*"Evolving Transmission Planning Approaches for Increasingly Uncertain Futures"*

# Risk-aware and flexible integrated system planning, with experiences from Great Britain and Australia


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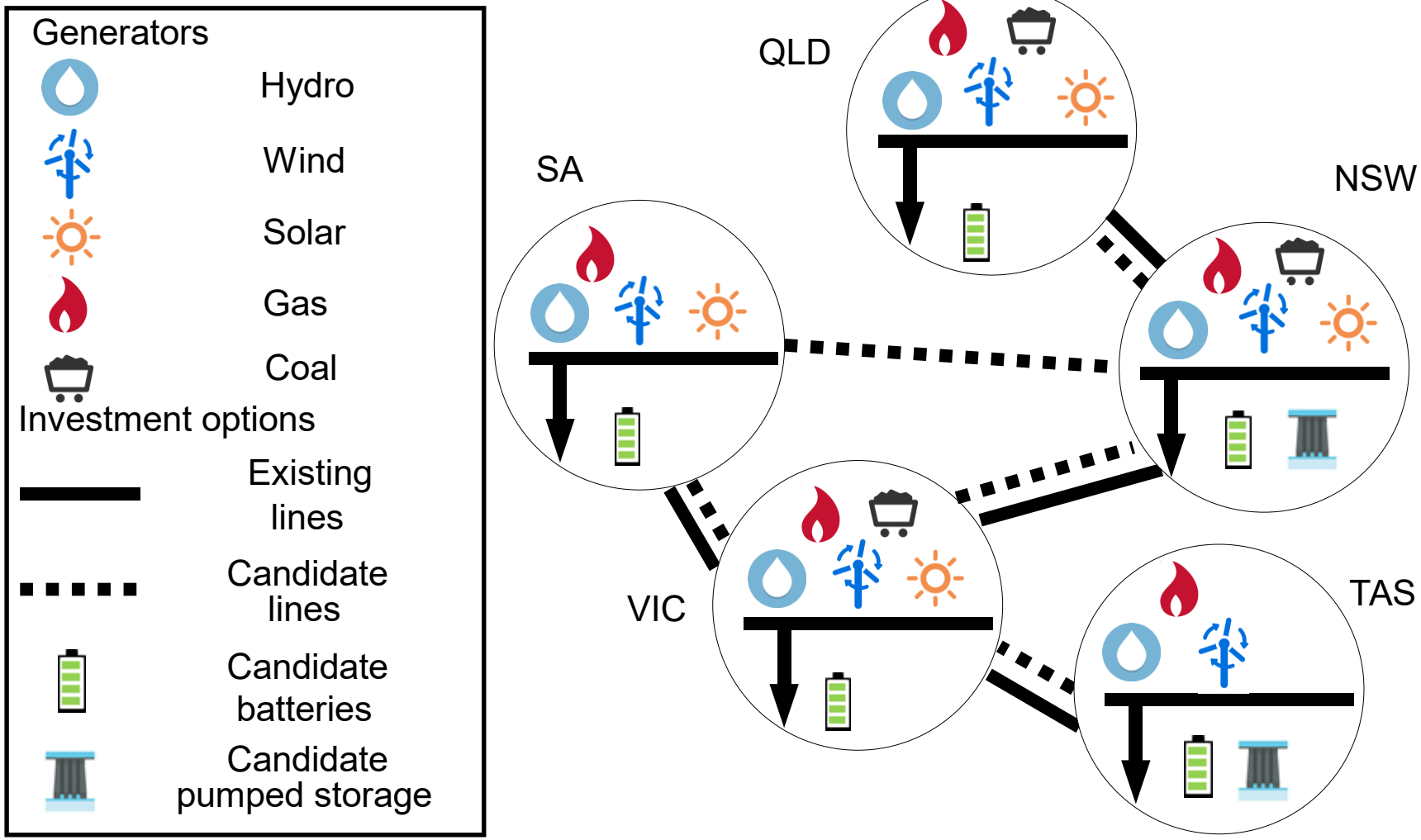
PMAPS22, Manchester, United Kingdom

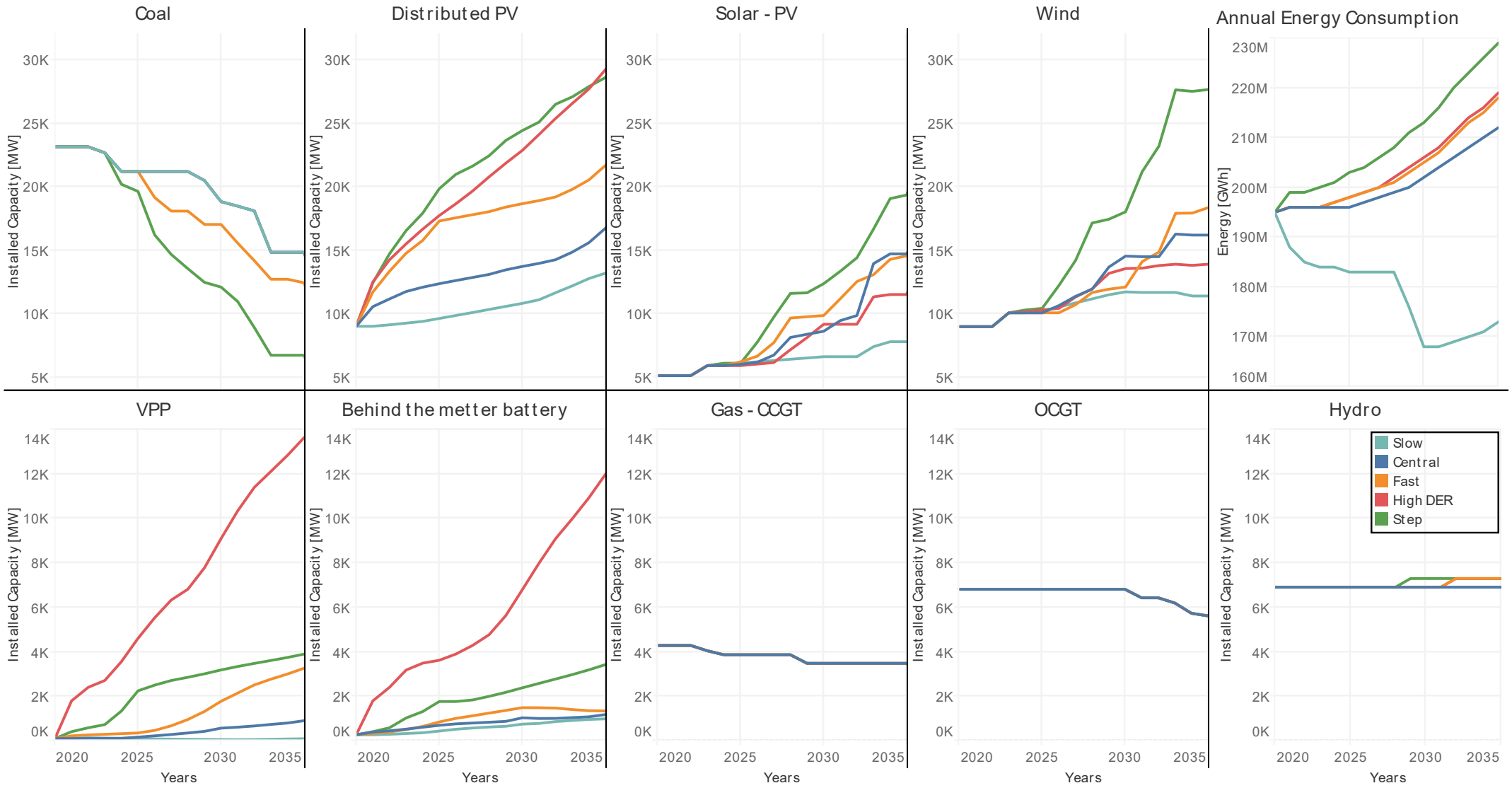
14th June 2022

# What planning option? Spoilt for choice!



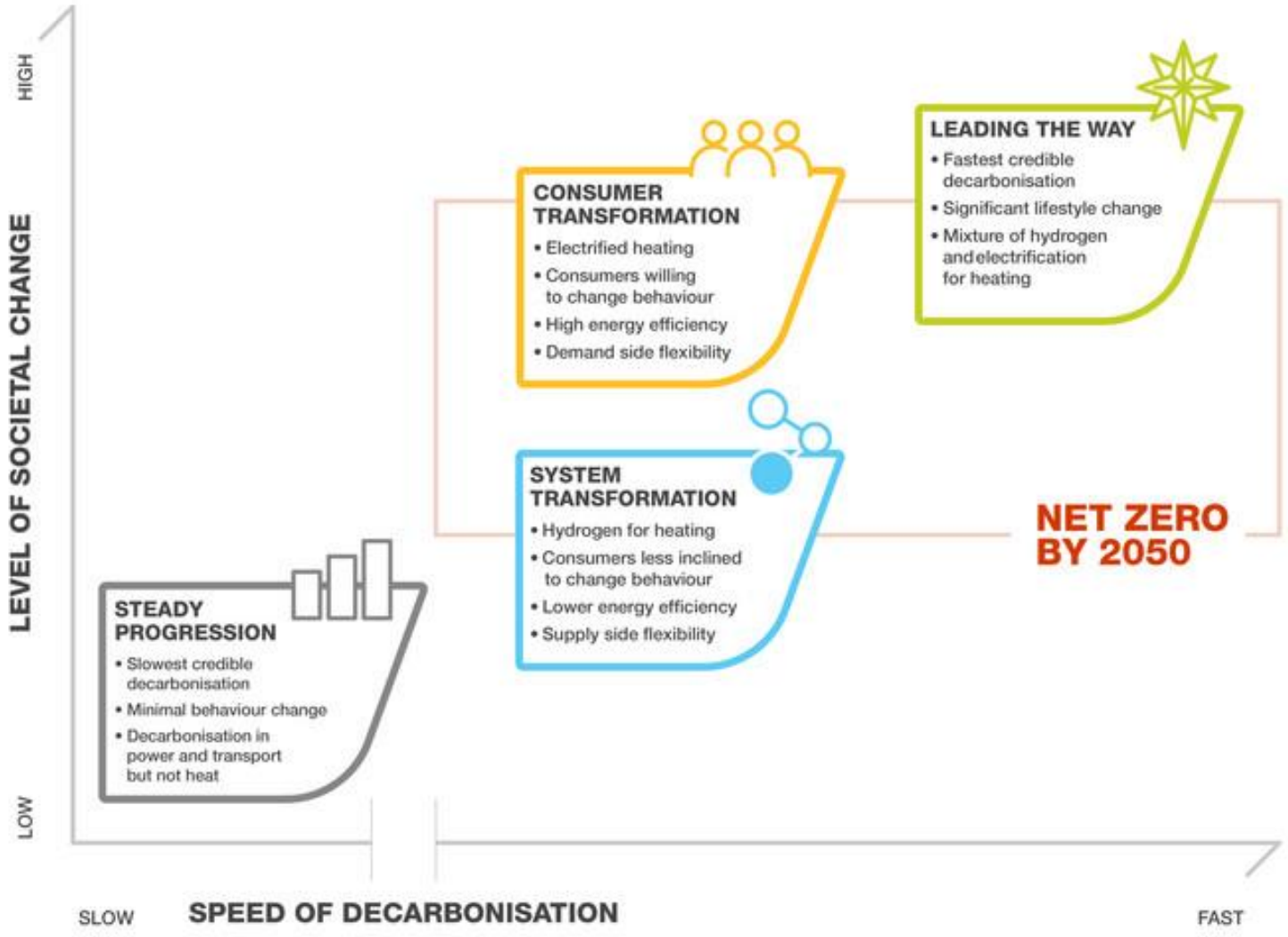

B. Moya, R. Moreno, S. Püschel-Løvengreen, A. M. Costa, P. Mancarella, "Co-optimized Energy Storage and Transmission Expansions with Various Representations of Long-Term Uncertainty and Decision Dynamics", *PSCC 2022, to appear*

# But what future do we plan for?



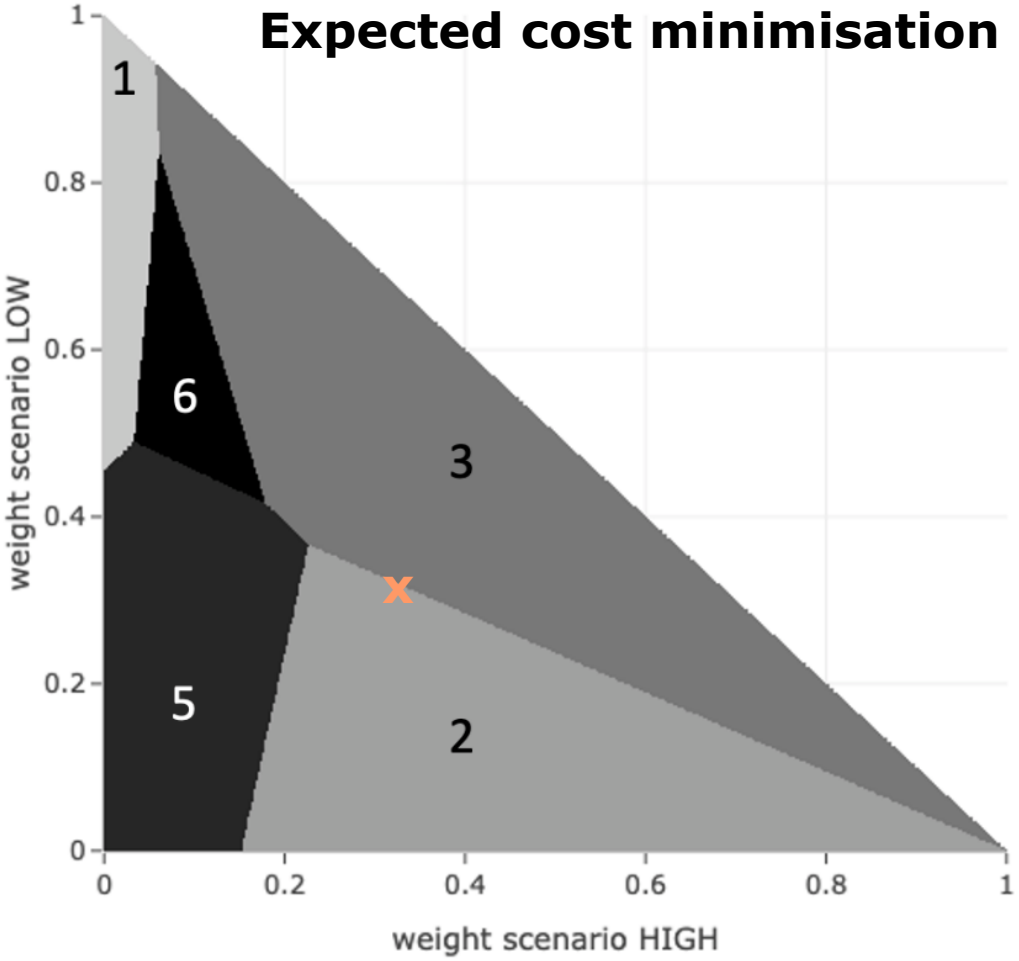

Source: AEMO, ISP 2020

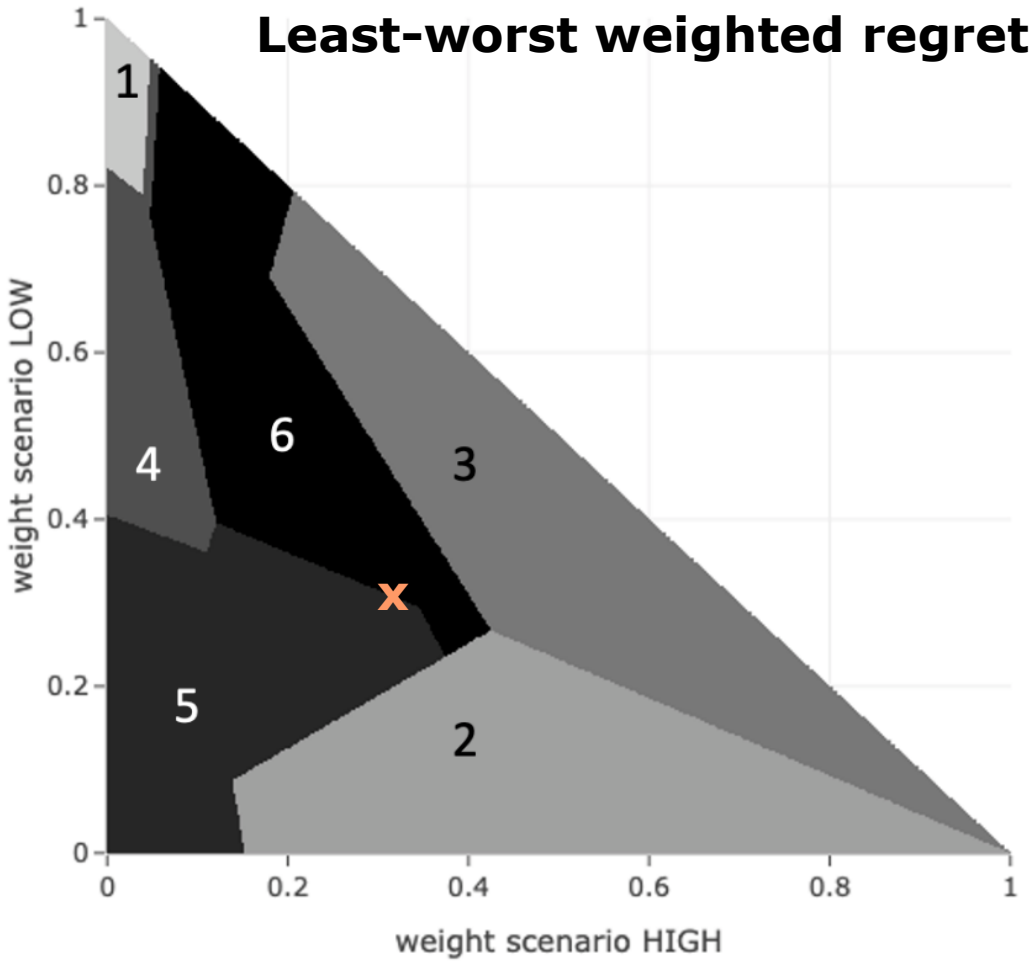
# Net zero can be reached in many ways…




Source: National Grid ESO, UK, FES 2021

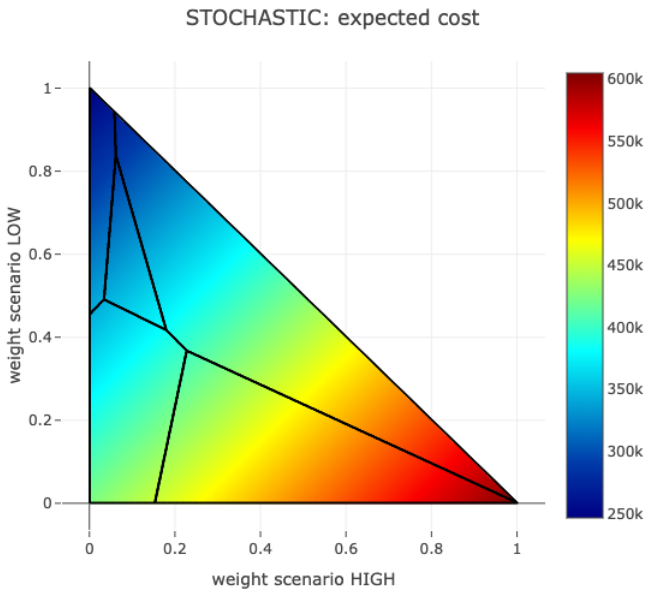
# How can I make a decision under uncertainty over *multiple* scenarios?

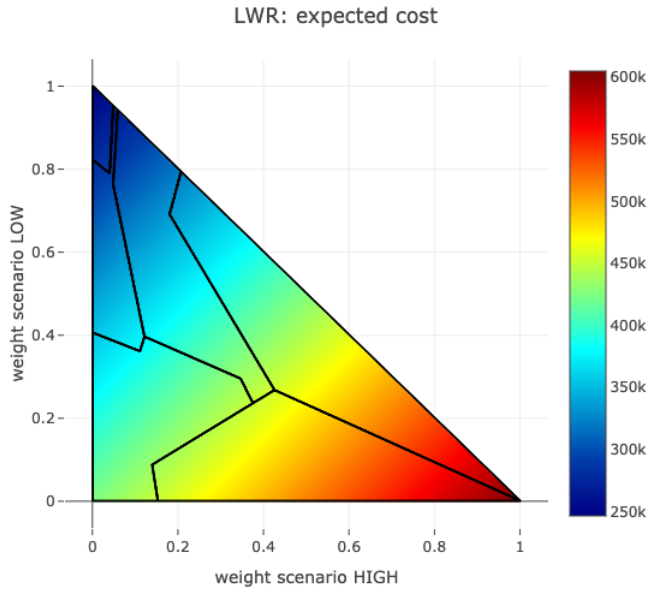


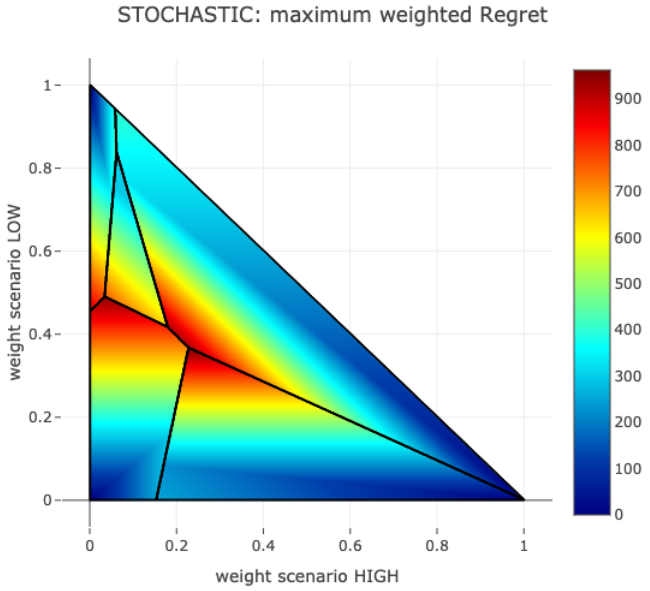



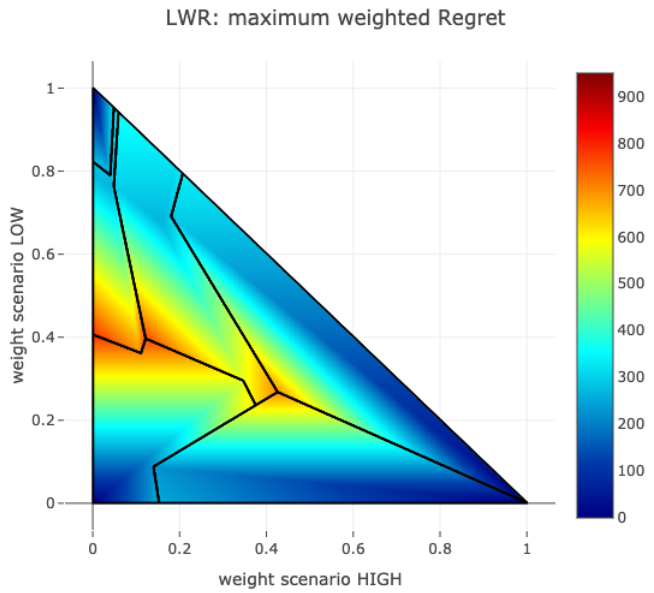

Source: P. Mancarella, *et al.*, "Study of advanced modelling for network planning under uncertainty - Part 1", Report for National Grid ESO, 2020: https://www.nationalgrideso.com/document/185821/download

# How can I measure costs and risks?

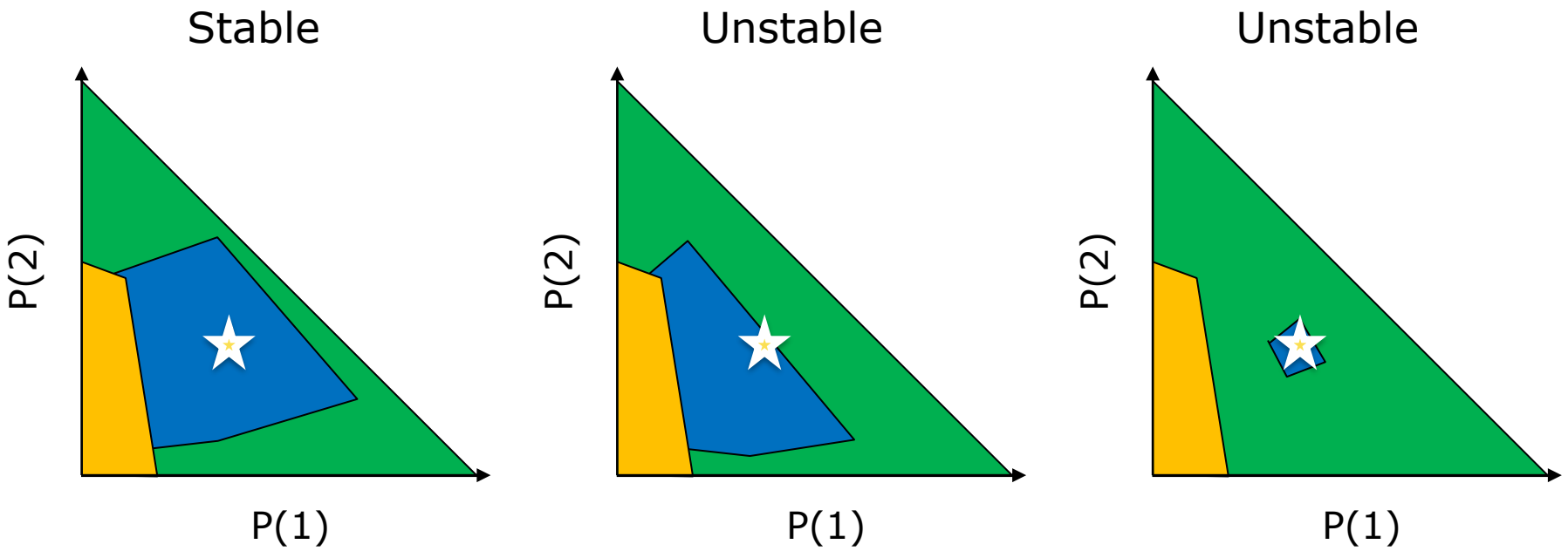


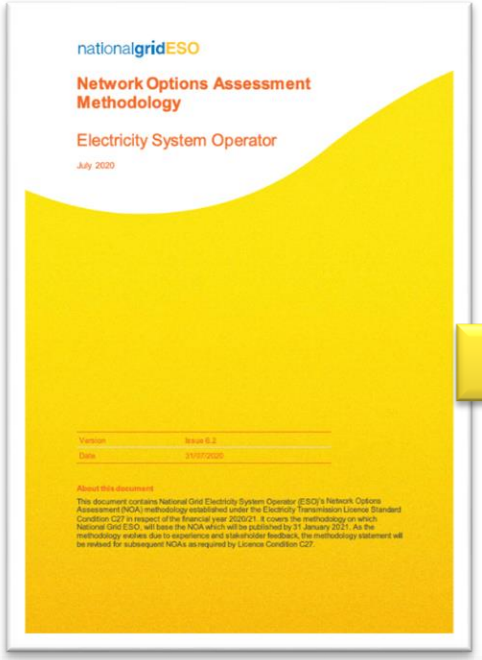



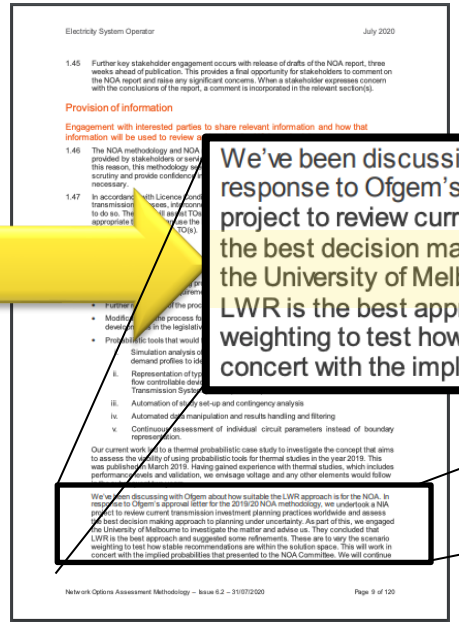



# How robust is my planning solution?

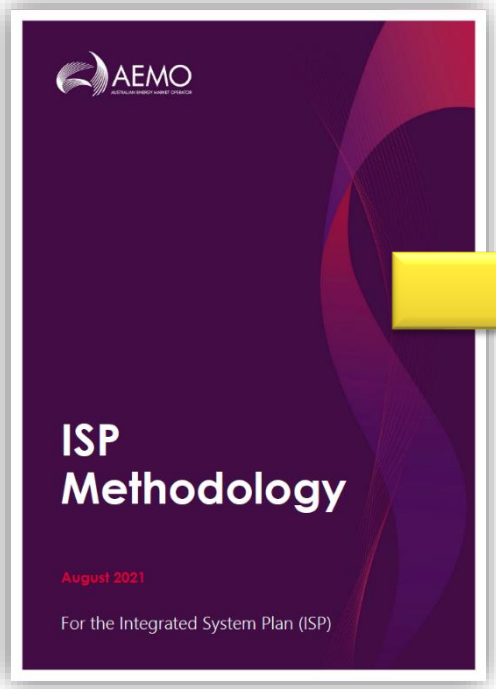


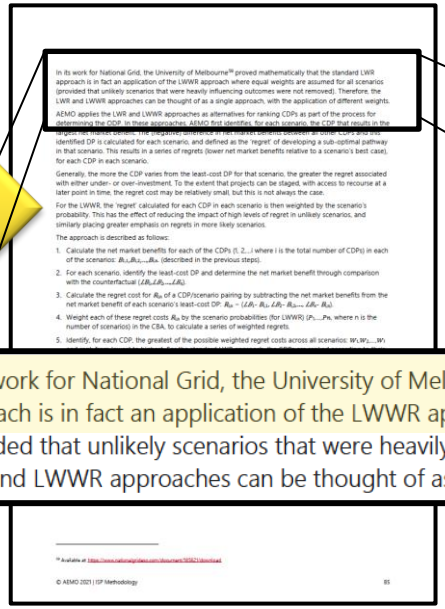
# LWWR applications



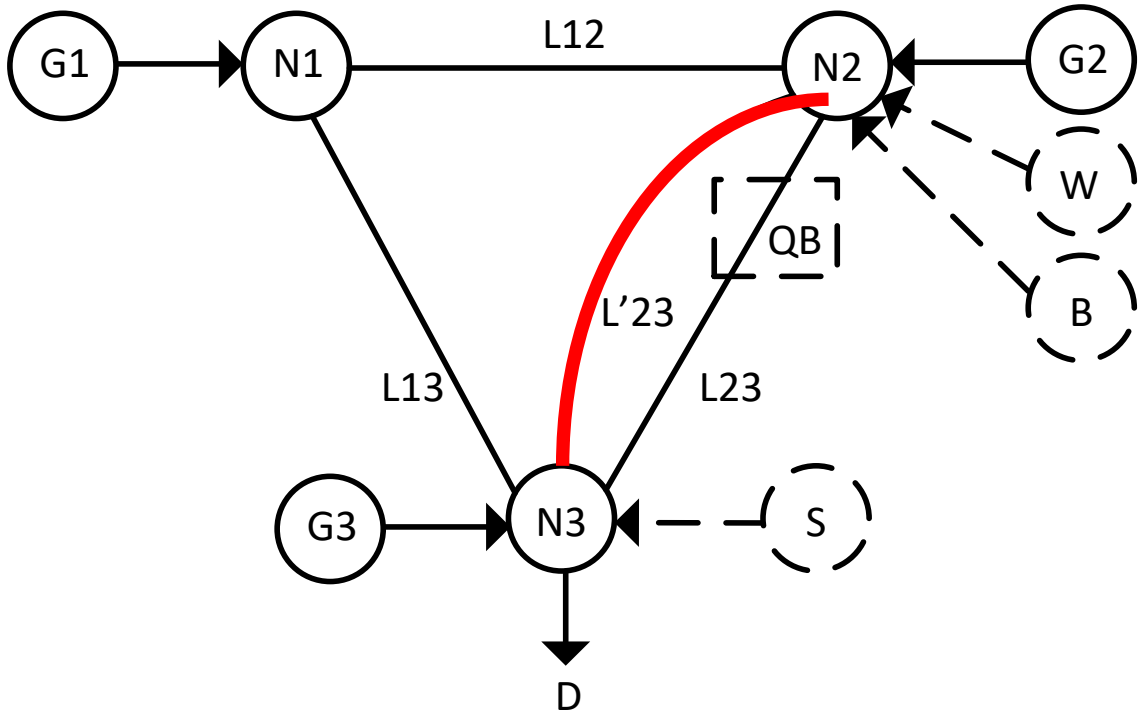
We've been discussing with Ofgem about how suitable the LWR approach is for the NOA. In response to Ofgem's approval letter for the 2019/20 NOA methodology, we undertook a NIA project to review current transmission investment planning practices worldwide and assess the best decision making approach to planning under uncertainty. As part of this, we engaged the University of Melbourne to investigate the matter and advise us. They concluded that LWR is the best approach and suggested some refinements. These are to vary the scenario weighting to test how stable recommendations are within the solution space. This will work in concert with the implied probabilities that presented to the NOA Committee. We will continue



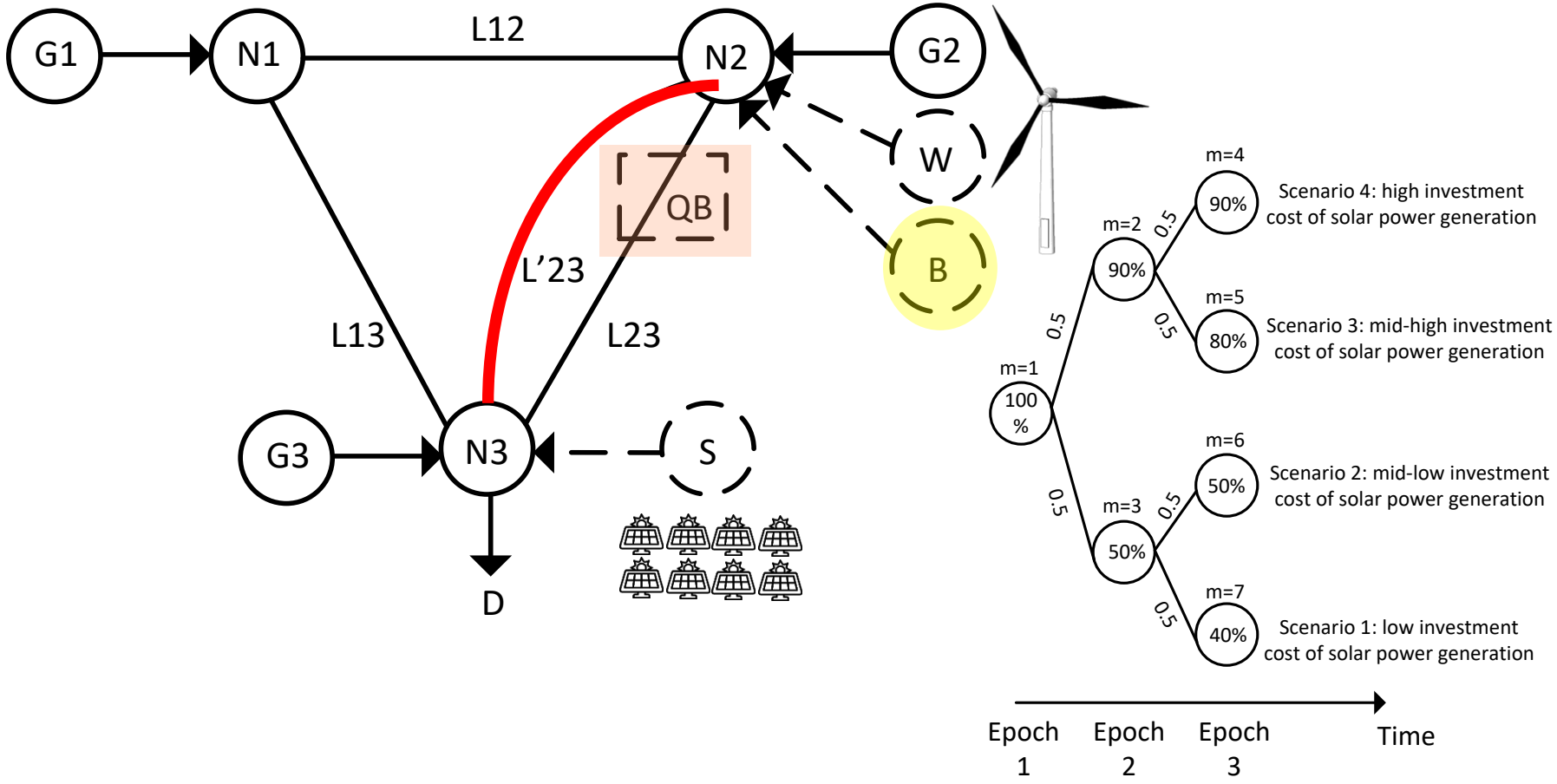
In its work for National Grid, the University of Melbourne[59] proved mathematically that the standard LWR approach is in fact an application of the LWWR approach where equal weights are assumed for all scenarios (provided that unlikely scenarios that were heavily influencing outcomes were not removed). Therefore, the LWR and LWWR approaches can be thought of as a single approach, with the application of different weights.

# Moving forward:
# A flexible investment planning methodology…



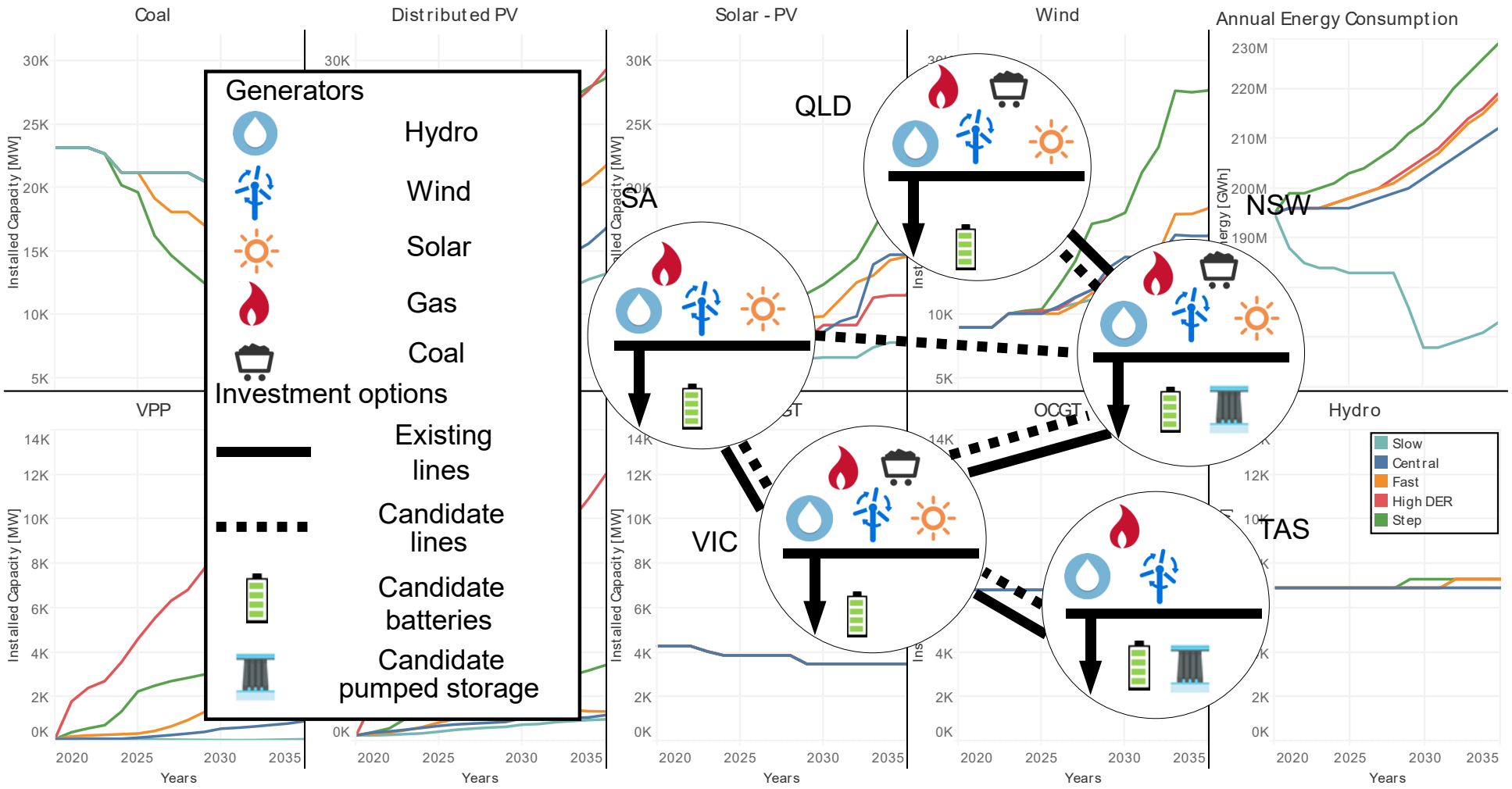

R. Moreno, A. Street, J.M. Arroyo, and P. Mancarella, "Planning Low-Carbon Electricity Systems under Uncertainty Considering Operational Flexibility and Smart Grid Technologies", *Philosophical Trans. Royal Society A*, June 2017

# … unlocks the *option value* of non-network solutions



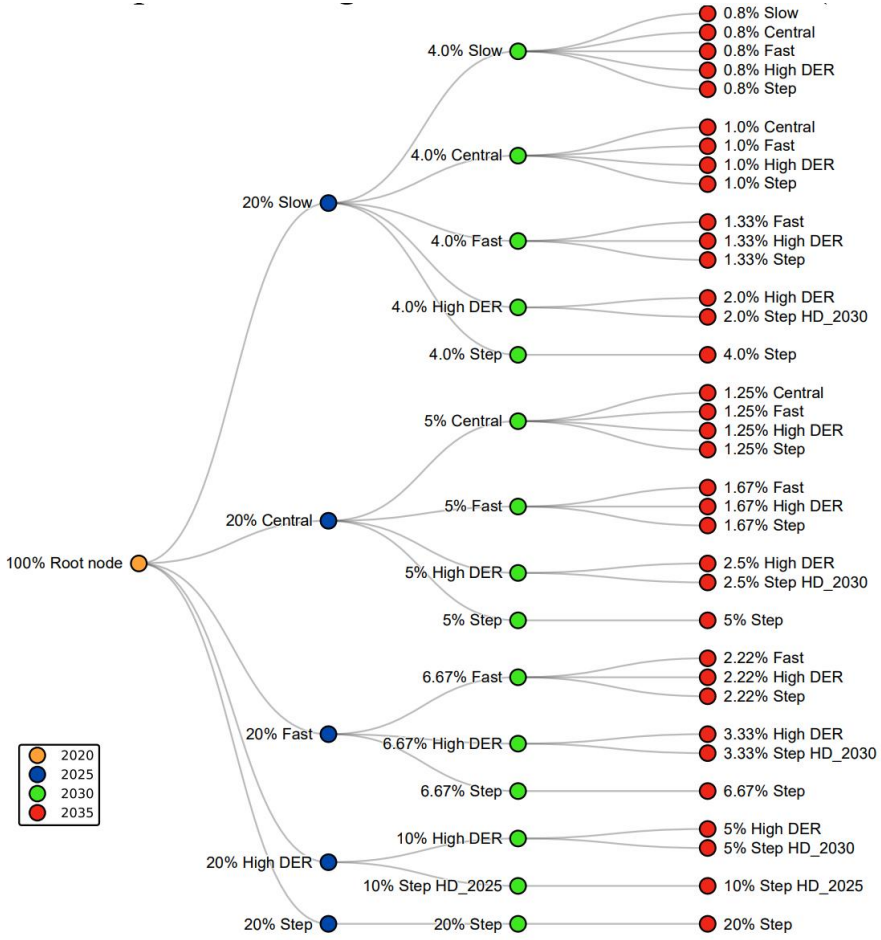

R. Moreno, A. Street, J.M. Arroyo, and P. Mancarella, "Planning Low-Carbon Electricity Systems under Uncertainty Considering Operational Flexibility and Smart Grid Technologies", *Philosophical Trans. Royal Society A*, June 2017

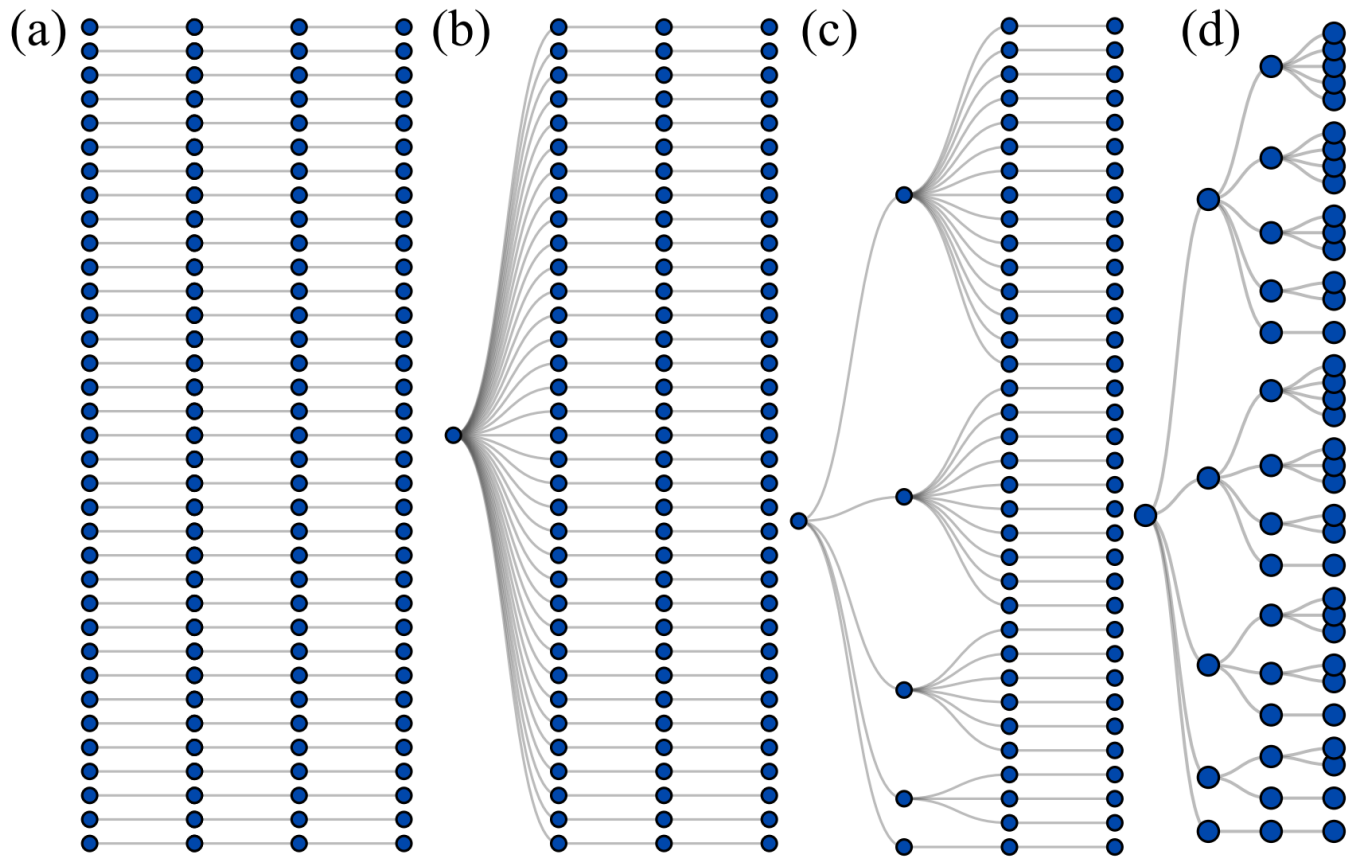
# Stochastic planning for the NEM: Multi-asset investment co-optimization…




B. Moya, R. Moreno, S. Püschel-Løvengreen, A. M. Costa, P. Mancarella, "Co-optimized Energy Storage and Transmission Expansions with Various Representations of Long-Term Uncertainty and Decision Dynamics", *PSCC 2022, to appear*

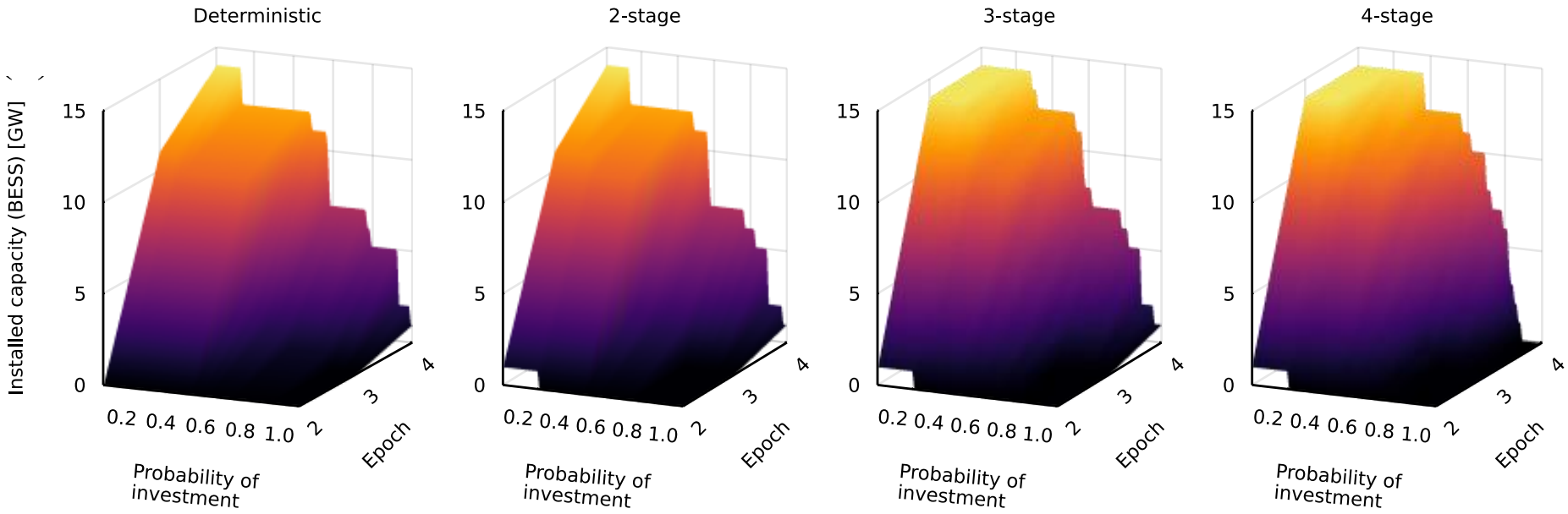
# … uncertainty representation and simplifications…




B. Moya, R. Moreno, S. Püschel-Løvengreen, A. M. Costa, P. Mancarella, "Co-optimized Energy Storage and Transmission Expansions with Various Representations of Long-Term Uncertainty and Decision Dynamics", *PSCC 2022, to appear*

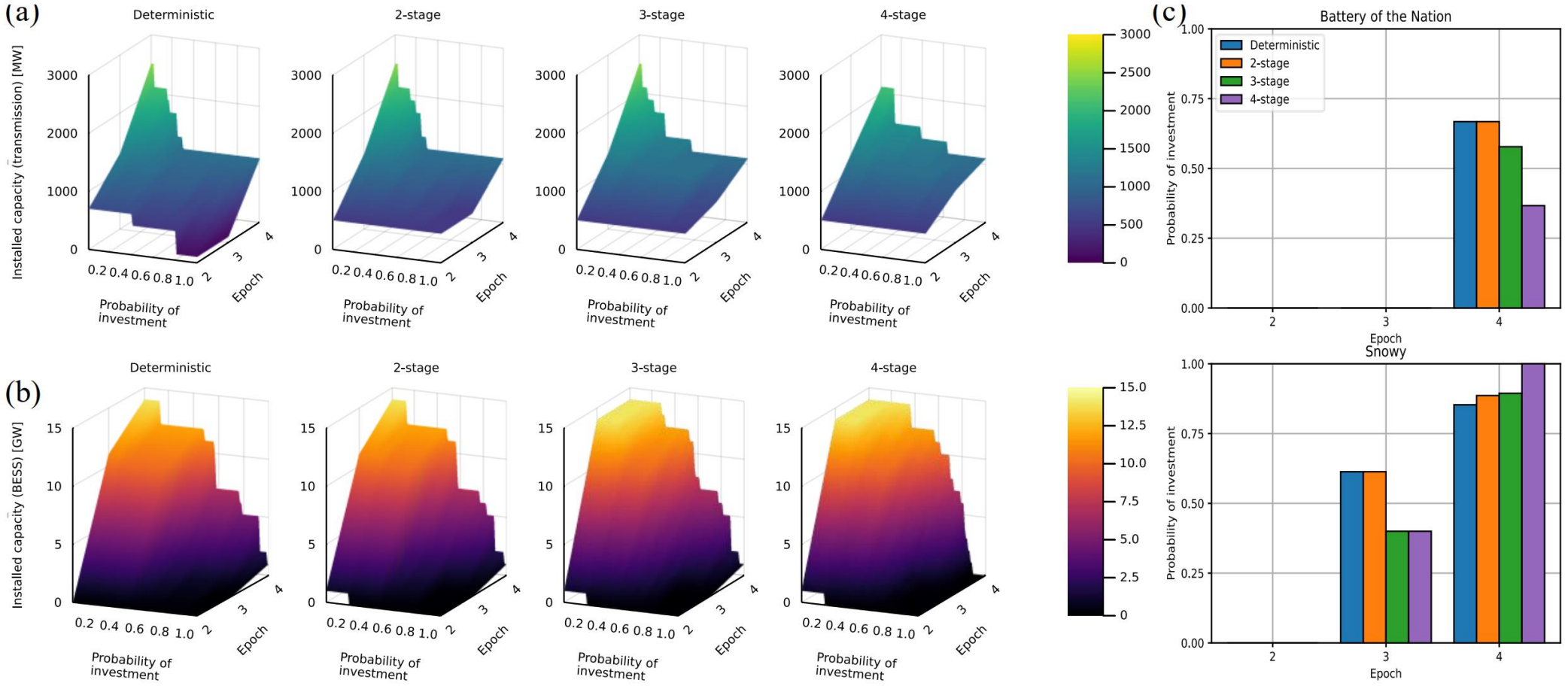
# … and the value of storage vs transmission




Stochastic planning reveals new role for storage

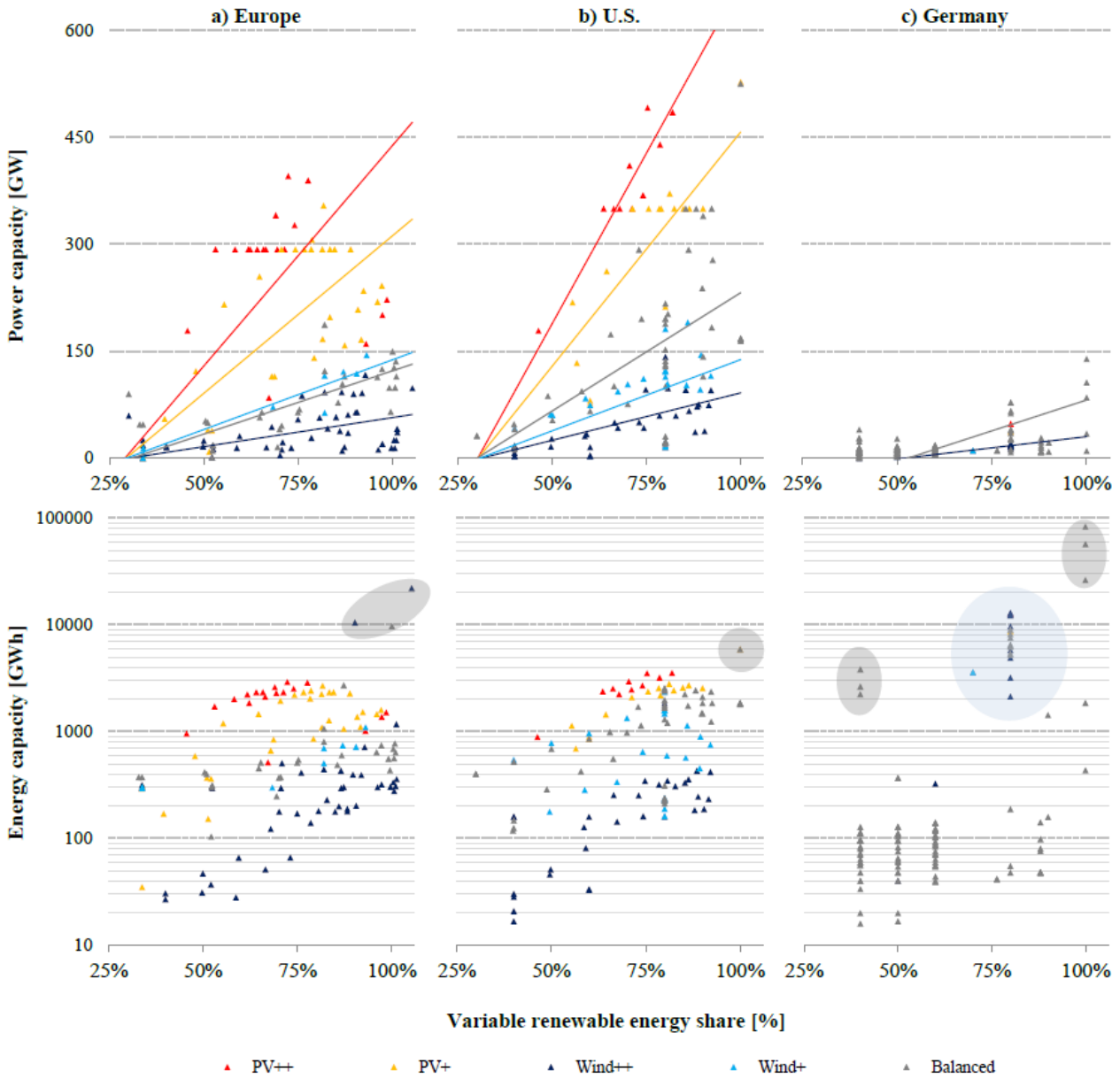
B. Moya, R. Moreno, S. Püschel-Løvengreen, A. M. Costa, P. Mancarella, "Co-optimized Energy Storage and Transmission Expansions with Various Representations of Long-Term Uncertainty and Decision Dynamics", *PSCC 2022, to appear*

# Complementarity and competition among technologies



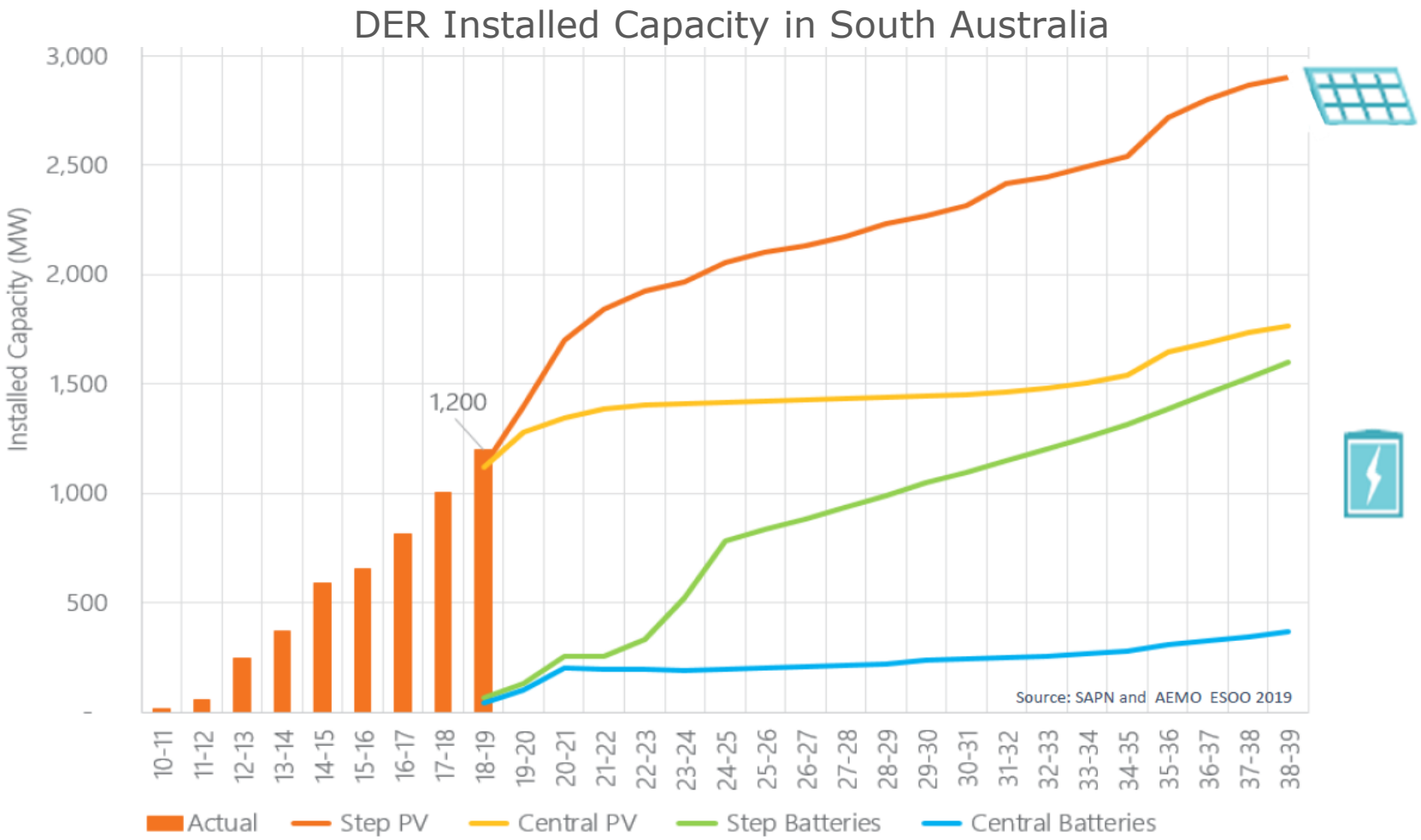

Moya, B., Moreno, R., Püschel-Løvengreen, Costa, A.M., Mancarella, P. Uncertainty representation in investment planning of low-carbon power systems. Electric Power System Research / PSCC, 2022

# How much and what storage do we need?




F. Cebulla, *et al.*, "How much electrical energy storage do we need?", *Journal of Cleaner Production*, Volume 181, 20 April 2018, 449-459

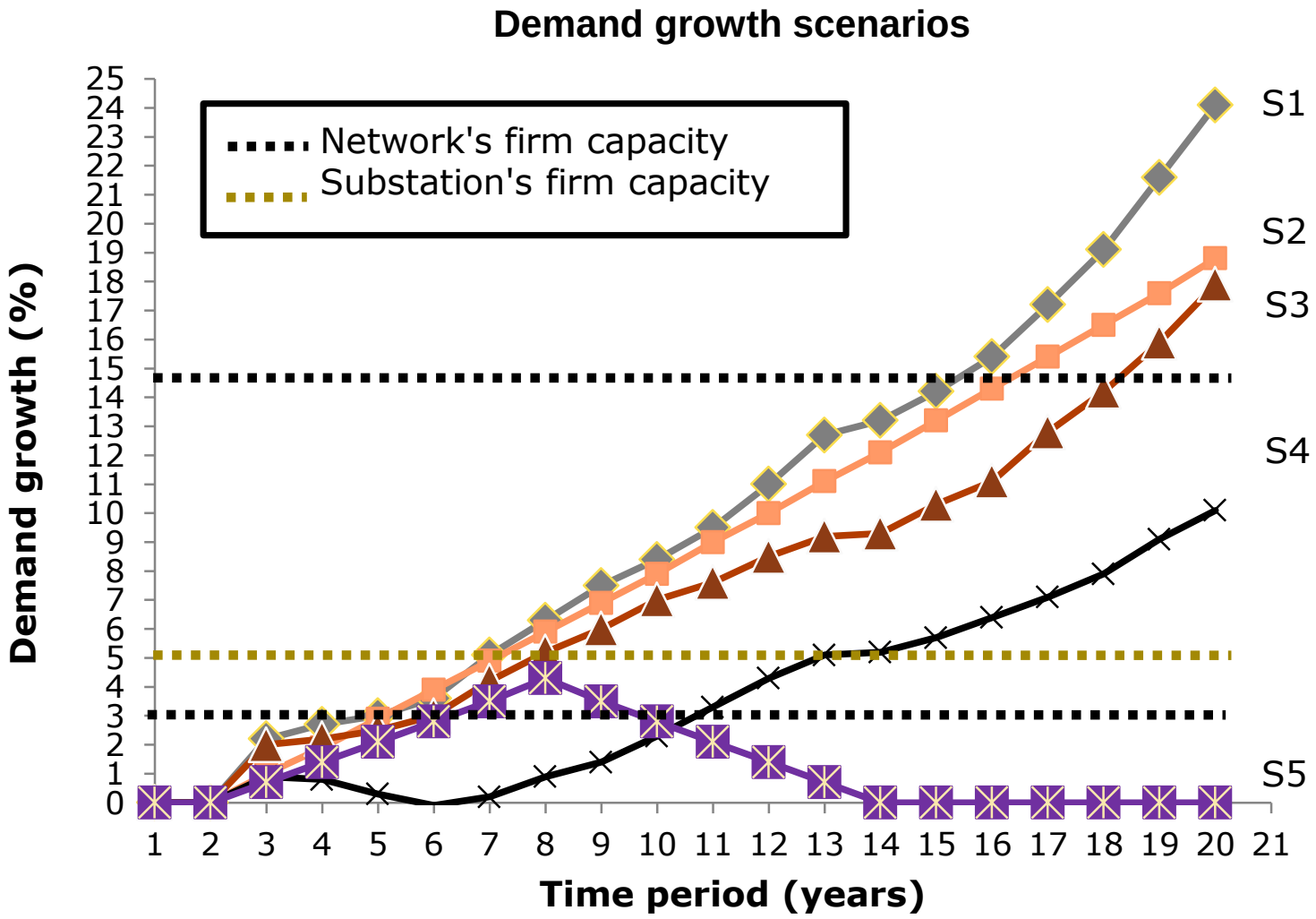
# Uncertainty is not only in transmission…




**Uncertain development of DER under AEMO's scenarios: Central and Step change**

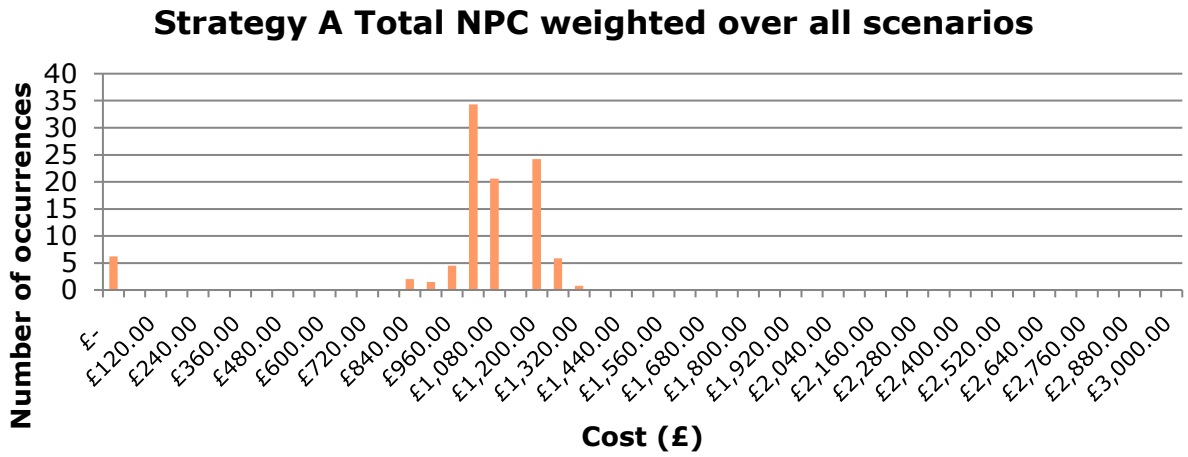
Source: South Australia Power Networks. (2020). Adelaide Power System Summer School – SA Power Networks Workshop [PowerPoint].

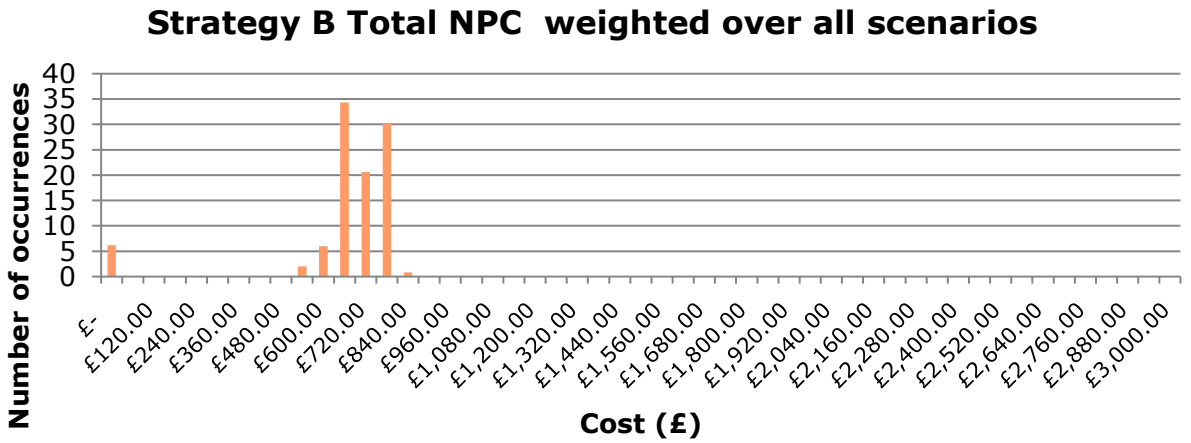
# The future(s) of a medium voltage network in Greater Manchester

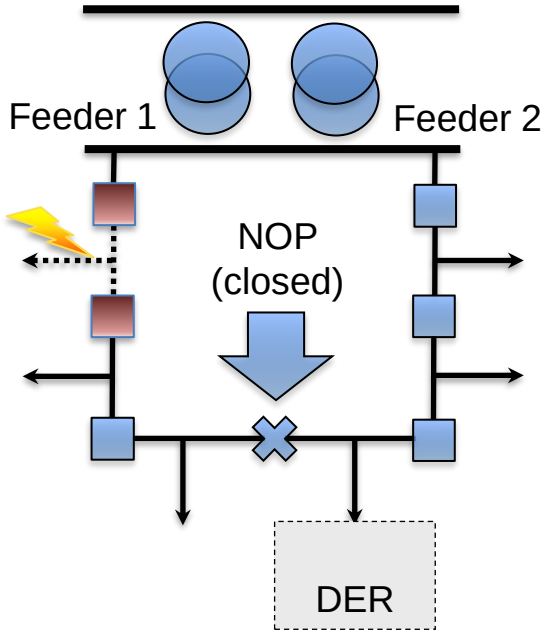



Courtesy of Electricity North West, UK, 2015

# Network vs non-network solutions: need for new regulation



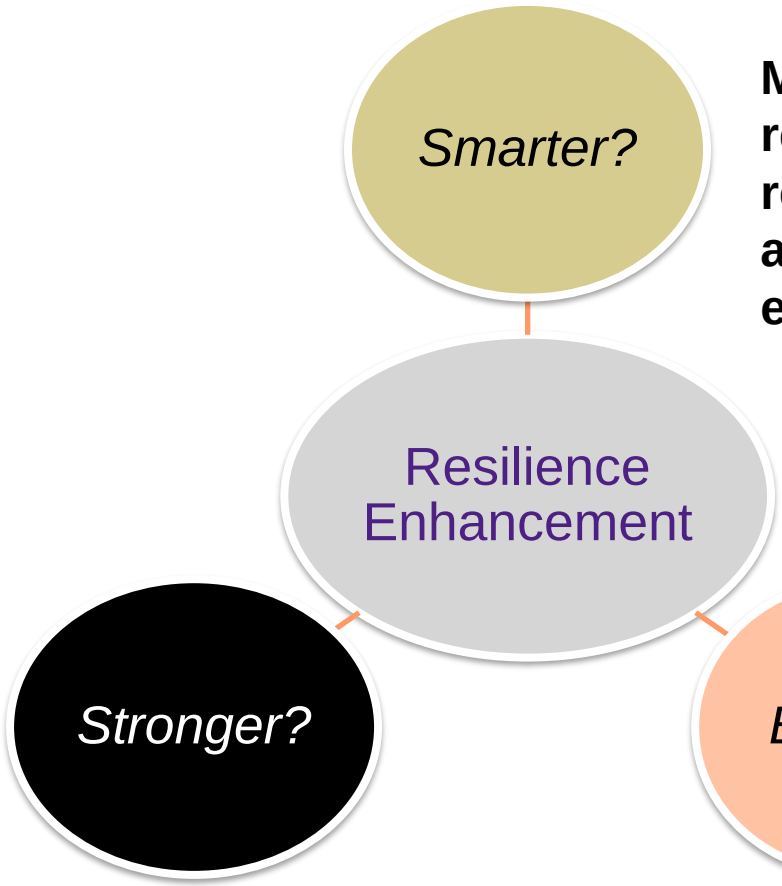




J. Schachter, P. Mancarella, J. Moriarty, and R. Shaw, Flexible investment under uncertainty in smart distribution networks with demand side response*:* Assessment framework and practical implementation, *Energy Policy*, Volume 97, October 2016, Pages 439–449.

# How to plan for the black swan?

# Planning for Resilience: The Resilience Trilemma




**Make the network more responsive (e.g. faster restoration), self-adaptive, resourceful, etc.**

**Upgrade existing infrastructure, asset life extension, etc.**

**Build new infrastructure, e.g. transmission lines, substations, etc.**

M. Panteli and P. Mancarella, The Grid: Stronger, Bigger, Smarter? Presenting a conceptual framework of power system resilience, *IEEE Power and Energy Magazine,* May/June 2015*, Invited Paper*.

# Will more transmission enhance resilience?

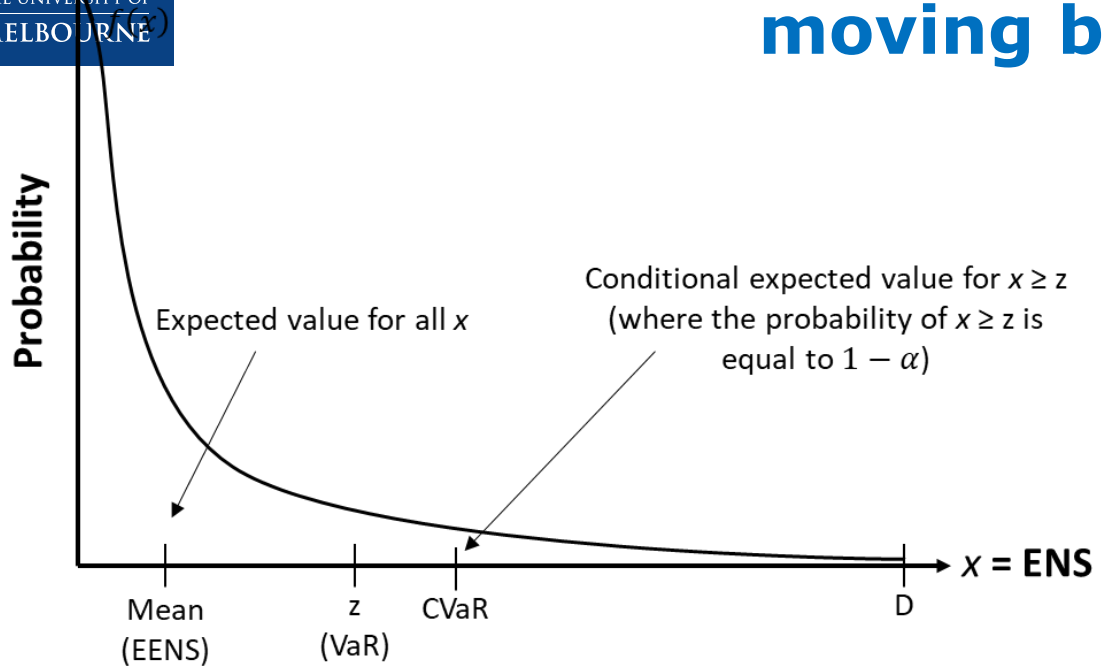
## Why Investments Do Not Prevent Blackouts

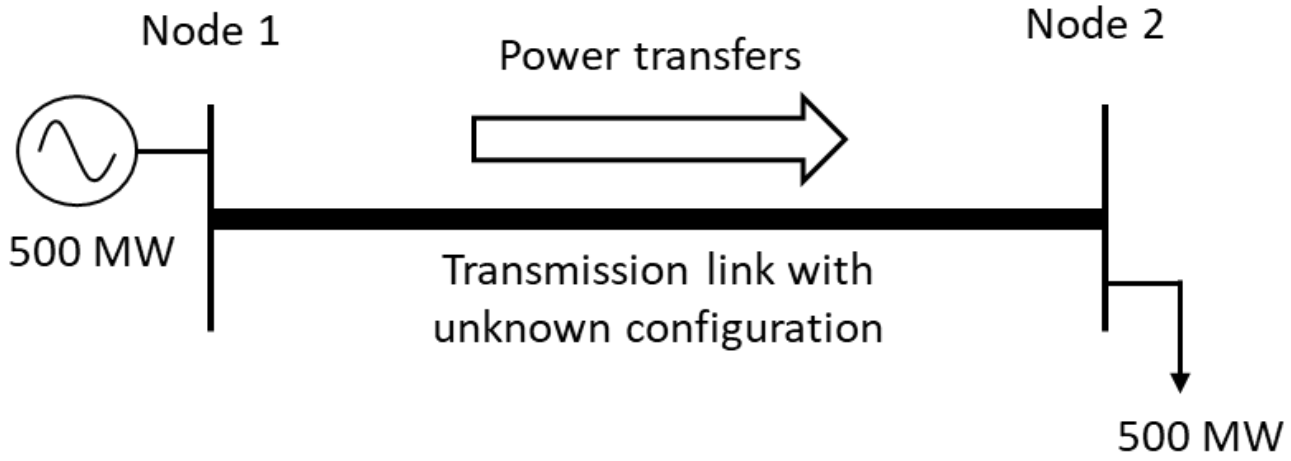
*The idea that increasing the capacity of the transmission network should improve the security of the system and reduce the probability of blackouts is intuitively appealing. However, this intuition does not withstand scrutiny.*

*Daniel Kirschen and Goran Strbac*

D. Kirschen and G. Strbac, "Why investments do not prevent blackouts", *The Electricity Journal*, March 2004

# Planning for "resilience": moving beyond adequacy




| Metric | N-0 base case | N-1 | N-0 shorter repair time | N-0 underground |
|---|---|---|---|---|
| VoLL x EENS [$] | 538,532 | 38,464 | 470,506 | 280,428 |
| VoLL x CVaR [$] | 4,113,206,199 | 3,846,412,398 | 2,690,095,838 | 2,837,833,988 |
| Probability of double outage under adverse weather [%] | 7.7% | 7.7% | 2.0% | 2.6% |

R. Moreno, et al., "From Reliability to Resilience: Planning the Grid Against the Extremes", IEEE Power and Energy Magazine, July-August 2020

# Planning for resilience: Complementarity and competition between network and non-network solutions

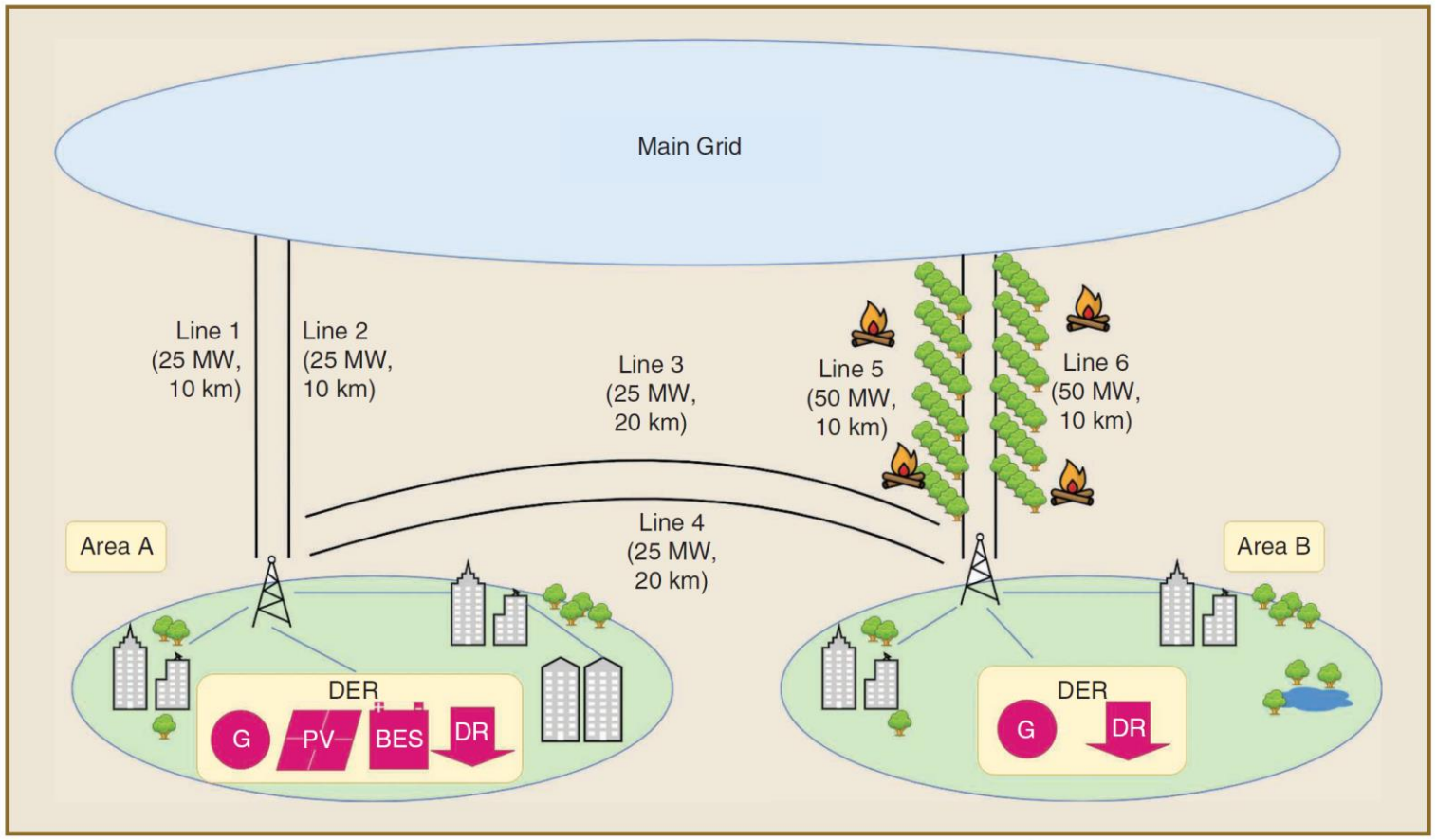



**figure 8.** The electricity network and DER candidates along with areas exposed to wildfires. BES: battery energy storage.

**table 2. Results with costs in thousand U.S. dollars (kUS$) per year.**

N-1

| | Case A | Case A (Reevaluated) | Case B |
|---|---|---|---|
| Assets and measures | L1, L2, L5, L6, MG, DR | L1, L2, L5, L6, MG, DR | L1, L2, L3, L4, L5, PV, BES, MG, DR |
| PV + BES investment cost | — | — | 11,500 |
| Line investment cost | 113 | 113 | 150 |
| Operational cost | 32,850 | 33,115 | 21,901 |
| Lost-load cost | 27 | 19,665 | 6 |
| Total cost | 32,990 | 52,893 | 33,558 |

L: line; MG: mobile generator.

Moreno, R., Trakas, D. N., Jamieson, M., Panteli, M., Mancarella, P., Strbac, G., ... & Hatziargyriou, N. (2022). Microgrids Against Wildfires: Distributed Energy Resources Enhance System Resilience. IEEE Power and Energy Magazine, 20(1), 78-89.

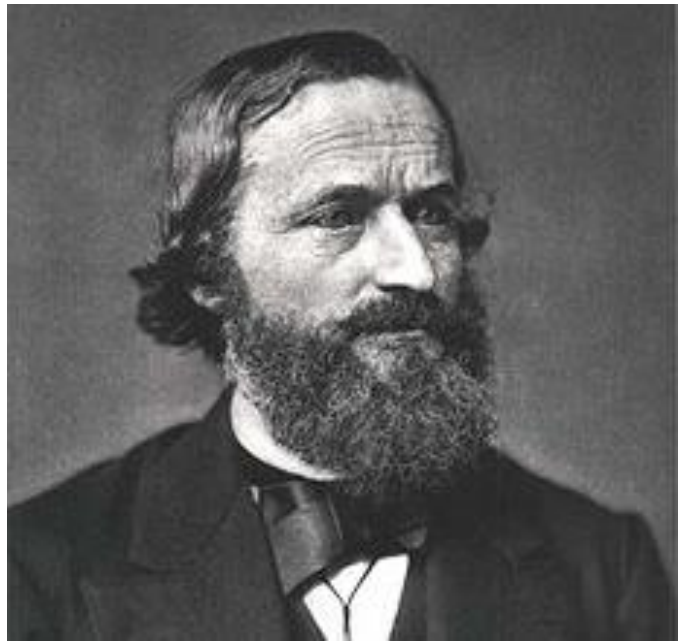
# Concluding remarks

- Future low-carbon grids are characterised by a **high degree of uncertainty**, both short-term (operation) and, even more markedly, long-term (planning)
- It is essential that **regulatory frameworks** be able to develop mechanisms to value **flexibility in planning**
- Flexible planning mechanisms should then be augmented by **risk analysis**, especially to deal with **resilience** (the most uncertain events!)
- These same mechanisms should and would allow investments in **network and nonnetwork solutions** to be evaluated on a more level playing field
  - Enabling development of optimal portfolios for both reliability and resilience
- Flexible planning should be carried out across **multi-energy infrastructure**
- There's lots of work to do, but things are fortunately moving forward…

R. Moreno, et al., "Planning low-carbon electricity systems under uncertainty considering operational flexibility and smart grid technologies", *Philosophical Transactions of the Royal Society A*, Vol. 375, Issue 2100, Aug 2017, pp. 1-29

B. Moya et al., "Uncertainty representation in investment planning of low-carbon power systems", *Power System Computation Conference*, 2022

F. Billimoria *et al.*, "Market and regulatory frameworks for operational security in decarbonising electricity systems: from physics to economics", *Oxford Open Energy,* 2022



Source: Wikipedia

# Acknowledgments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- CSIRO GPST

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