

# Transmission planning and investment for our changing energy system

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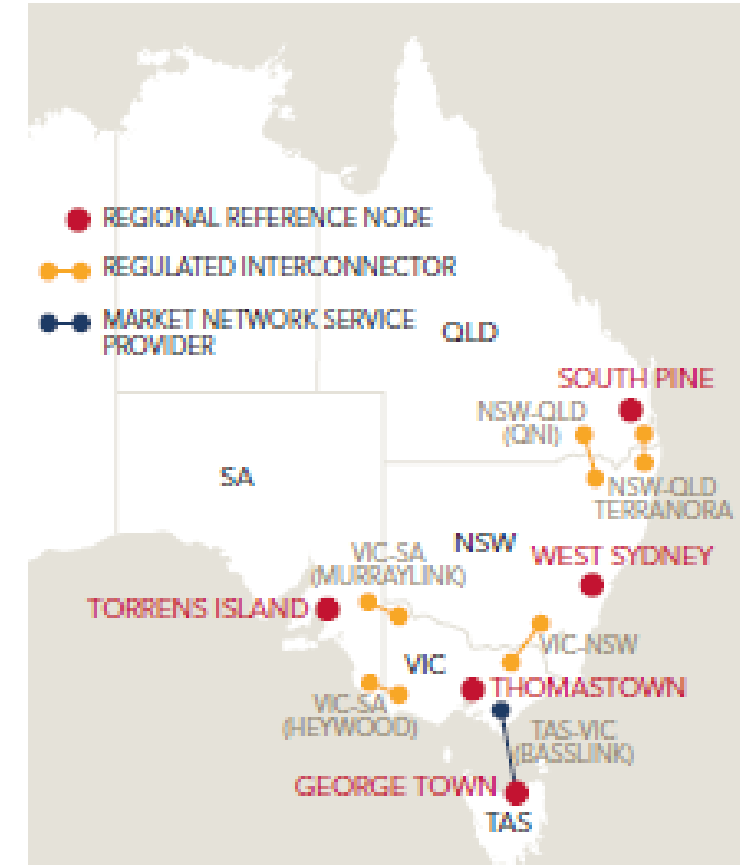
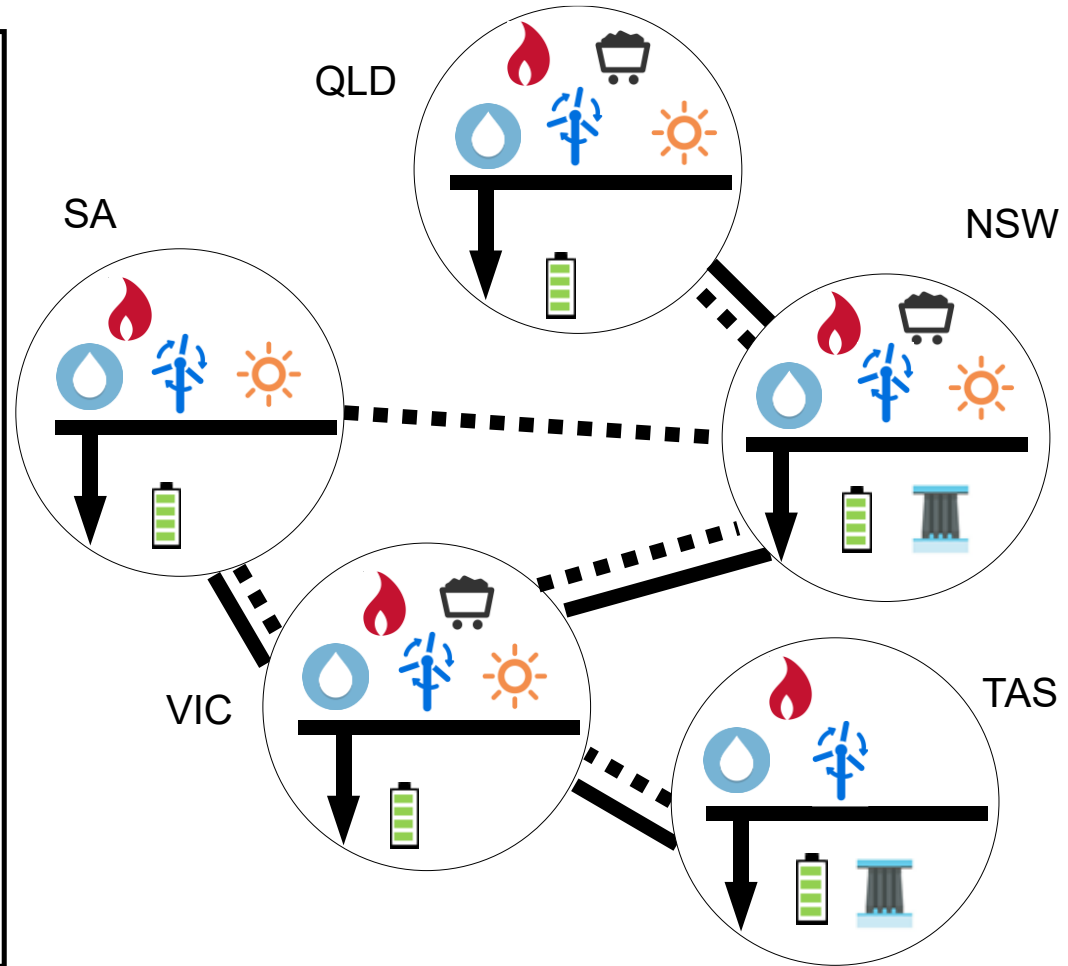
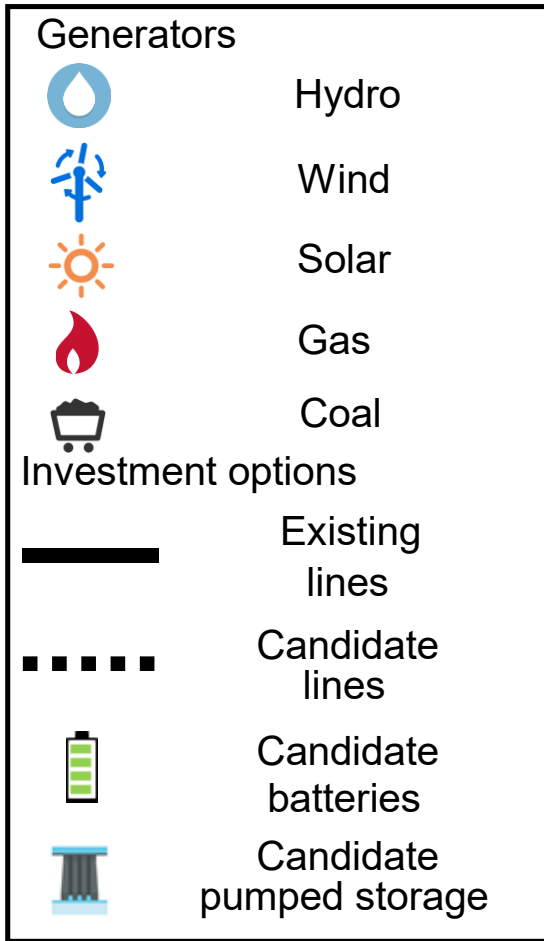
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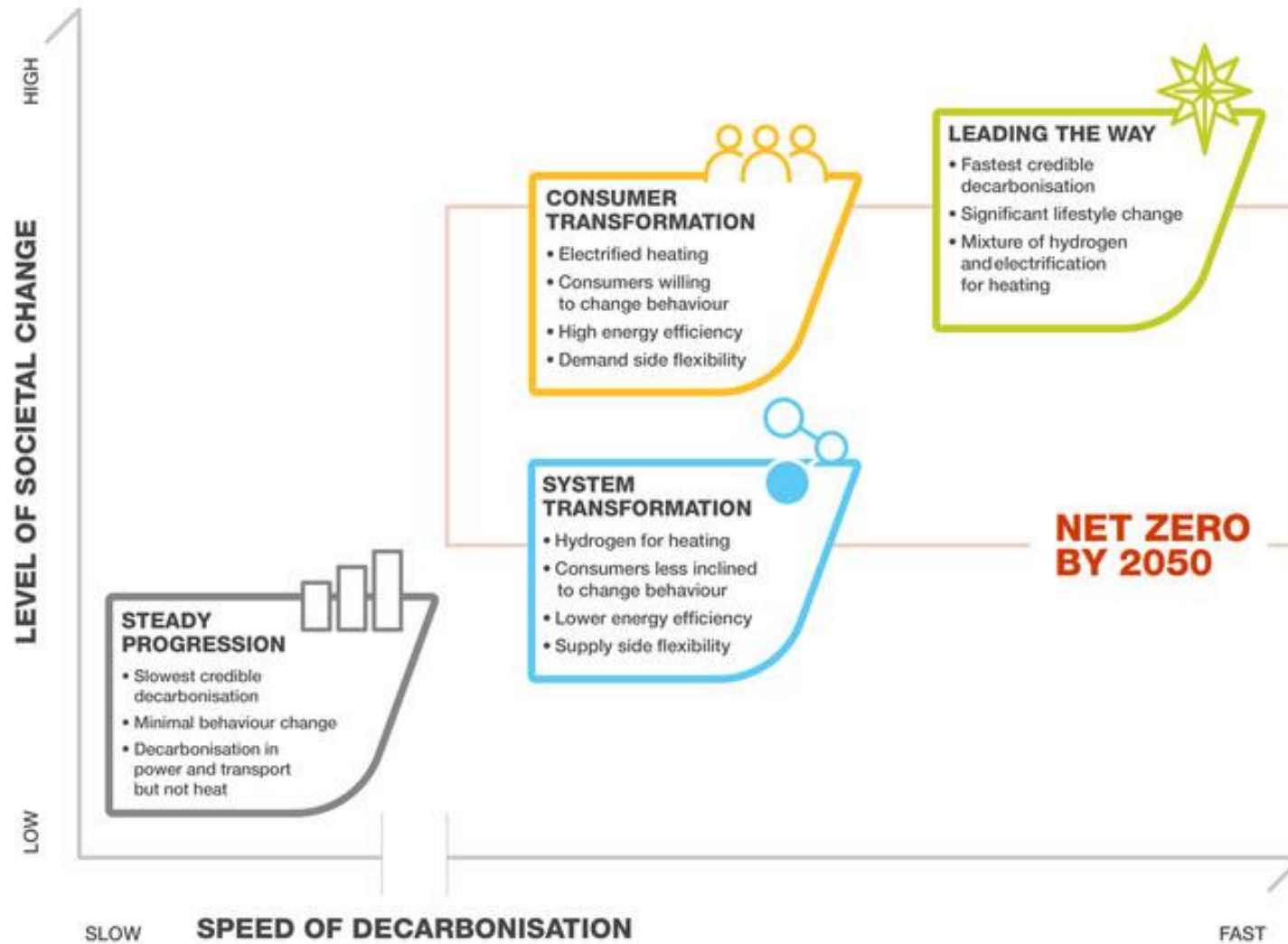
IRED 2022, Adelaide, Australia

October 2022

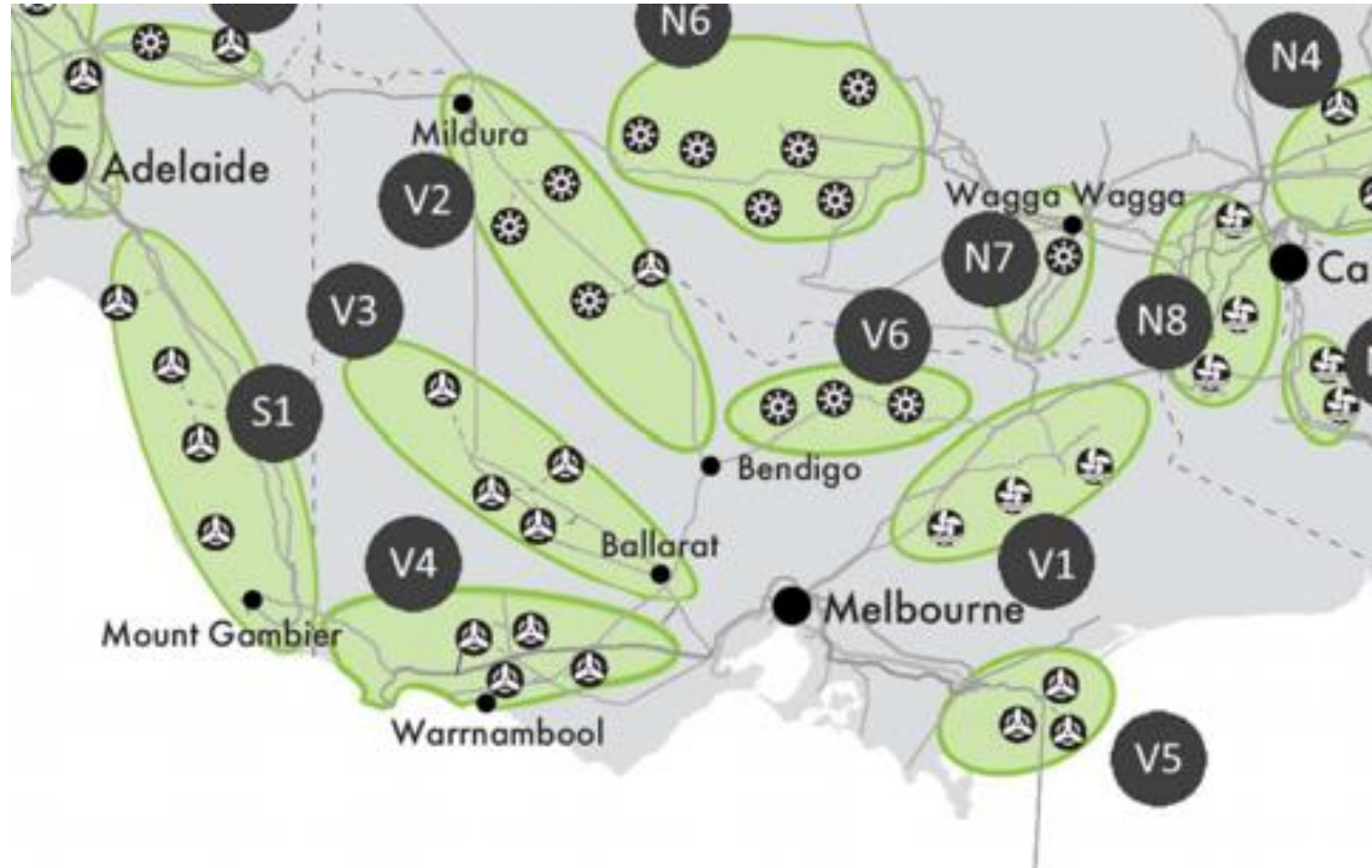
# Technology solutions? Spoilt for choice!



# Net zero can be reached in many ways...

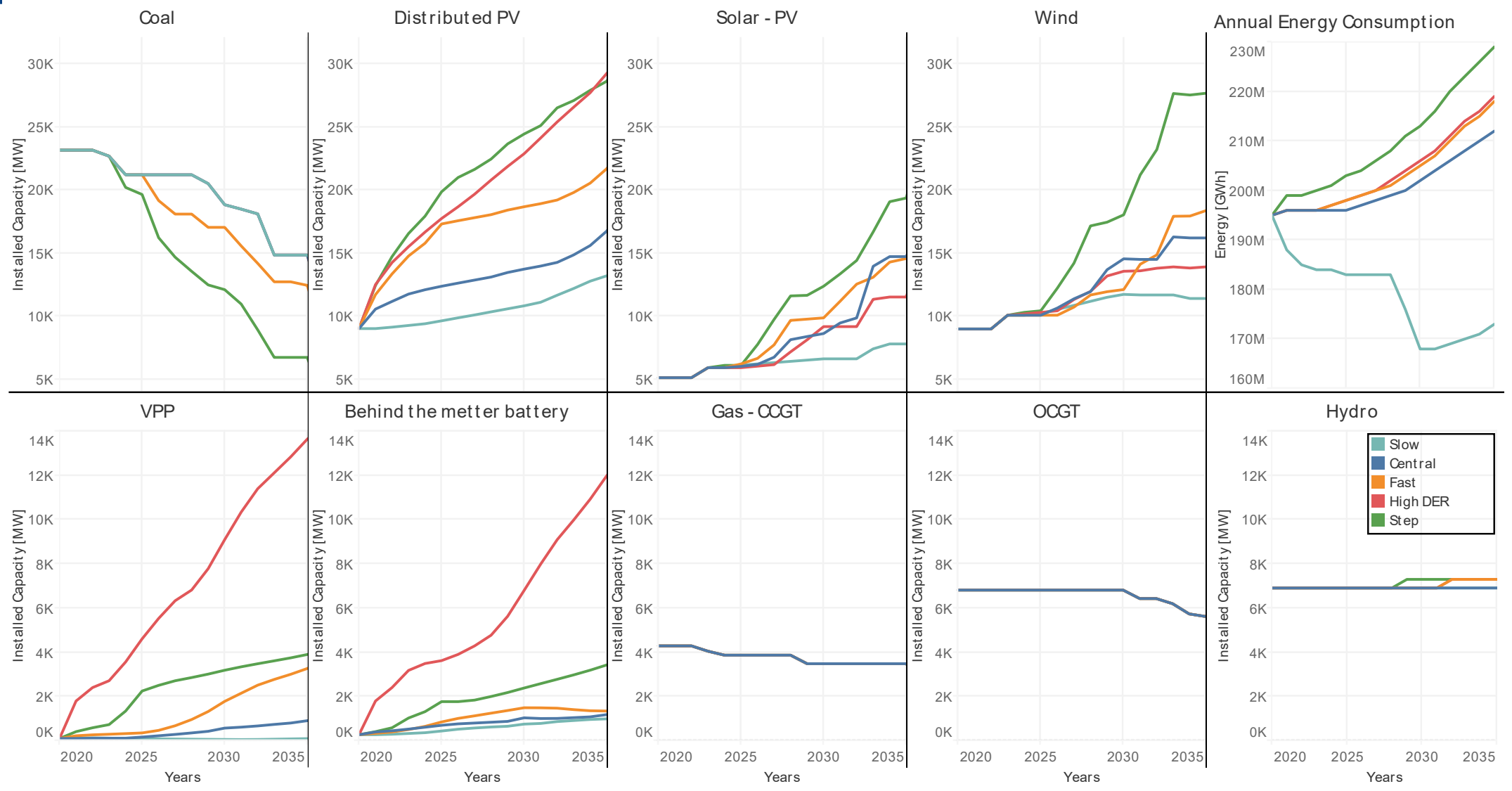


# How can we facilitate *risk-aware proactive* infrastructure investment?



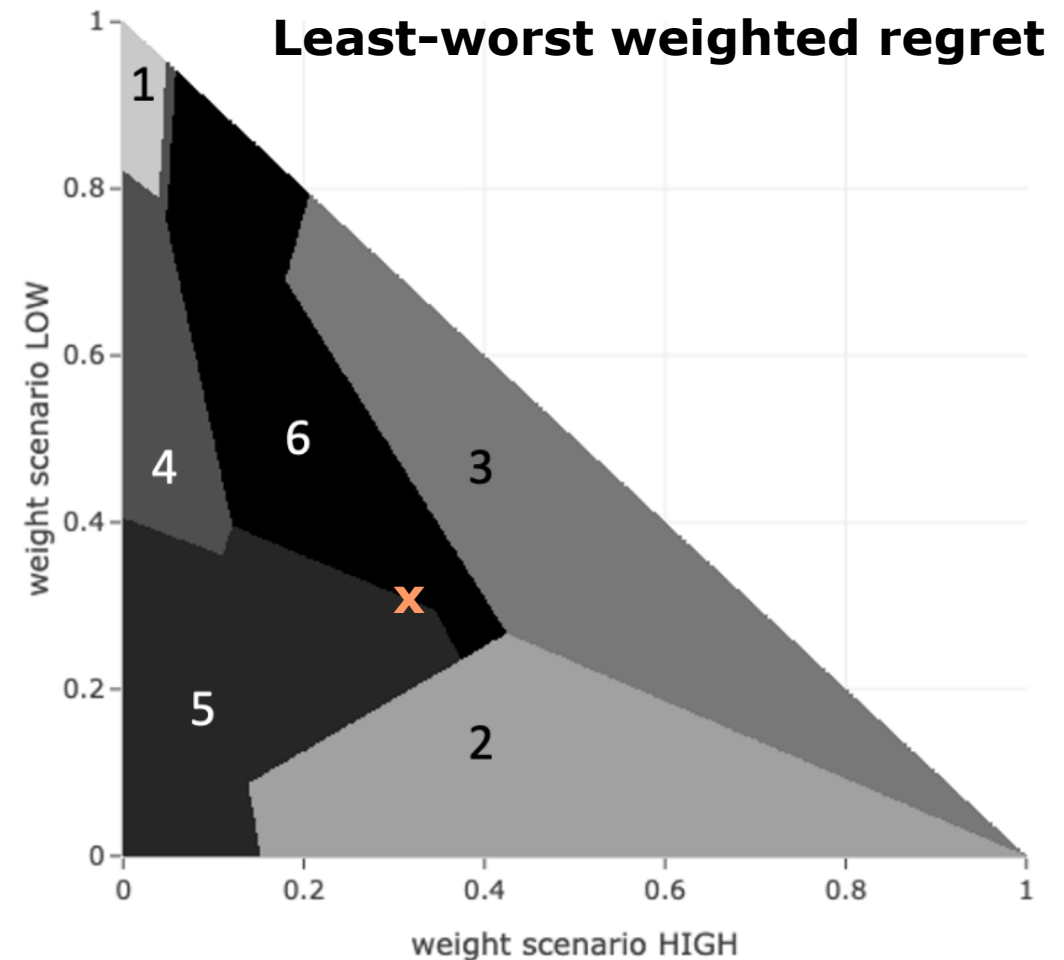
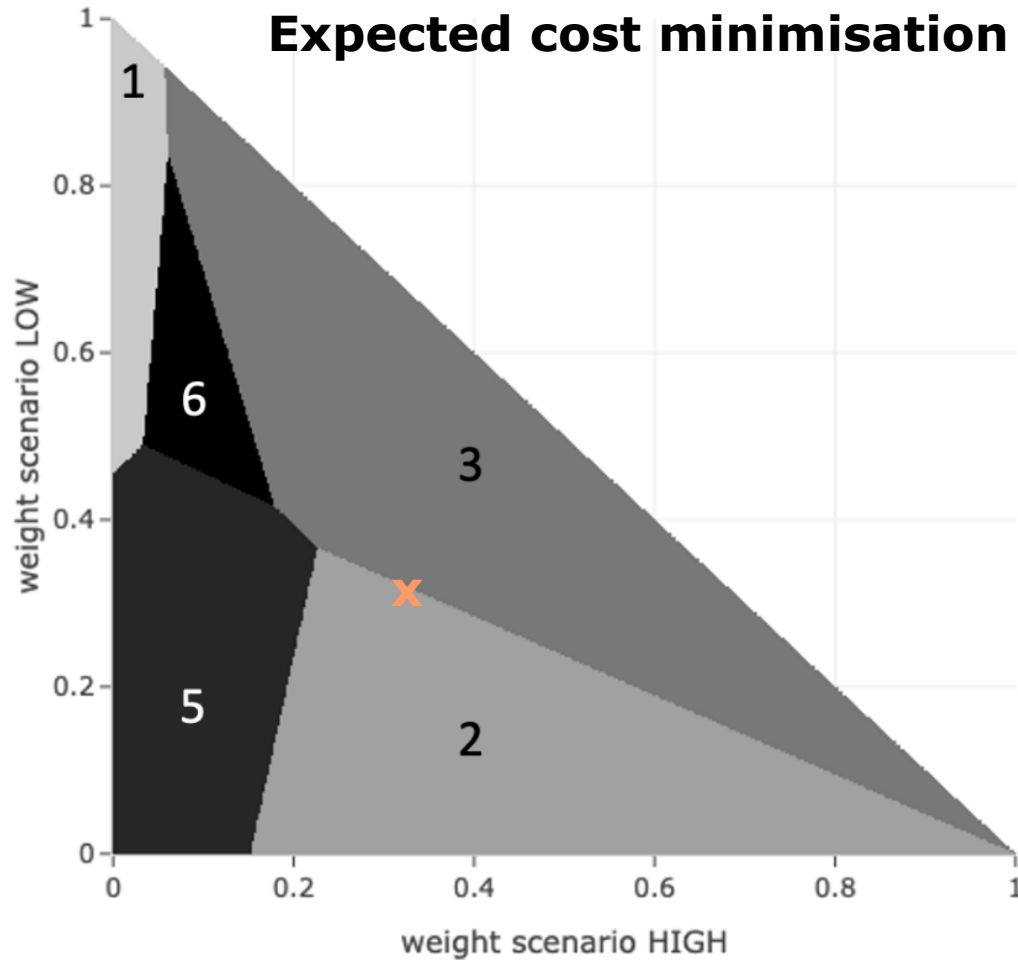
Source: AEMO ISP 2020 and Environment Victoria

# What future do we plan for?



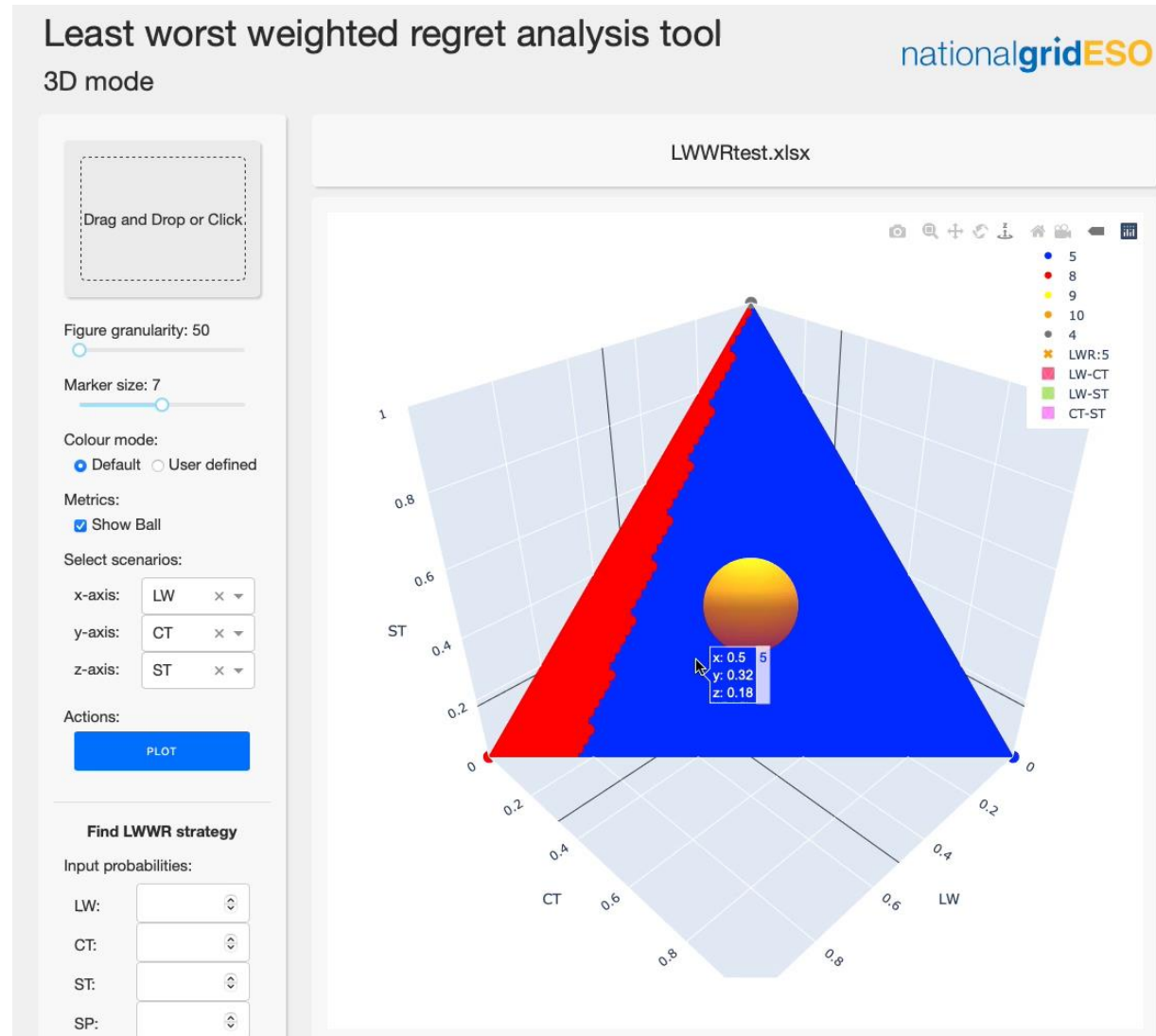
Source: AEMO, ISP 2020

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



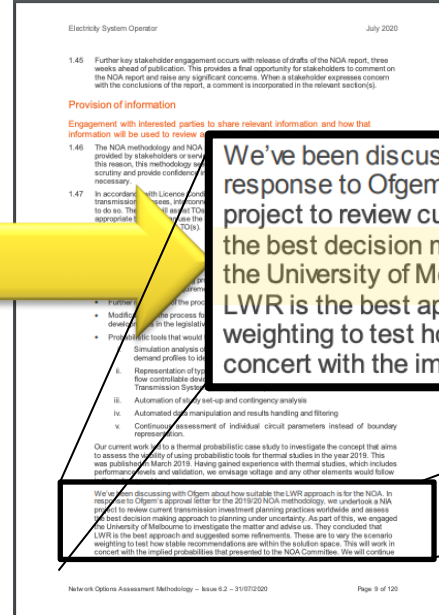
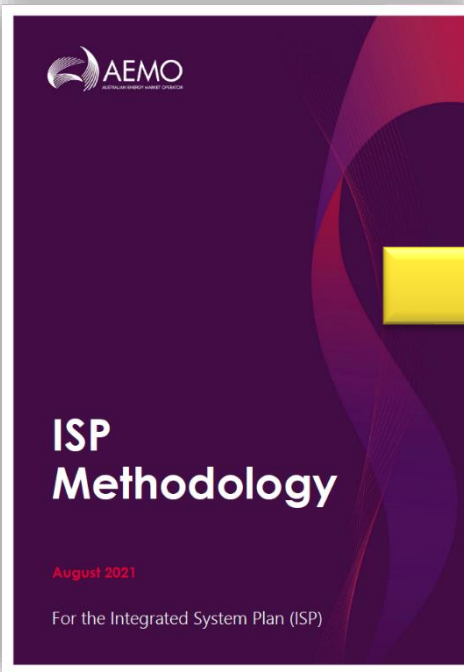
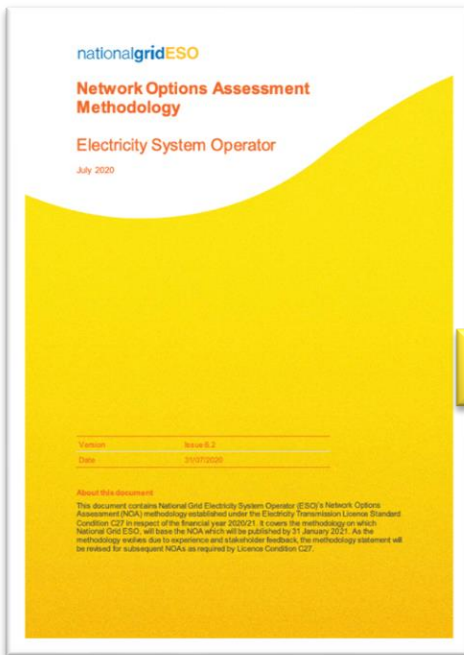
Source: P. Mancarella, *et al.*, "Study of advanced modelling for network planning under uncertainty - Part 1", Report for National Grid ESO, 2020: <https://www.nationalgrideso.com/document/185821/download>

# LWWR analysis tool for National Grid ESO

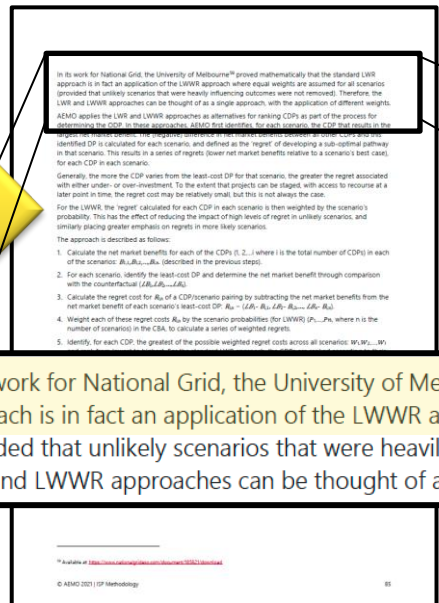


Courtesy of National Grid ESO

# LWWR applications



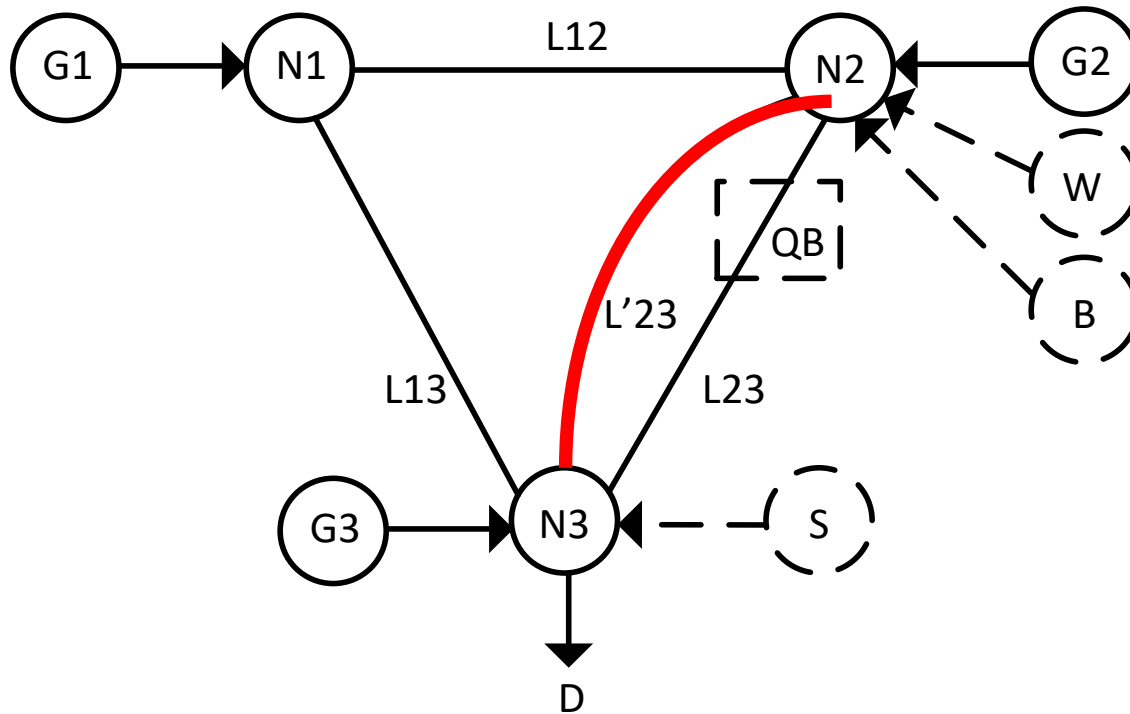
We've been discussing with Ofgem about how suitable the LWR approach is for the NOA. In response to Ofgem's approval letter for the 2019/20 NOA methodology, we undertook a NIA project to review current transmission investment planning practices worldwide and assess the best decision making approach to 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<sup>59</sup> 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.

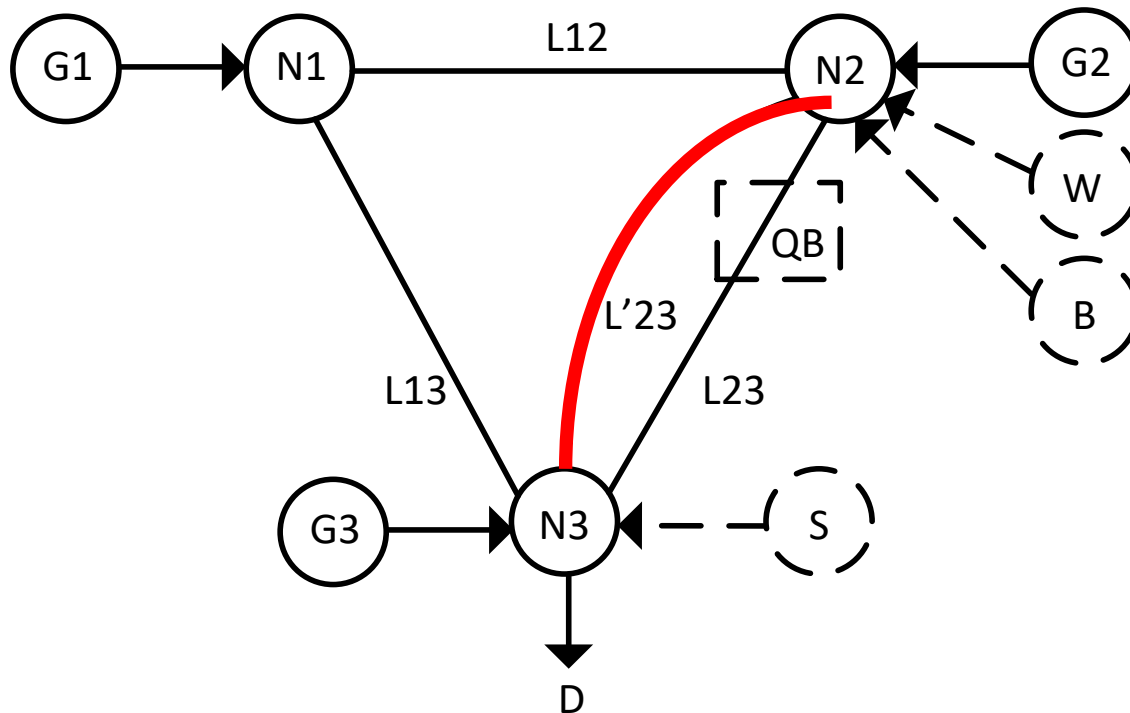


# Deterministic planning

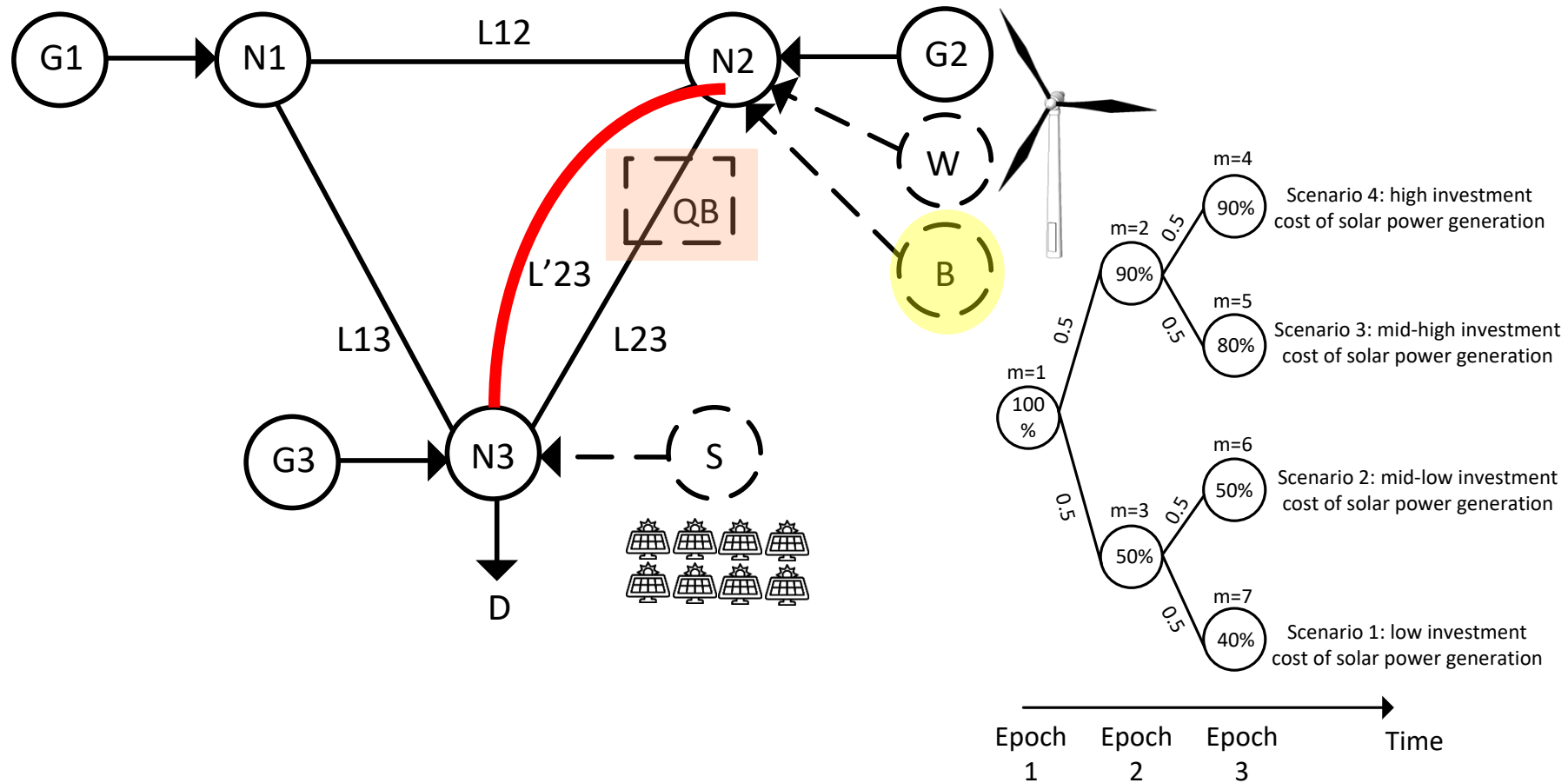


R. Moreno, A. Street, J.M. Arroyo, and P. Mancarella, "Planning Low-Carbon Electricity Systems under Uncertainty Considering Operational Flexibility and Smart Grid Technologies", *Philosophical Trans. Royal Society A*, June 2017

# Moving forward: A *flexible* investment planning methodology...

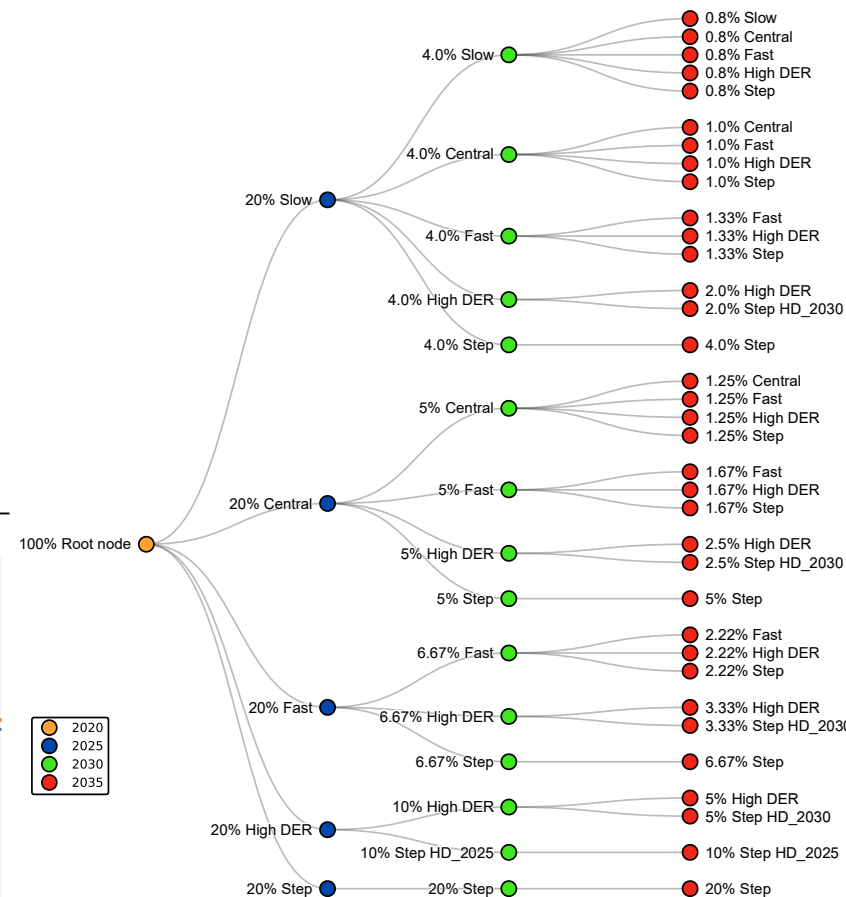
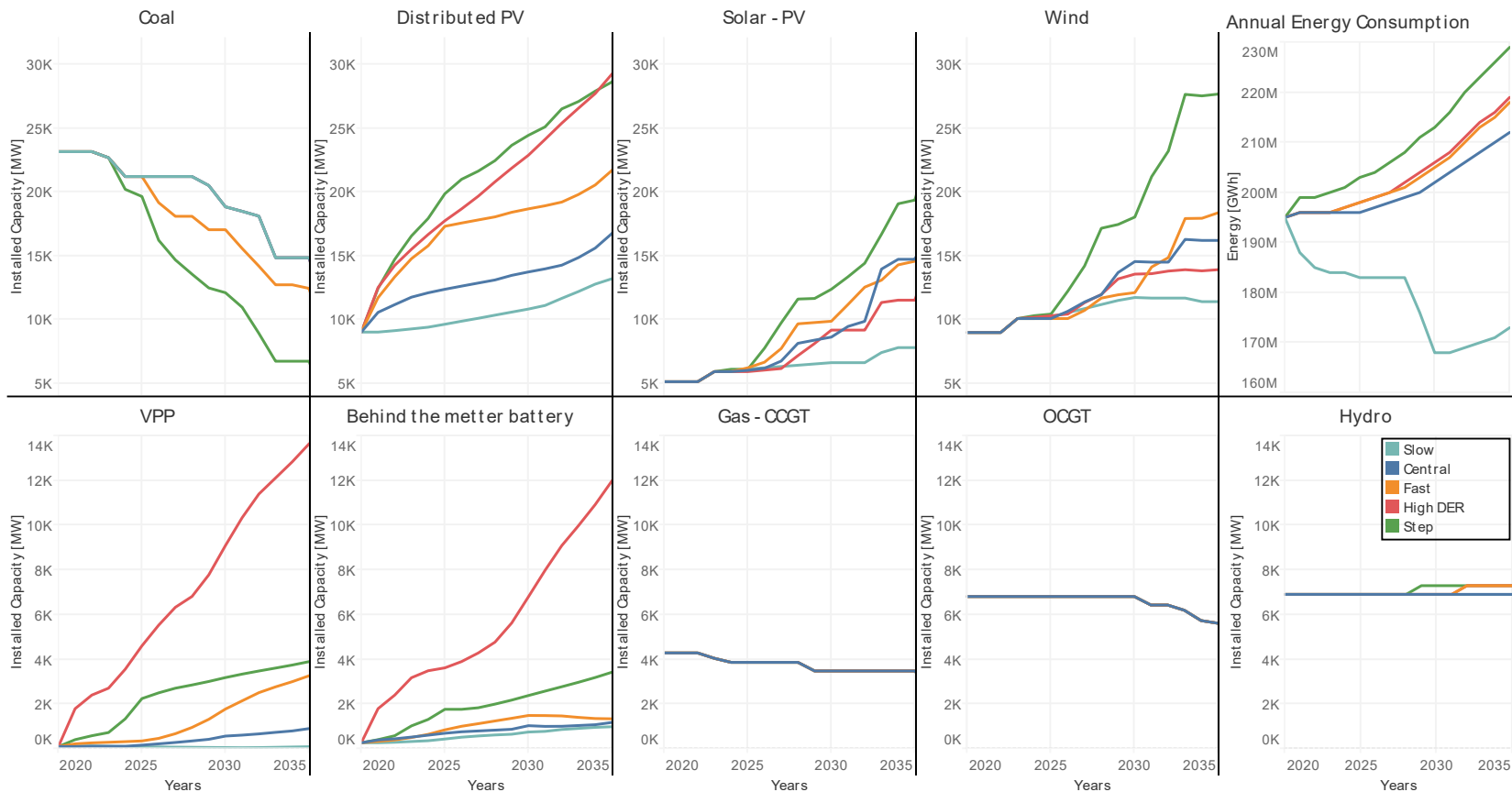


# ... unlocks the *option value* of *proactive network and non-network investment*



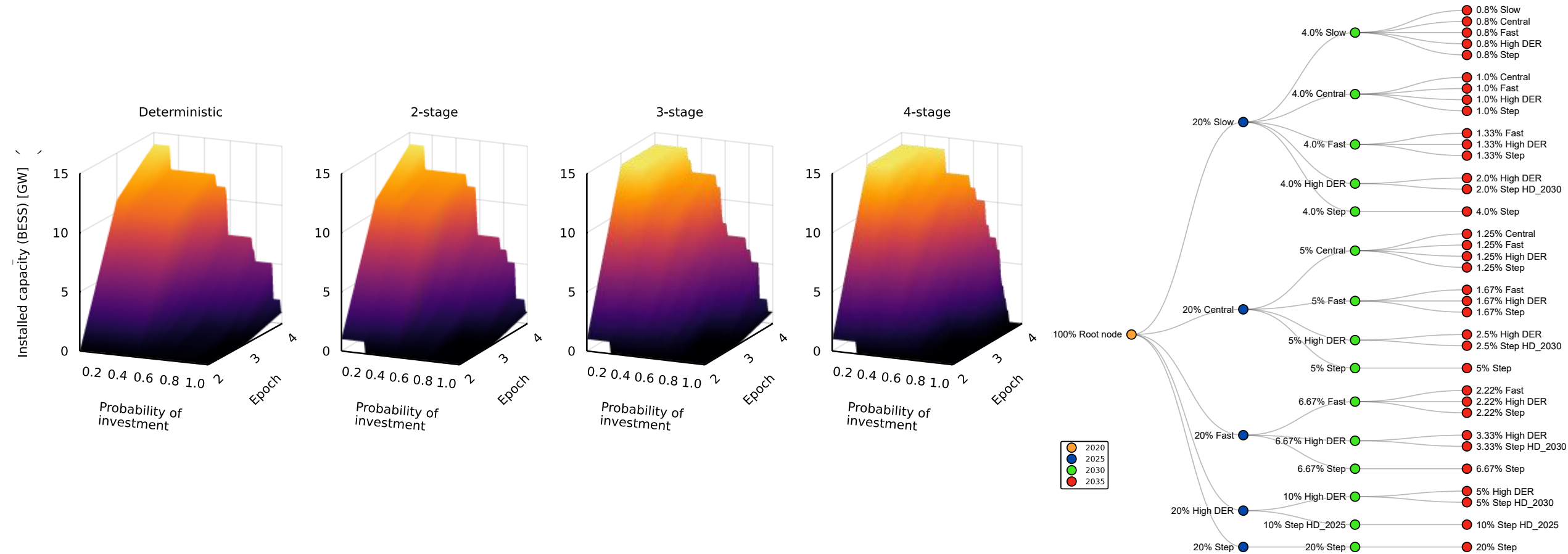
R. Moreno, A. Street, J.M. Arroyo, and P. Mancarella, "Planning Low-Carbon Electricity Systems under Uncertainty Considering Operational Flexibility and Smart Grid Technologies", *Philosophical Trans. Royal Society A*, June 2017

# Stochastic Integrated System Plan: 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", *EPSR 2022*

# ... and the value of storage vs transmission

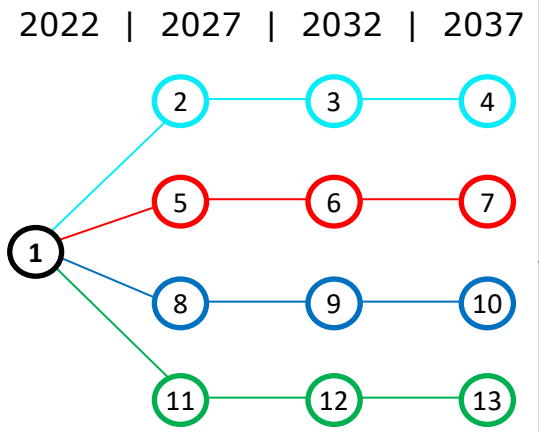
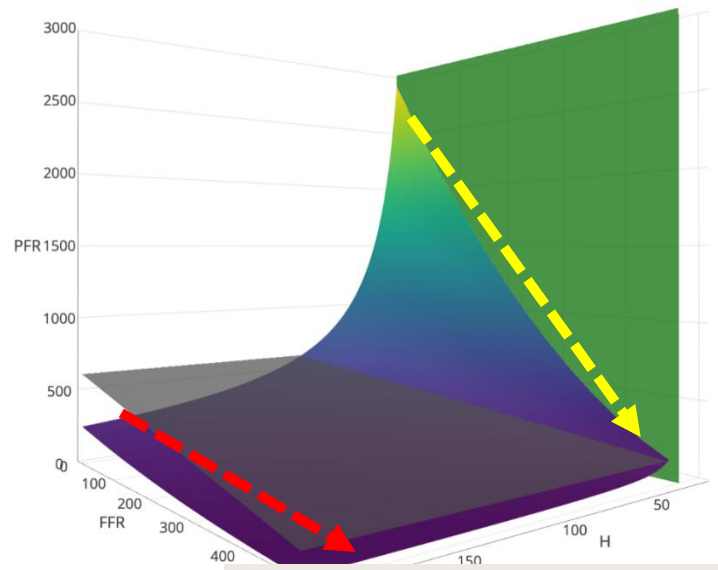


Stochastic planning reveals new role for storage

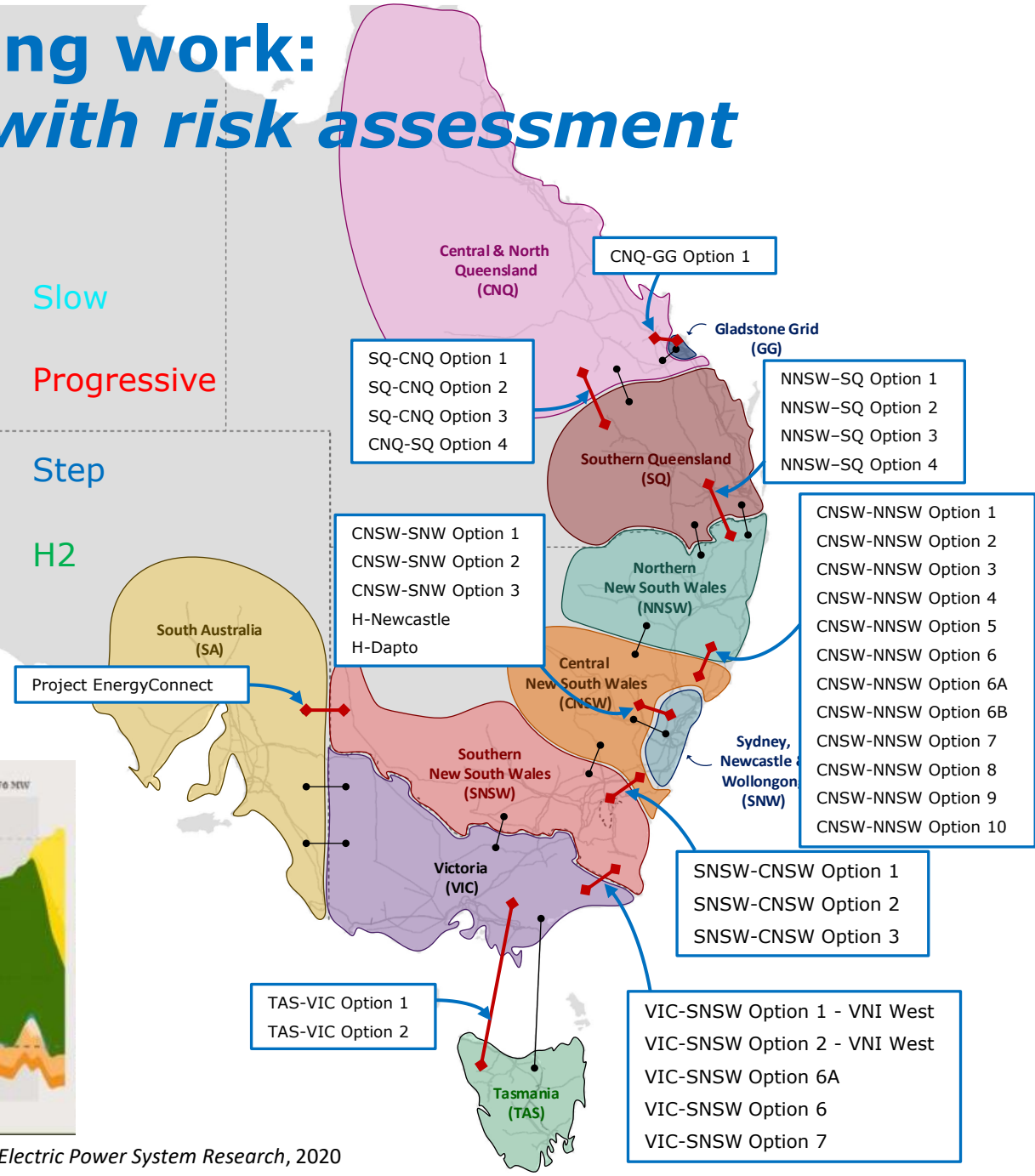
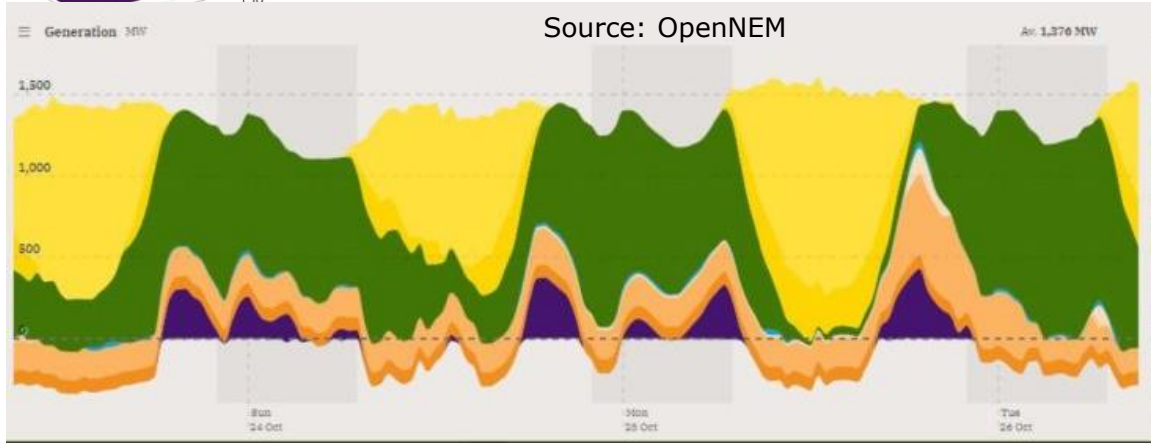
B. Moya, R. Moreno S. Püschel-Løvengreen, A. M. Costa, P. Mancarella, "Co-optimized Energy Storage and Transmission Expansions with Various Representations of Long-Term Uncertainty and Decision Dynamics", *EPSR 2022*

# GPST ongoing work: A 2022 stochastic ISP with risk assessment

Demand (HD) 17GW Gen Loss 700MW  
Load-damping factor 1%/Hz Nadir Target 49.3Hz  
FFR Resources: 0.3s Activation Time - Delivery time 0.05s "



Slow  
Progressive  
Step  
H2

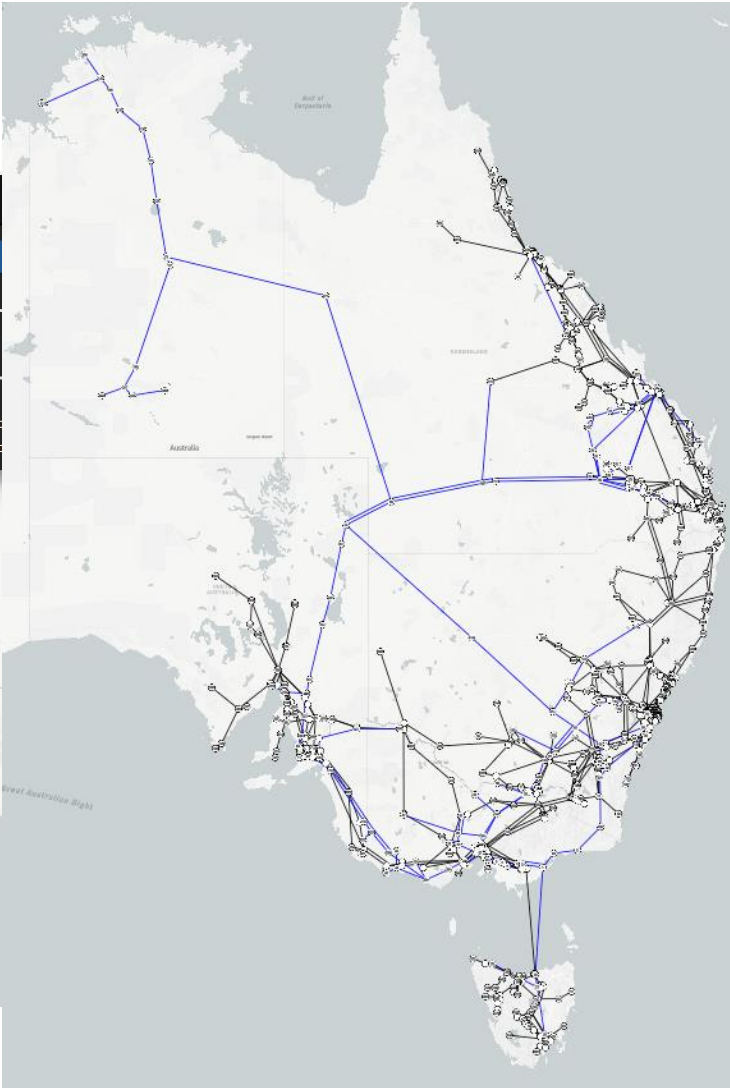
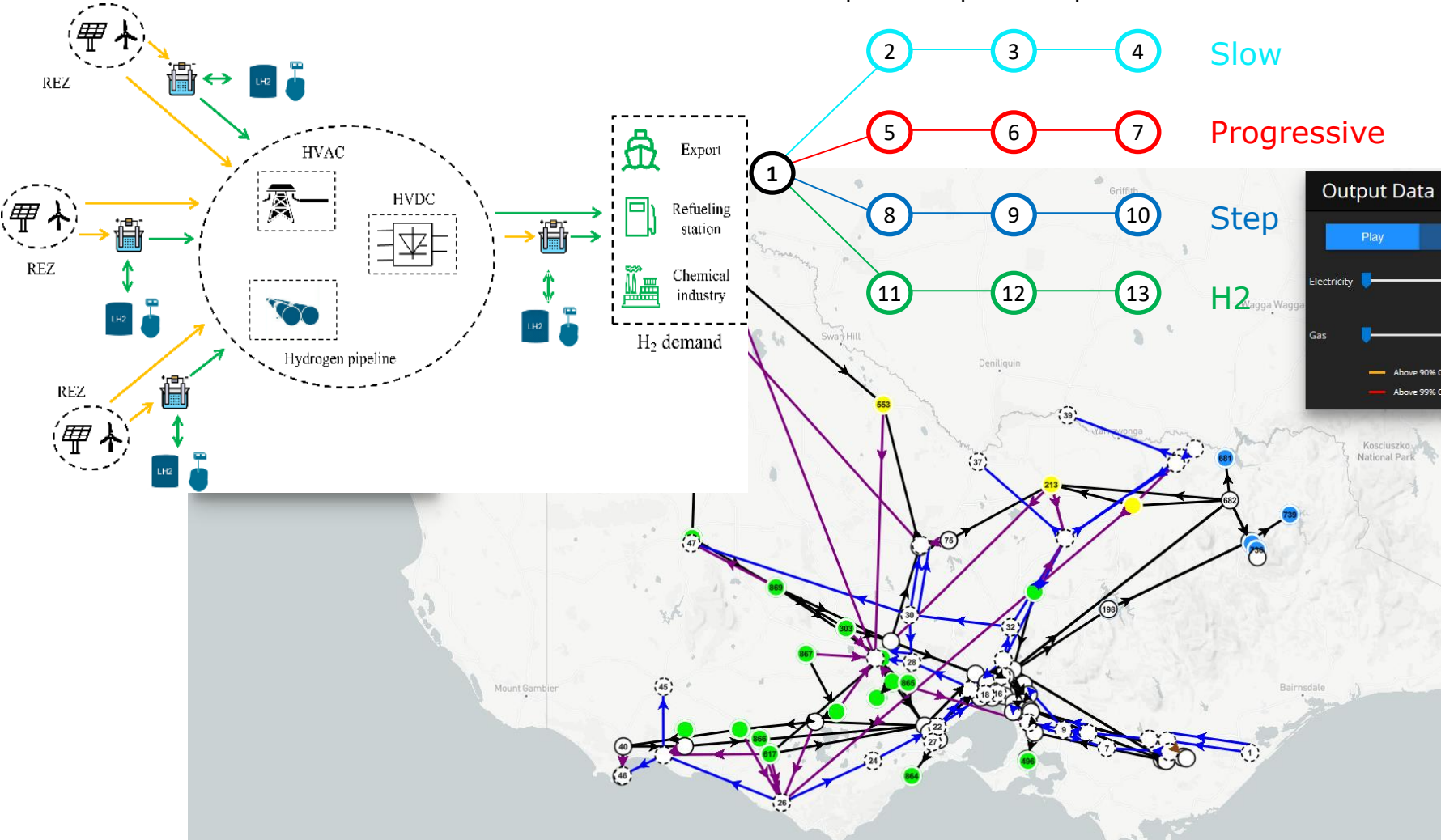


S. Puschel, et al. "Separation event-constrained optimal power flow to enhance resilience in low-inertia power systems", *Electric Power System Research*, 2020

# GPST ongoing work: *Do we transport electrons of molecules?*

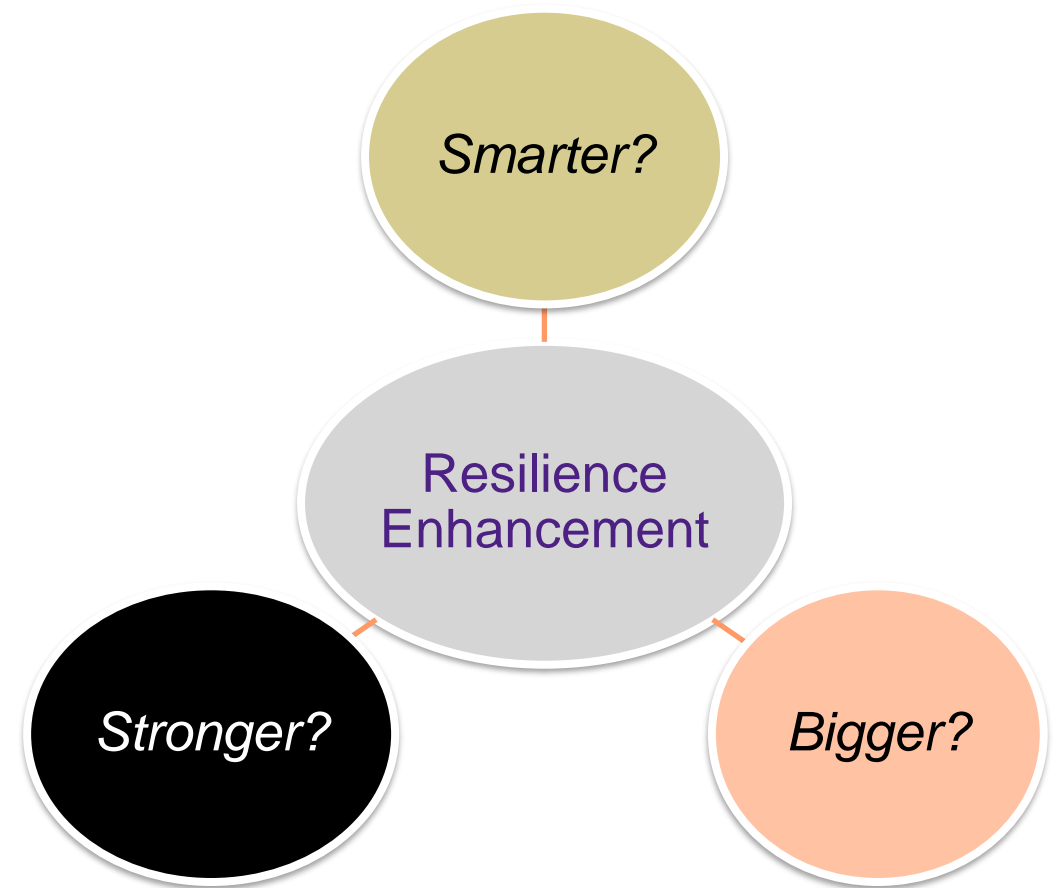
2022 | 2027 | 2032 | 2037

Courtesy of Future Fuels CRC



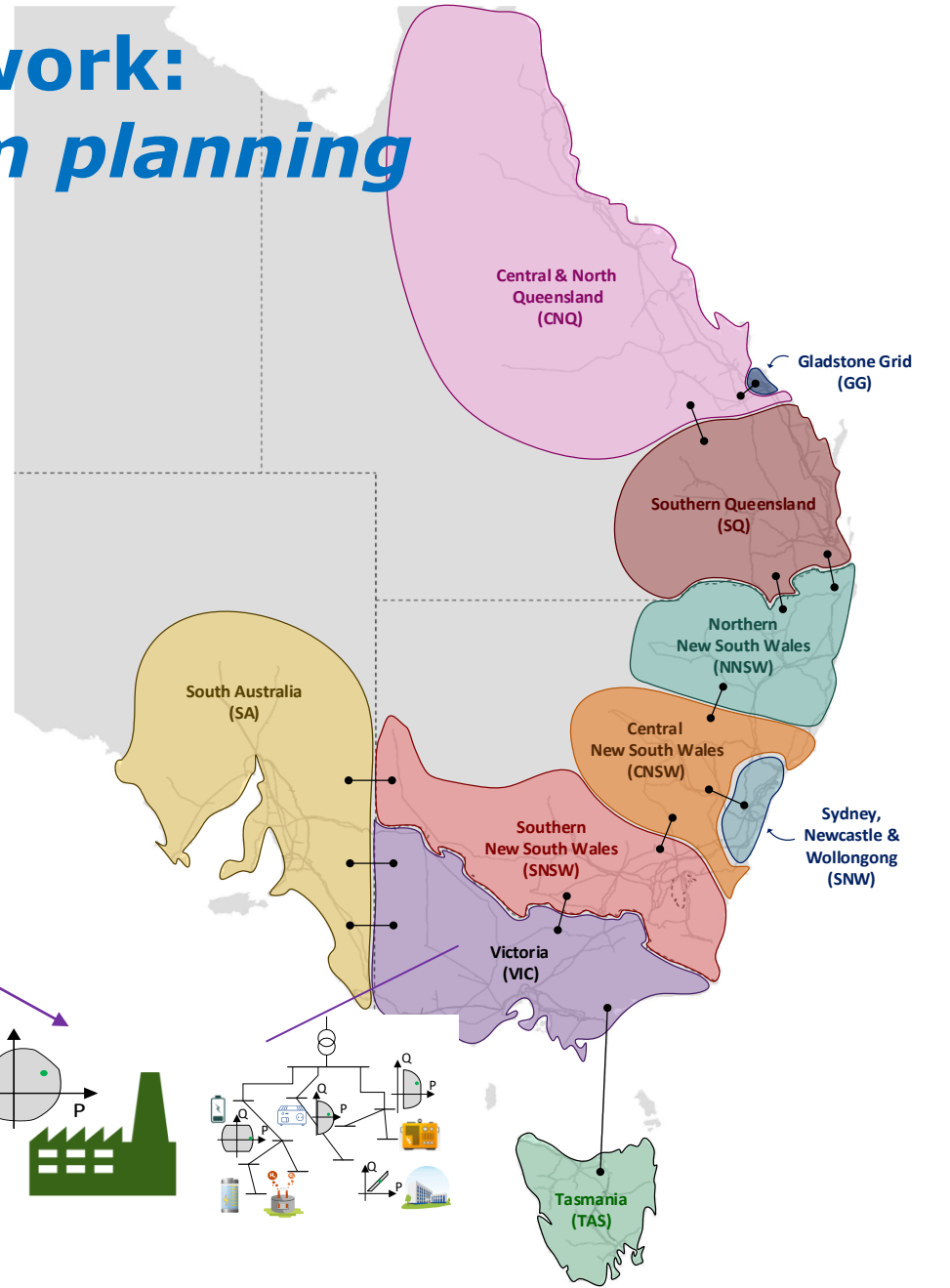
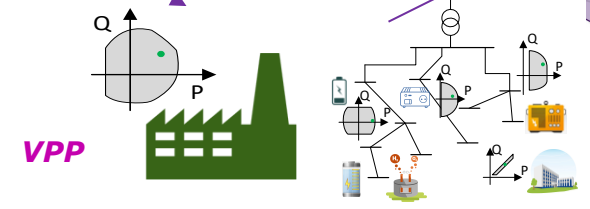
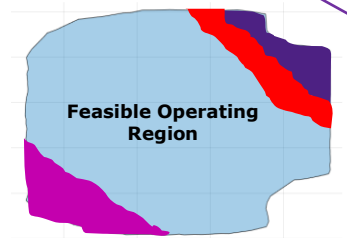
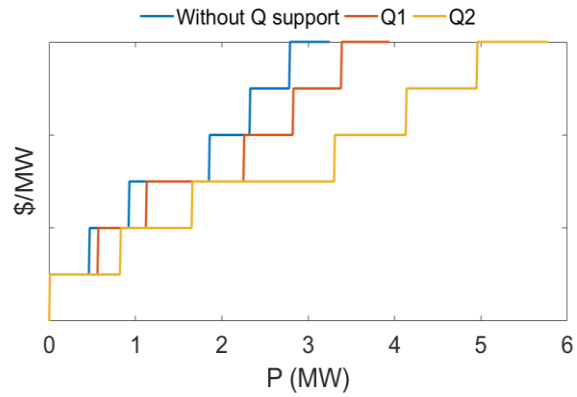
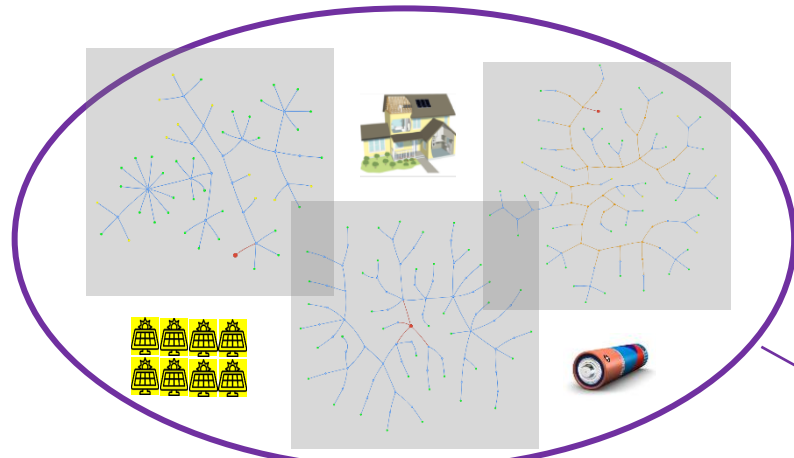
I. Saedi, et al., "Integrated Electricity and Gas System Modelling with Hydrogen Injections and Gas Composition Tracking", *Applied Energy*, 2021  
 S. Mhanna, et al., "Iterative LP-based Methods for the Multiperiod Optimal Electricity and Gas Flow Problem", *IEEE Trans. on Power Systems*, 2021

# GPST ongoing work: *Planning for the black swan*



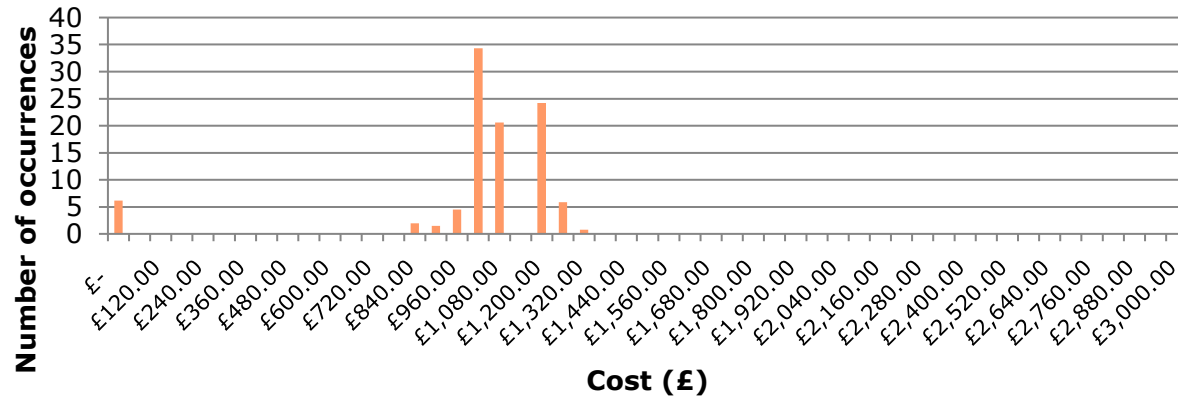


# GPST ongoing work: Role of DER in system planning

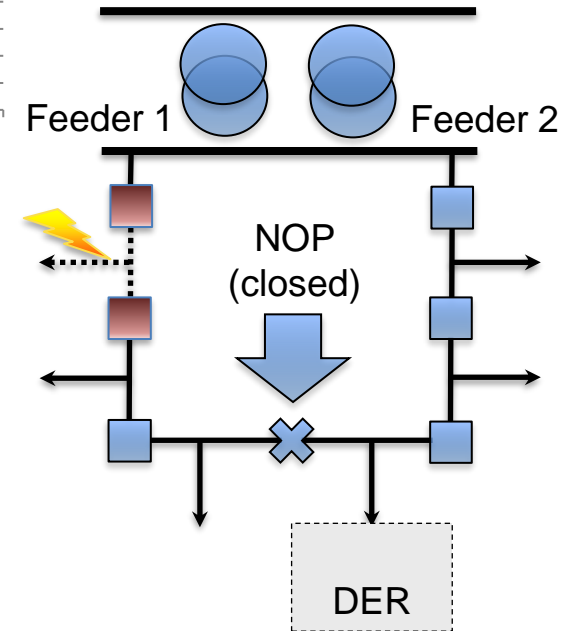
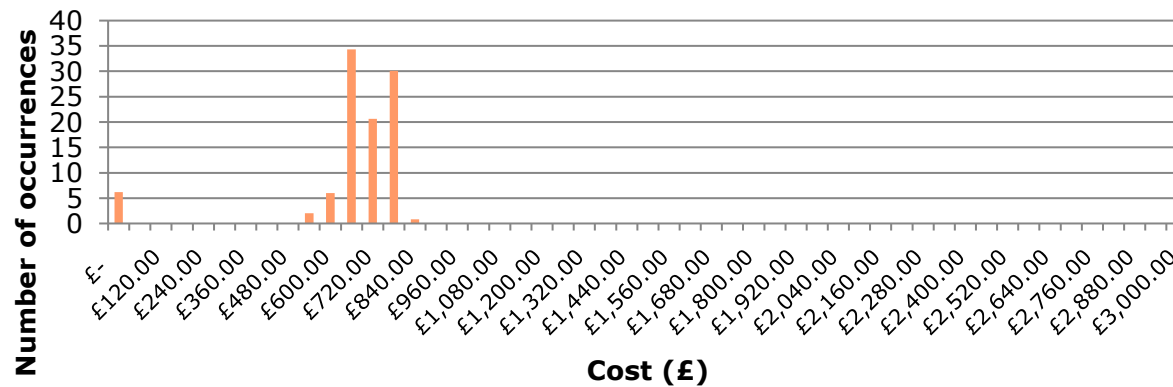


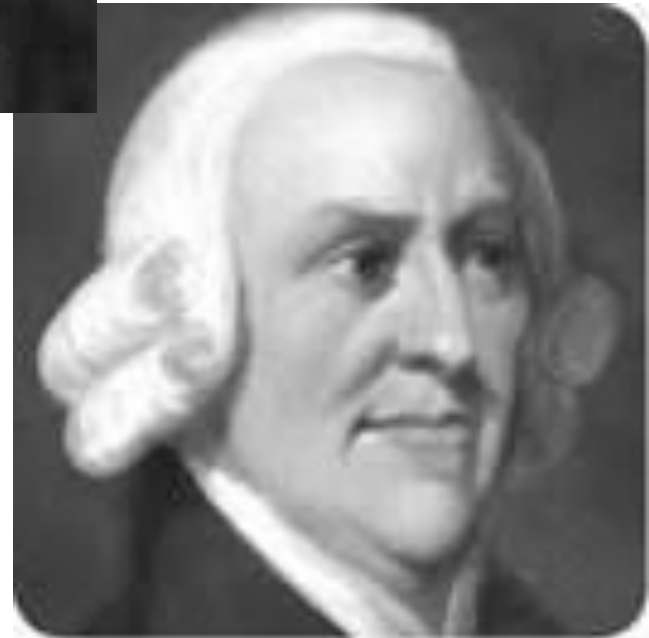
# Modelling extension: Investment under uncertainty for distribution networks with DER

**Strategy A Total NPC weighted over all scenarios**



**Strategy B Total NPC weighted over all scenarios**





# Acknowledgments

- CSIRO, AEMO, and the GPST consortium
- Ausnet, Mondo and AEMO (Project EDGE)
- National Grid ESO, UK
- Future Fuels CRC
- My research team, and in particular Dr Sebastian Puschel and Dr Sleiman Mhanna



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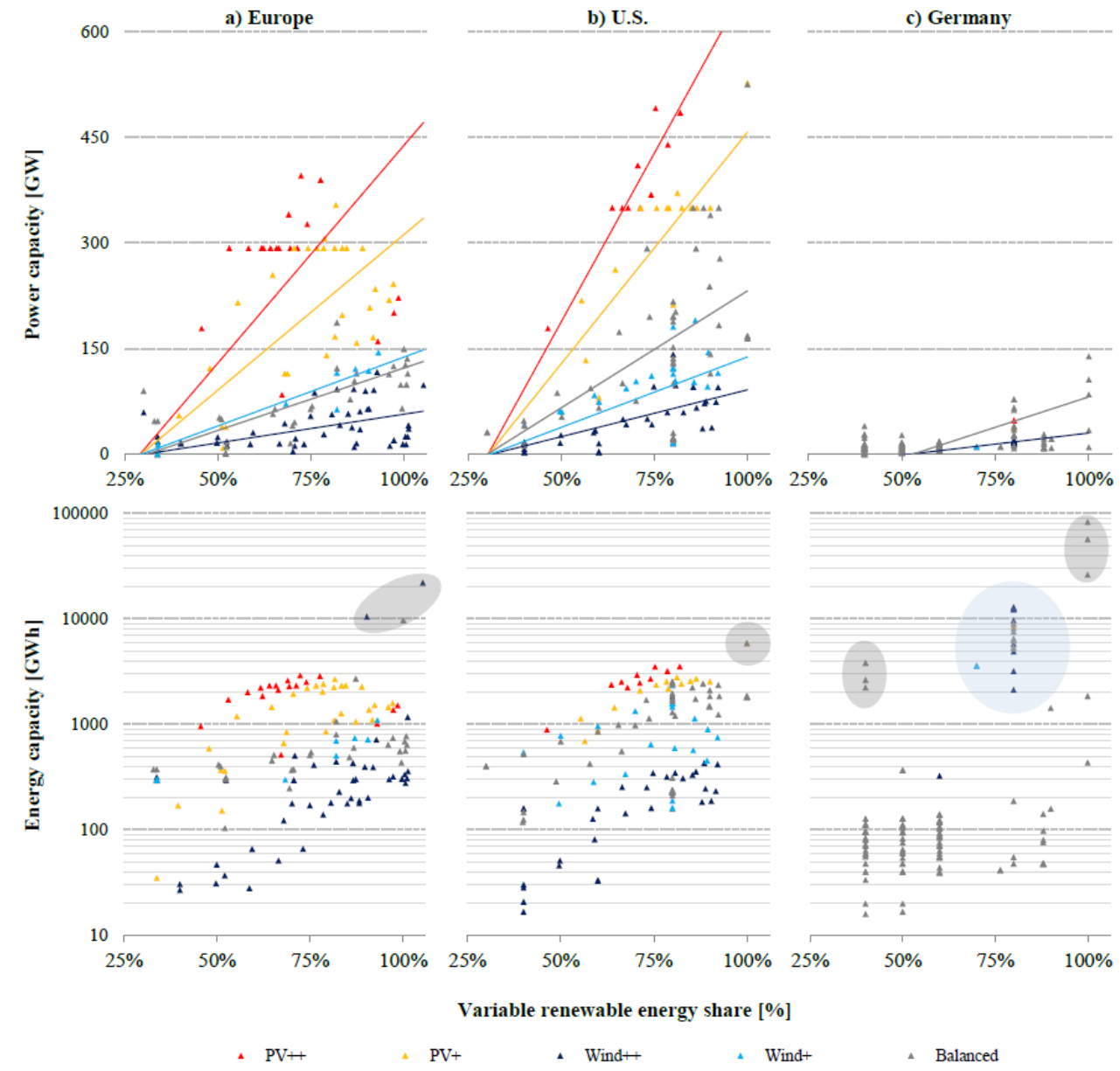
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IRED 2022, Adelaide, Australia

October 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