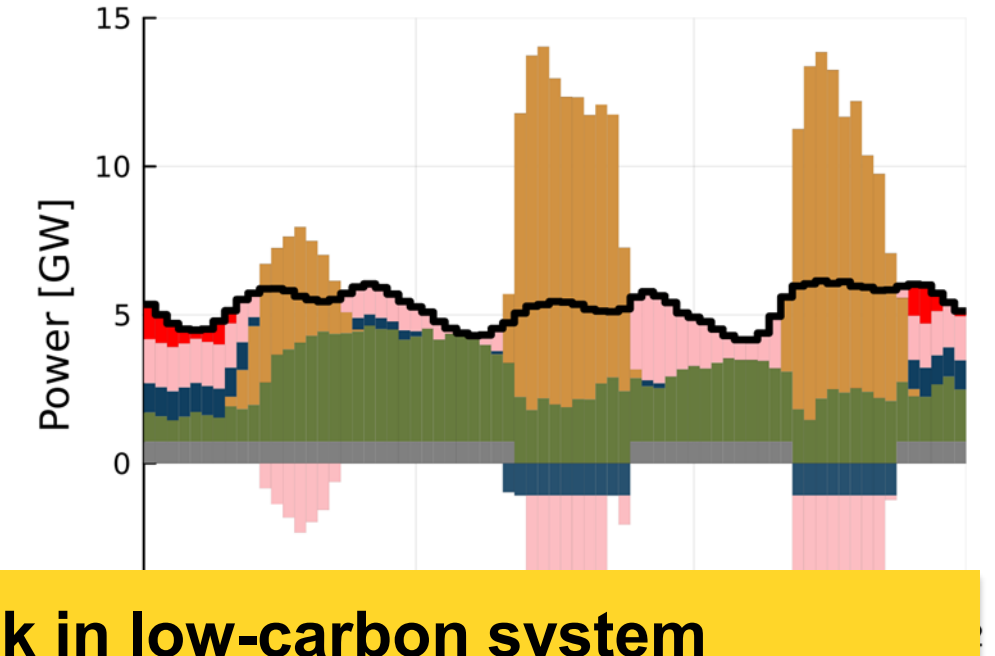
OCGT: Open-Cycle Gas Turbine
VRE: Variable Renewable Energy
DER: Distributed Energy Resources
BESS (4h): Battery Energy Storage System
(Max discharge of 4h at maximum capacity)
PHES (48h): Pumped Hydro Energy Storage
(Max discharge of 48h at maximum capacity)

Serving the demand + outages + different weather

Only thermal technologies



All technologies



Coal
OCGT
Solar PV
Wind
BESS (4h)
PHES (48h)

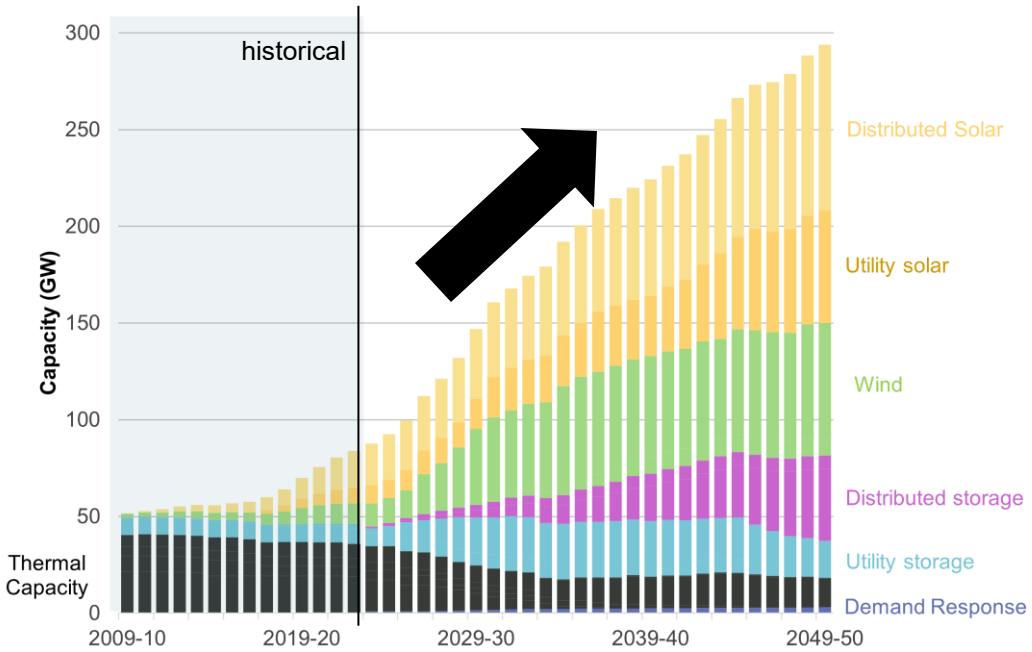
Weather shifts risk in low-carbon system

- Risk no longer at peak demand
- Larger risk events

OCGT: Open-Cycle Gas Turbine
VRE: Variable Renewable Energ
DER: Distributed Energy Resou
BESS (4h): Battery Energy Stor
(Max discharge of 4h
PHES (48h): Pumped Hydro Energy Storage
(Max discharge of 48h at maximum capacity)

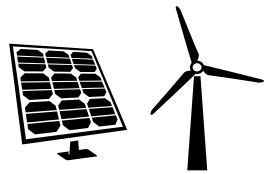
Adequacy will be defined by energy shifting

We will have a lot of power capacity …



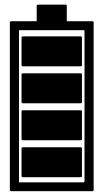
… but the available energy needs to be shifted.

Large-scale VRE



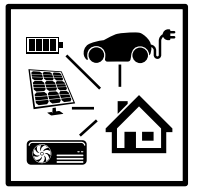
- Wind
- Solar PV

Large-scale storage



- Batteries
- Hydro Storage

DER



- Rooftop PV
- Demand Flexibility

aping
mand

Storage and DER operation are essential for adequacy

AEMO: *NEM Integrated System Plan* (2024)

VRE: Variable Renewable Energy | **DER**: Distributed Energy Resources

Research Question

How does the adequacy risk change with increasing penetrations of VRE and storage?

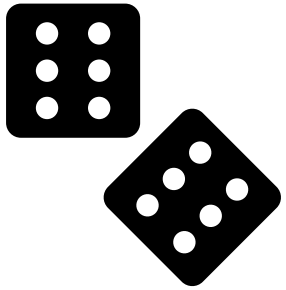
VRE: Variable Renewable Energy generation | **DER**: Distributed Energy Resources

Methodology: Probabilistic Adequacy Assessment

NEM ISP 2024 data

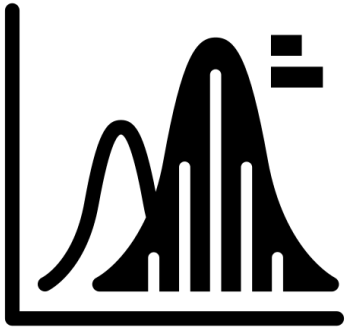
*Credits to **Pablo**!*

PRASNEM



Enabling PRAS[1] simulation and analysis

Sequential Monte-Carlo Sampling

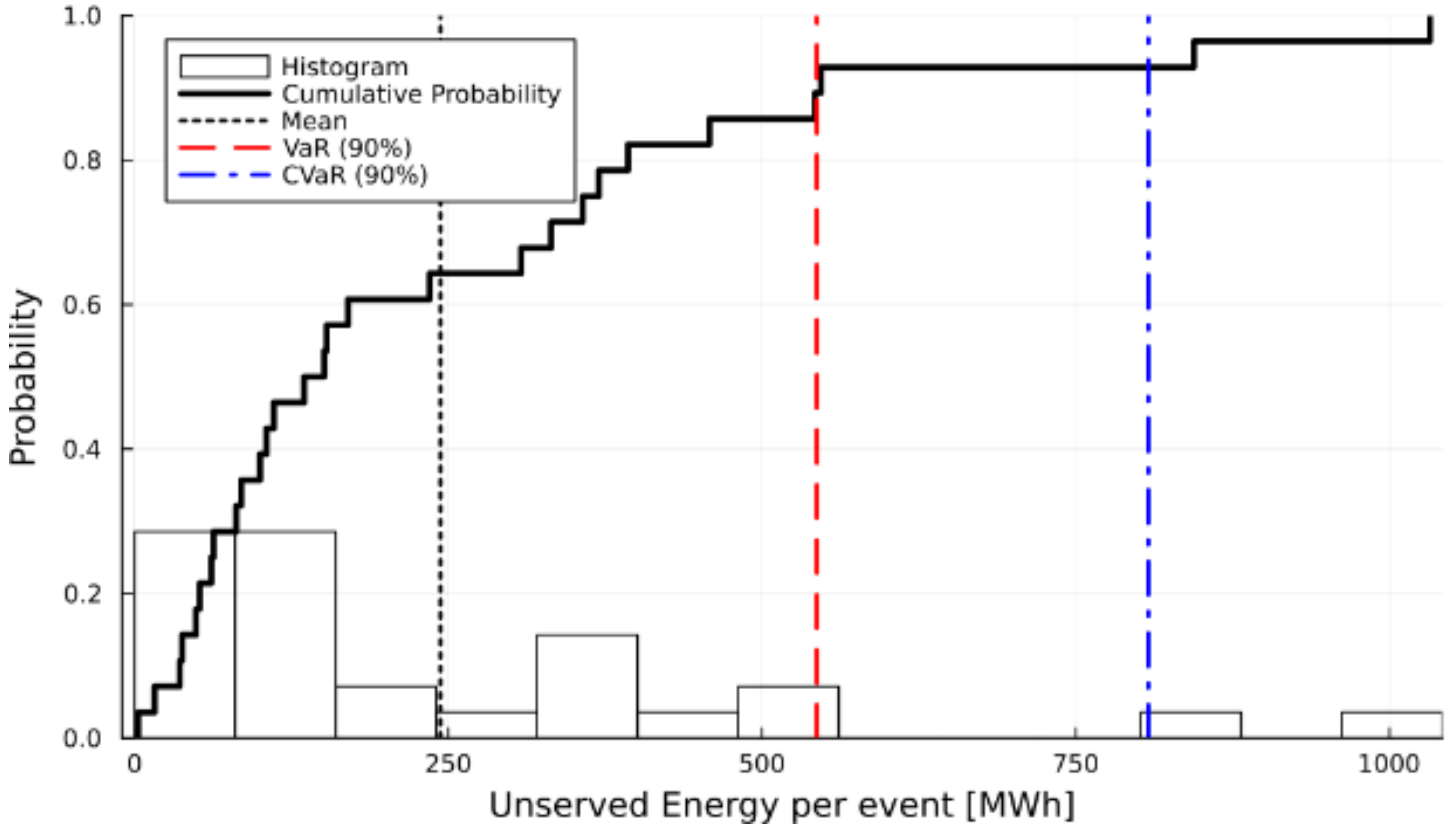


Reliability risk profile

Open-source NEM model in PRAS to assess system adequacy

[1] G. Stephen, "Probabilistic Resource Adequacy Suite (PRAS) v0.6 Model Documentation," NREL/TP--5C00-79698, May 2021

Understanding the risk in detail



** Preliminary results*

Simulation parameters: *Step Change* scenario | 12-node representation | Anticipated + actionable transmission projects | Weather reference trace 4006 (ODP) | Demand POE 10% | 500 Outage Samples | Target calendar year 2030

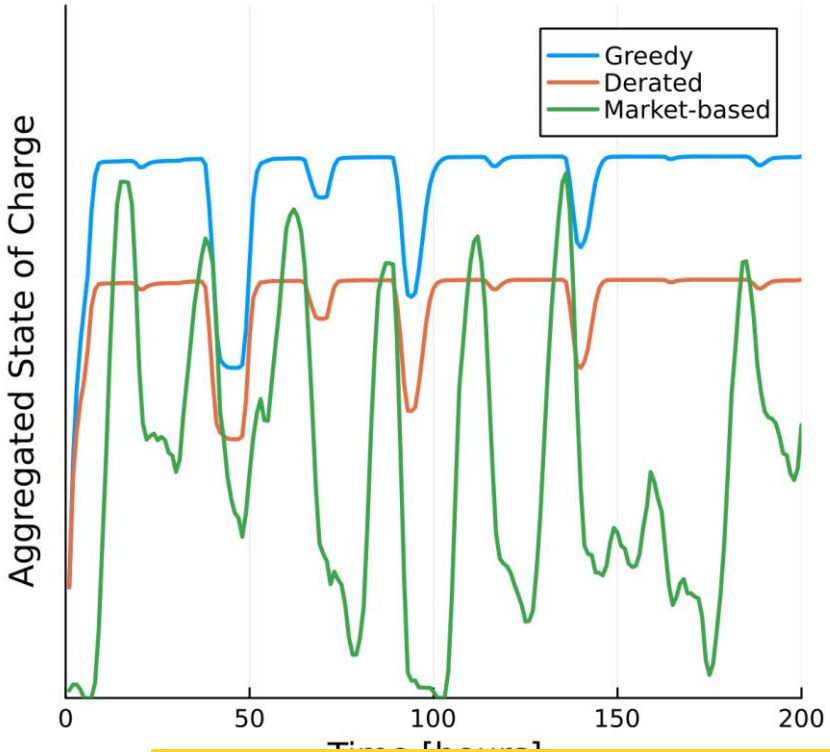
VaR: Value-at-Risk | **CVaR**: Conditional Value-at-Risk

Research Question

How can we most accurately capture the operation of storage and DER ?

VRE: Variable Renewable Energy generation | **DER**: Distributed Energy Resources

Storage operation and resource adequacy



Modelling storage operation

1. **Greedy management** (PRAS default)
   Adequacy-optimal operation to minimise unserved energy
2. **Energy derated** (AEMO aligned)
   Reduce energy capacity of short-duration storage
   (-50% for <1.5h, -25% for 1.5-3.5h, -10% for 3.5-7.5h)
3. **Market-based dispatch**
   Storage dispatch based on least cost optimisation before sampling system conditions

Need to capture imperfect storage operation

NEM: National Electricity Market | **PRAS**: Probabilistic Resource Adequacy Suite (by NLR)

DER operation and resource adequacy

Coordination

Contribution depends on asset coordination

- **Schedule uncoordinated DER with different objective**

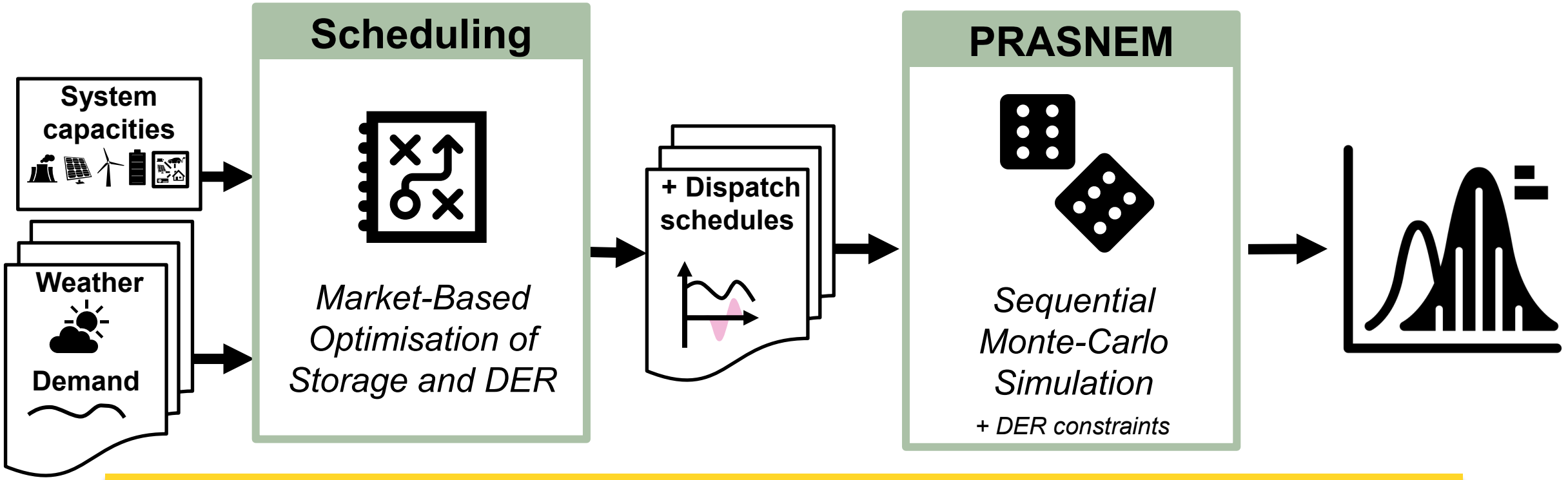
Constraints

Payback constraints and availability might limit contribution

- **Add payback limits explicitly to PRASNEM**

Capture DER operation with scheduling and constraints

Methodology: Enhanced adequacy modelling

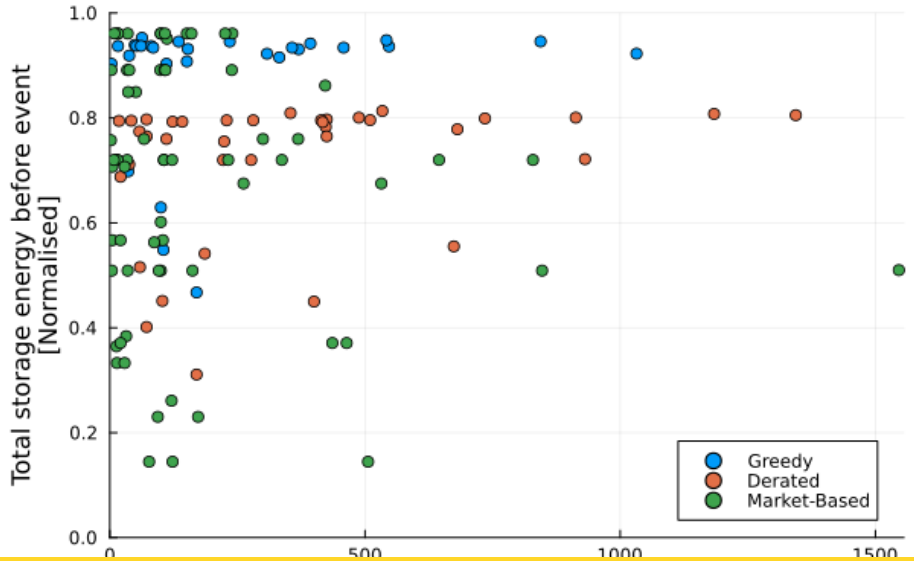


Add **scheduling with imperfect foresight**
for accurate storage and DER operation

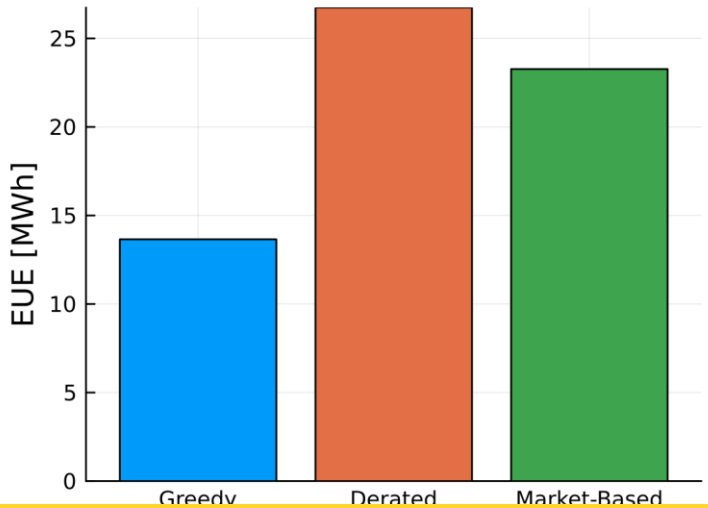
DER: Distributed Energy Resources | **PRAS**: Probabilistic Resource Adequacy Suite (by NLR)

Impact of storage operation *(work in progress)*

Storage levels
before load shedding events



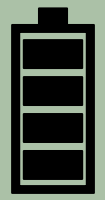
System Adequacy
based on different metrics



Storage operation modelling impacts adequacy results significantly

EUE: Expected Unserved Energy | **LOLH**: Loss of Load Hours | **CVaR**: Conditional Value-at-Risk

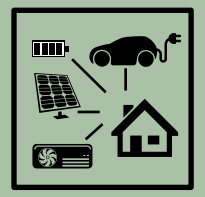
Ongoing EPICS Collaborations



The role of storage in RA

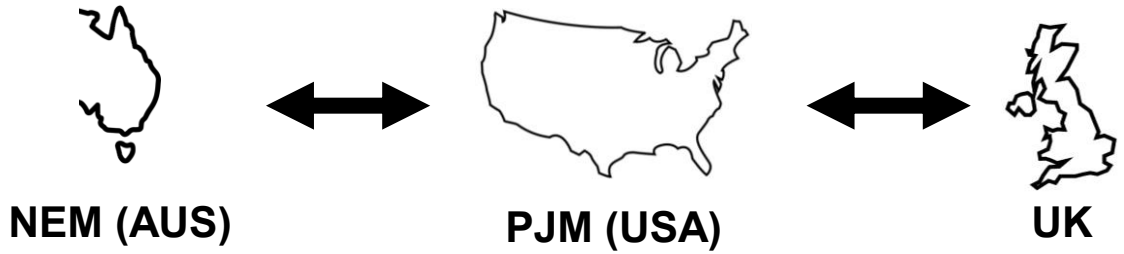
What system conditions may require system operator inventions on storage behaviour?

*With **Adam Suski** (Imperial)*



The role of DR in RA

What is the role of demand response in different power systems?



*With **Ignacio Serrano van der Schraft** (Imperial), **Eshagh Safarzadeh Ravajiri** (JHU) + support from NLR*

DR: Demand Response | **RA**: Resource Adequacy | **NEM**: National Electricity Market (East Australia)

Capturing storage and DER operation for resource adequacy in low-carbon power systems

Thank you. Questions?

Tim Kopka, PhD Candidate

Australian EPICS Workshop, 29th January 2026

Supervisor *Prof. Pierluigi Mancarella*
Co-Supervisor *Dr. Sleiman Mhanna*