UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

SERG serg.co.nz

Sustainable Energy Research Group

PV yield
Mai
Int. PhD
Haas/Breyer

Green farming systems
Hadi
PhD
Haas/Peer

NZ energy plan
Rafaella
PhD
Haas/Peer

Pacific Islands
Akash
PhD
Haas/Peer

Green farming scenarios
Sam
MSc
Haas/Gallardo

Urban systems
Stella
PhD
Haas/Peer

Sustainable transport
Cong
Postdoc
Keyvan/Haas

Deep uncertainty
Matias
Int. PhD
Palma/Haas

H2 co-impacts
tba
PhD
Peer/Haas

Resilient systems
Melissa
Int. MSc
Moreno/Haas

Water-energy plan
Patrick
Int. PhD
Nowak/Haas

C negative geotherma
Karan
PhD
Peer/Dempsey

Resilient systems
Maddy
PhD
Peer/Haas

Energy game theory
Francisco
Int. PhD
Feijoo/..Haas

Ranking Civil: 11th ARWU, 54th QS, 24th QS employers' reputation

Research

- Energy systems optimization
- Transitions pathways
- Lifecycle assessments
- Planning for carbon negativity

Study

- Master of Engineering in Renewable Energy
- Doctorate on Renewable Energy

Always looking for outstanding PhD students. UC scholarships!

jannik.haas@canterbury.ac.nz
Director of Programmes in Renewable Energy

EPOC Winter Workshop 2023, Auckland, New Zealand

Planning multi-sector energy systems: new models and insights for New Zealand

Authors: Haas, Canessa, Vatankhah, Ale, Peer.

Dr. –Ing. Jannik Haas | Senior Lecturer | Sustainable Systems
Director of Postgraduate Programmes in Renewable Energy
Civil and Natural Resources Engineering, University of Canterbury

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NZ-German platform for green hydrogen integration

HINT: New Zealand-German platform for green hydrogen integration

(System analysis/modelling)

UC-PIs: Rebecca Peer and Jannik Haas | Senior Lecturers | Sustainable Civil Systems | UC
UC: Mehdi Keyvan-Ekbatani, Alan Wood, Tom Logan, Hamish Avery, Grant Read
UA: Andy Philpott, Tony Downward
Researchers: Rafaella, Akash, Stella, Hadi, Cong

DLR-PIs: Hans-Christian Gils/Wided Medjroudbi | Group leaders |Energy System Analysis | DLR
DLR: Manuel Wetzel, Alaa Alhamwi

Board: Academics: Pierluigi Mancarella, Christian Breyer, Rodrigo Palma. Industry: Hiringa, FirstGas, Mercury, Genesis

DLR

UNIVERSITY OF AUCKLAND
Waipapa Taumata Rau
NEW ZEALAND

UC
UNIVERSITY OF CANTERBURY
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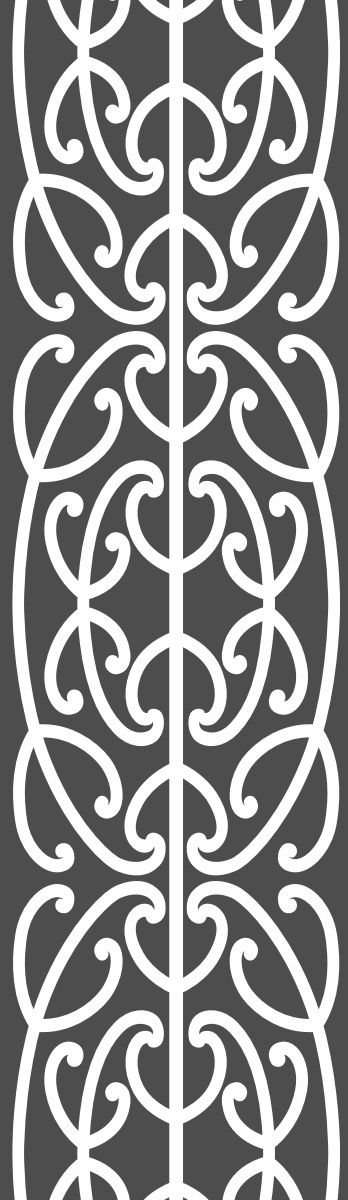
CHRISTCHURCH NEW ZEALAND

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

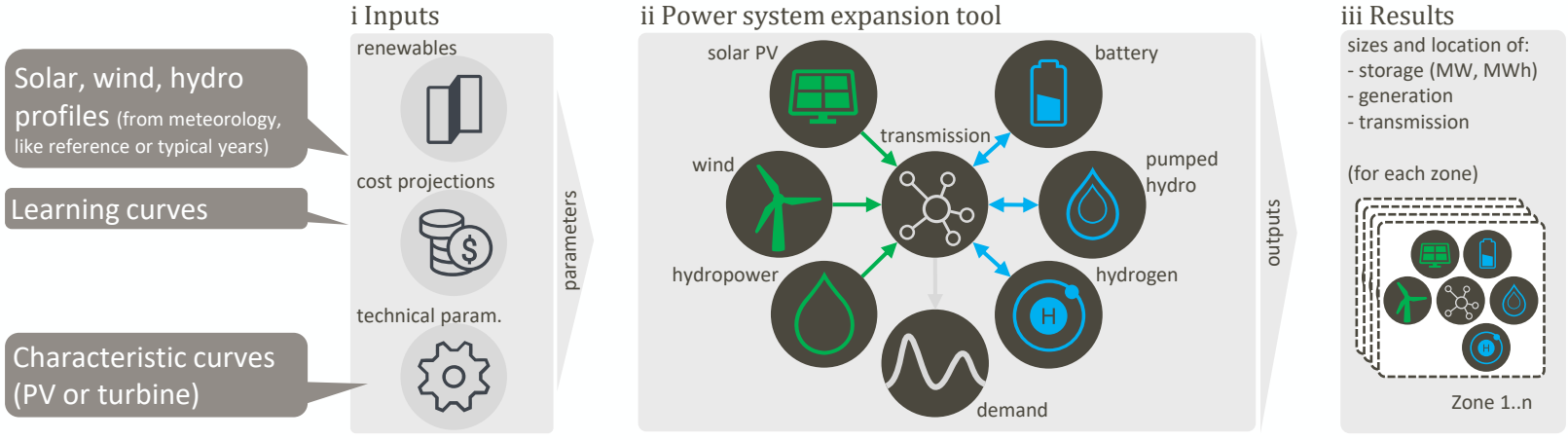
CATALYST FUND



- **Energy transitions and modelling gaps**
- Does sector coupling matter?
- Are we getting the costs right?
- HINT Platform for Hydrogen Integration

Capacity expansion planning

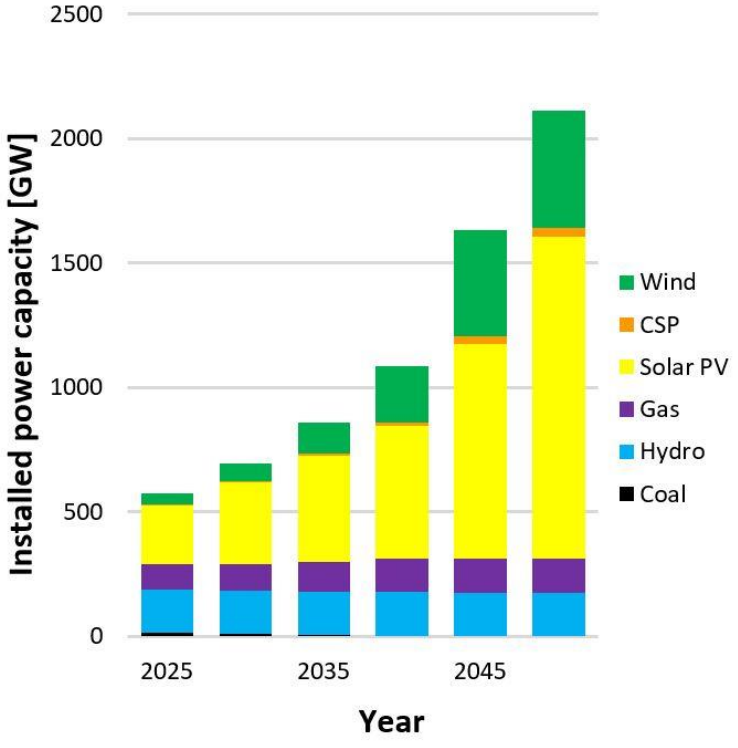
Minimize total costs, subject to meeting demand

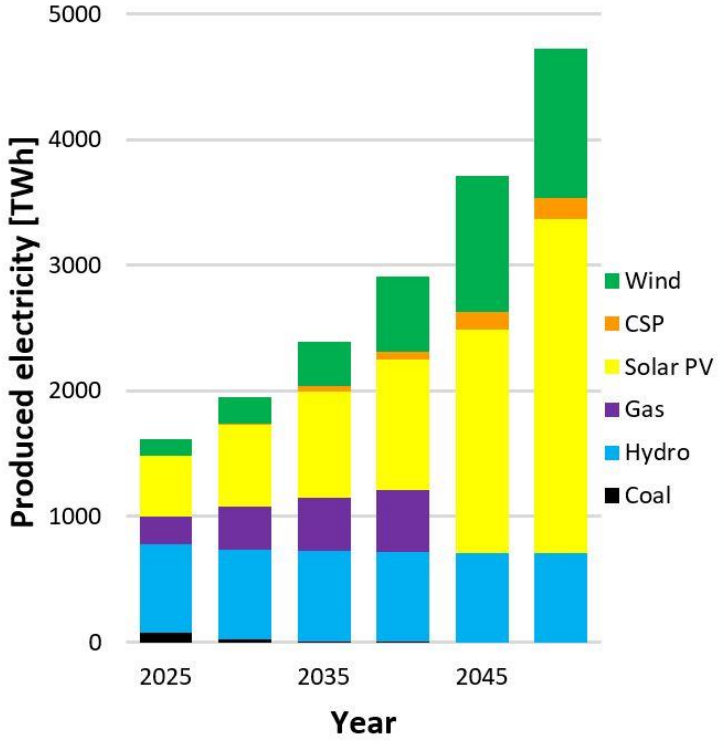


Haas, Cebulla, Nowak, Rahmann, Palma. A multi-service approach for planning the optimal mix of energy storage technologies..., Energy Management and Conversion 2018

Capacity expansion planning = strategy for growth

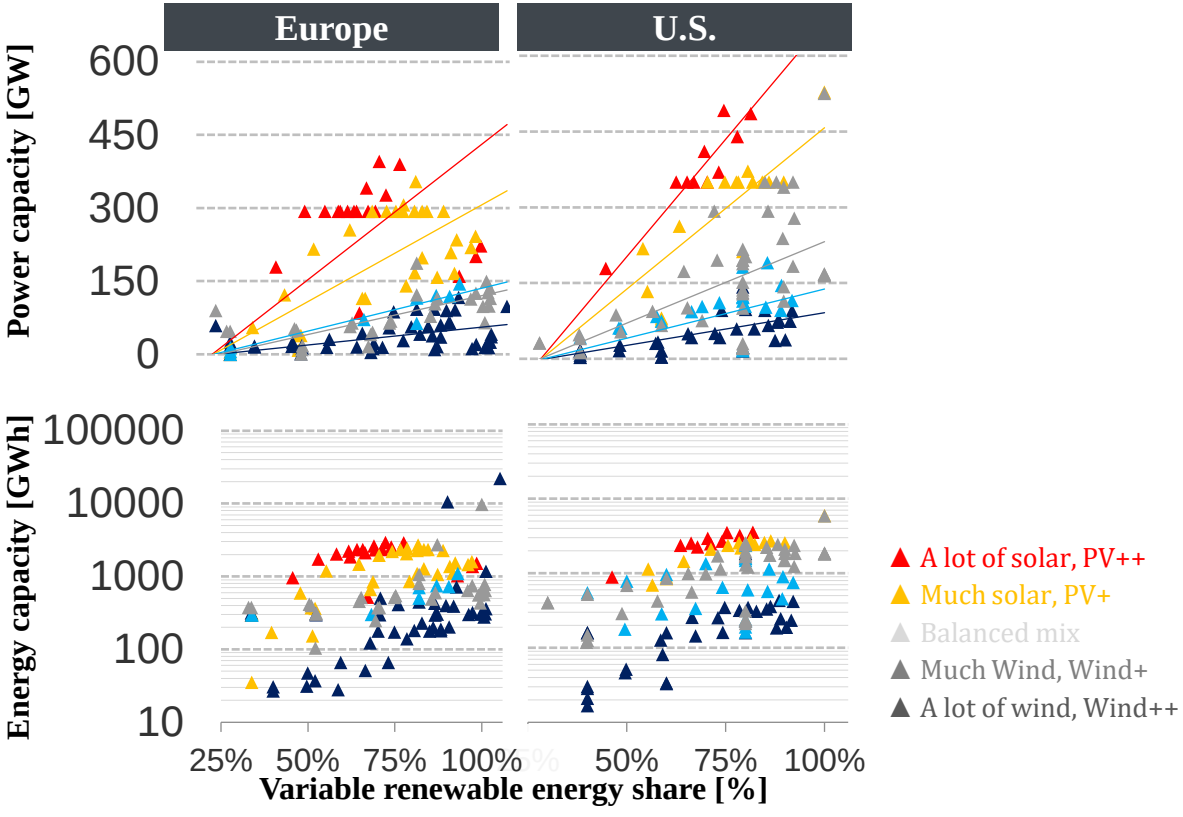
Example South America: optimal pathway of generation capacities





Galvan, Haas et al. Exporting sunshine: Planning South America's electricity transition with green hydrogen. Applied Energy 2022

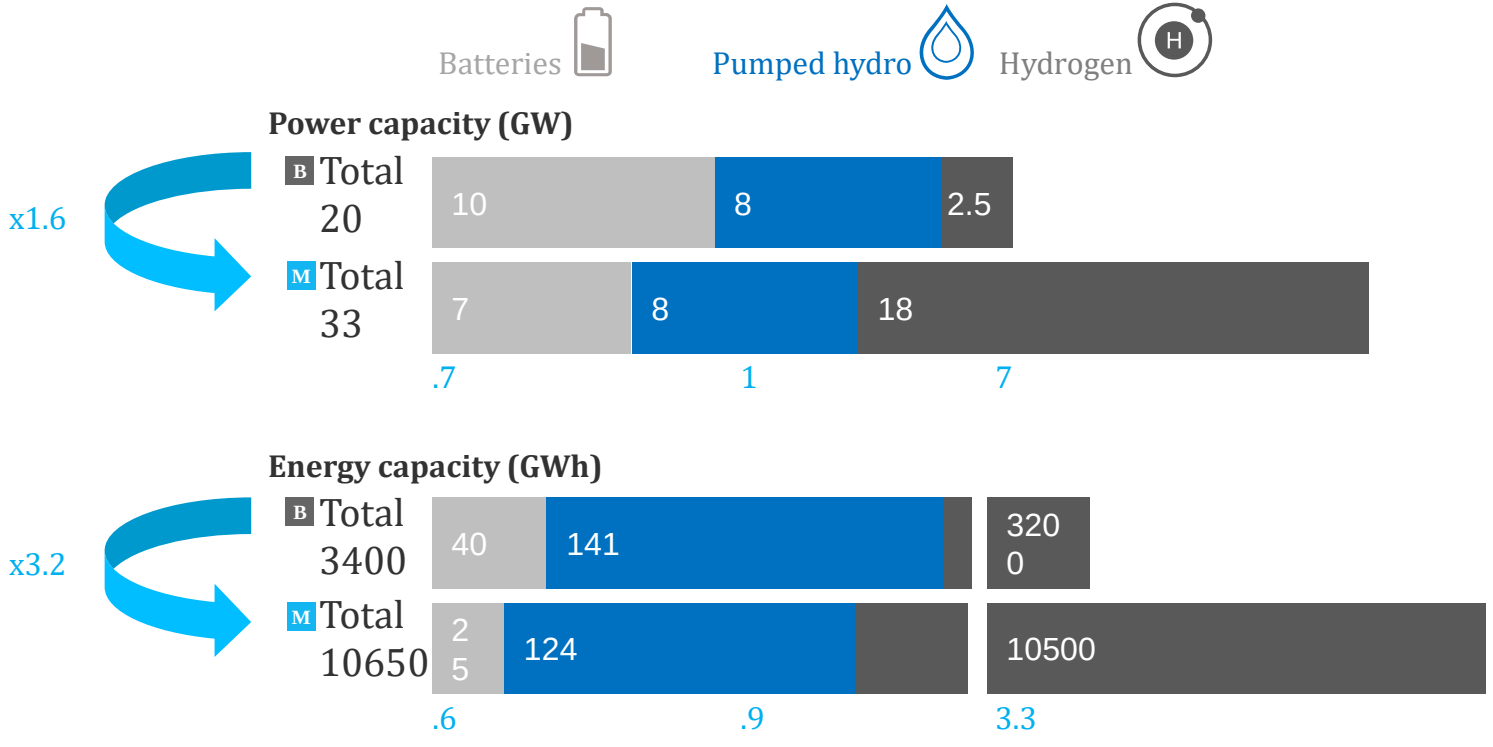
Strong need for storage



Cebulla, Haas, Eichmann, Nowak, Mancarella. How much Electrical Energy Storage do we need? A synthesis for the U.S., Europe, and Germany, Journal of Cleaner Production, 2018

More than just providing energy

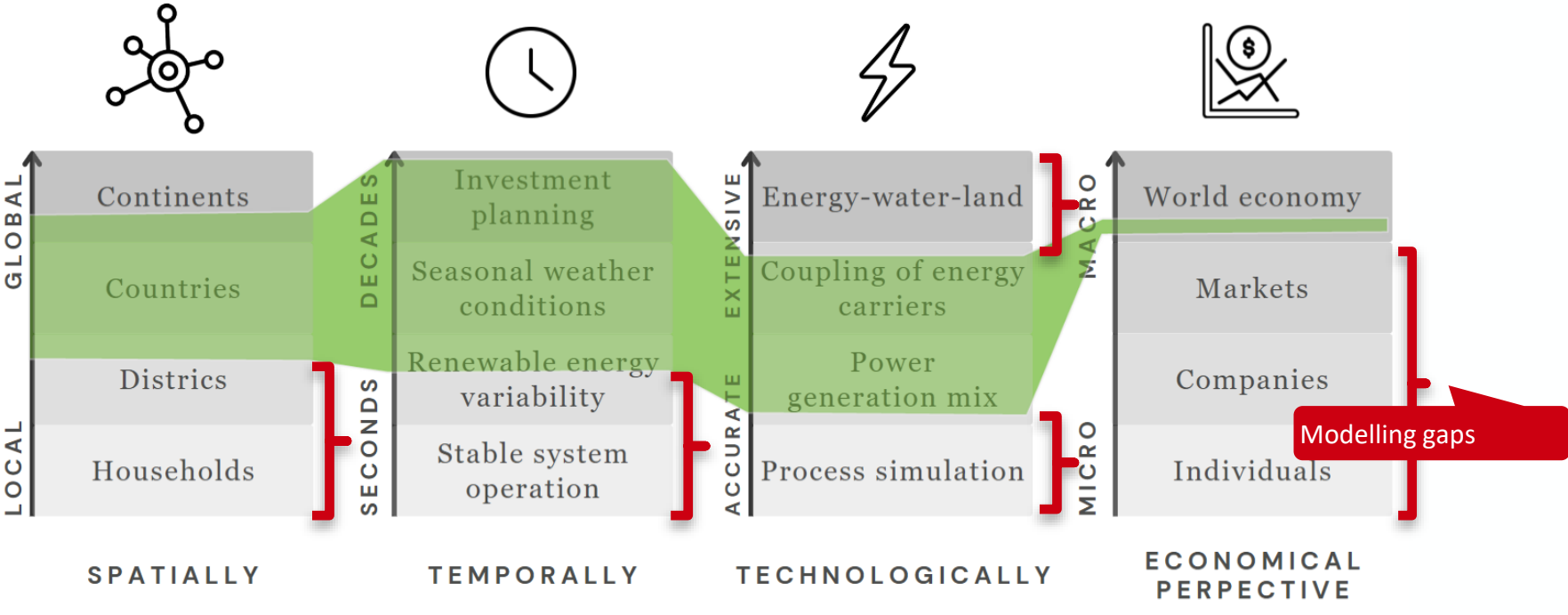
Energy autonomy and power reserves, impact investment decisions



Haas, Cebulla, Nowak, Rahmann, Palma. A multi-service approach for planning the optimal mix of energy storage technologies..., Energy Management and Conversion 2018

Tools for expansion planning are inherently limited

=> Modelling gaps!



Typical scope of energy system optimization tools

Cao, Haas, et al: "Bridging granularity gaps to decarbonize large- scale energy systems— The case of power system planning" Energy, Science and Engineering 2021

Does sector coupling matter?

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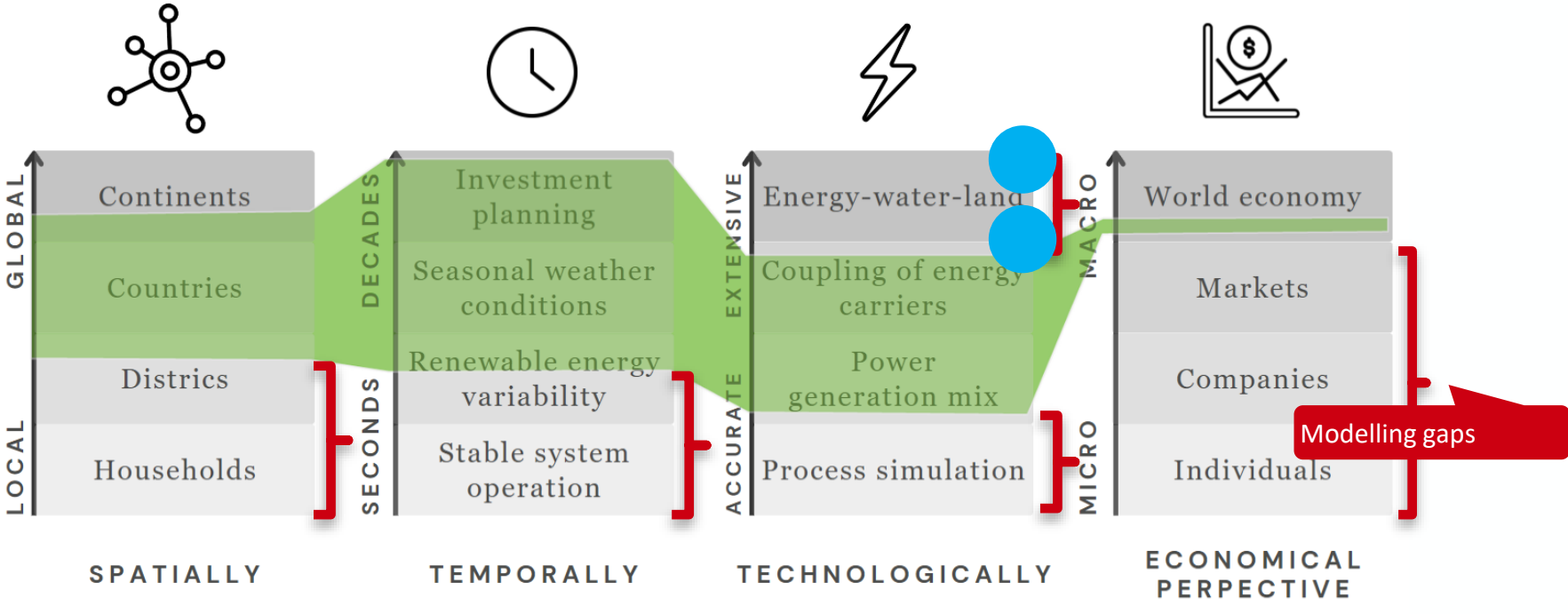


Typical scope of energy system optimization tools

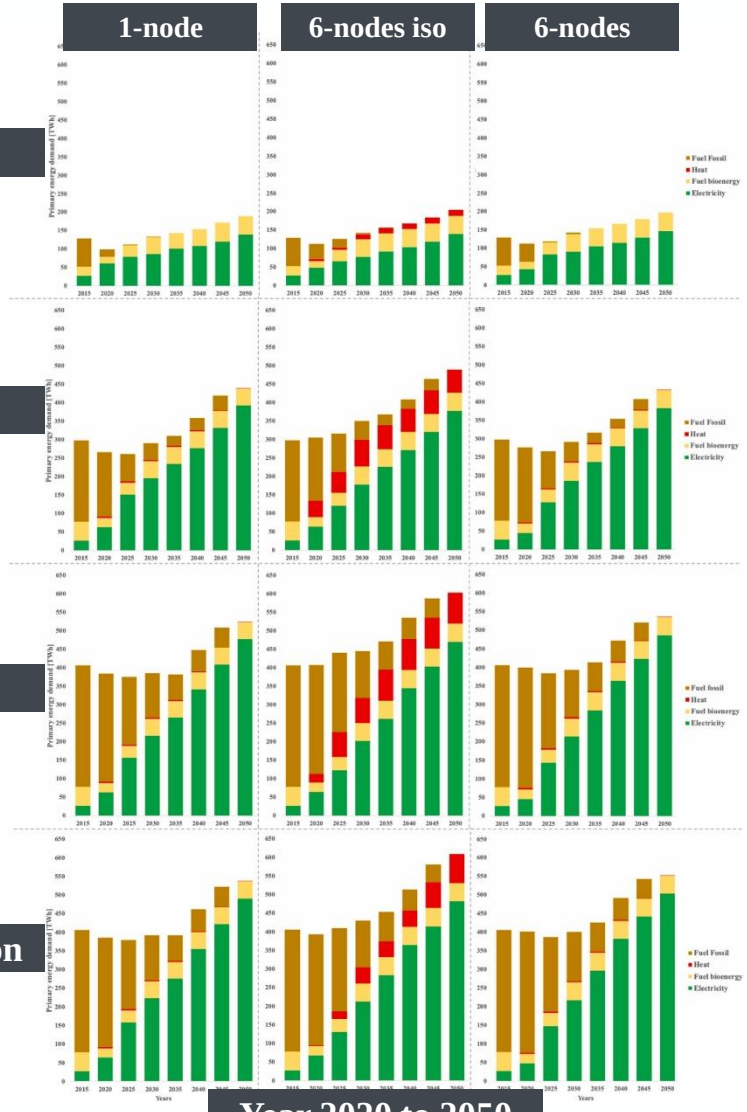
Cao, Haas, et al: "Bridging granularity gaps to decarbonize large- scale energy systems— The case of power system planning" Energy, Science and Engineering 2021

Does sector-coupling matter?

Spoilers: Yes!

This plot shows the full transition

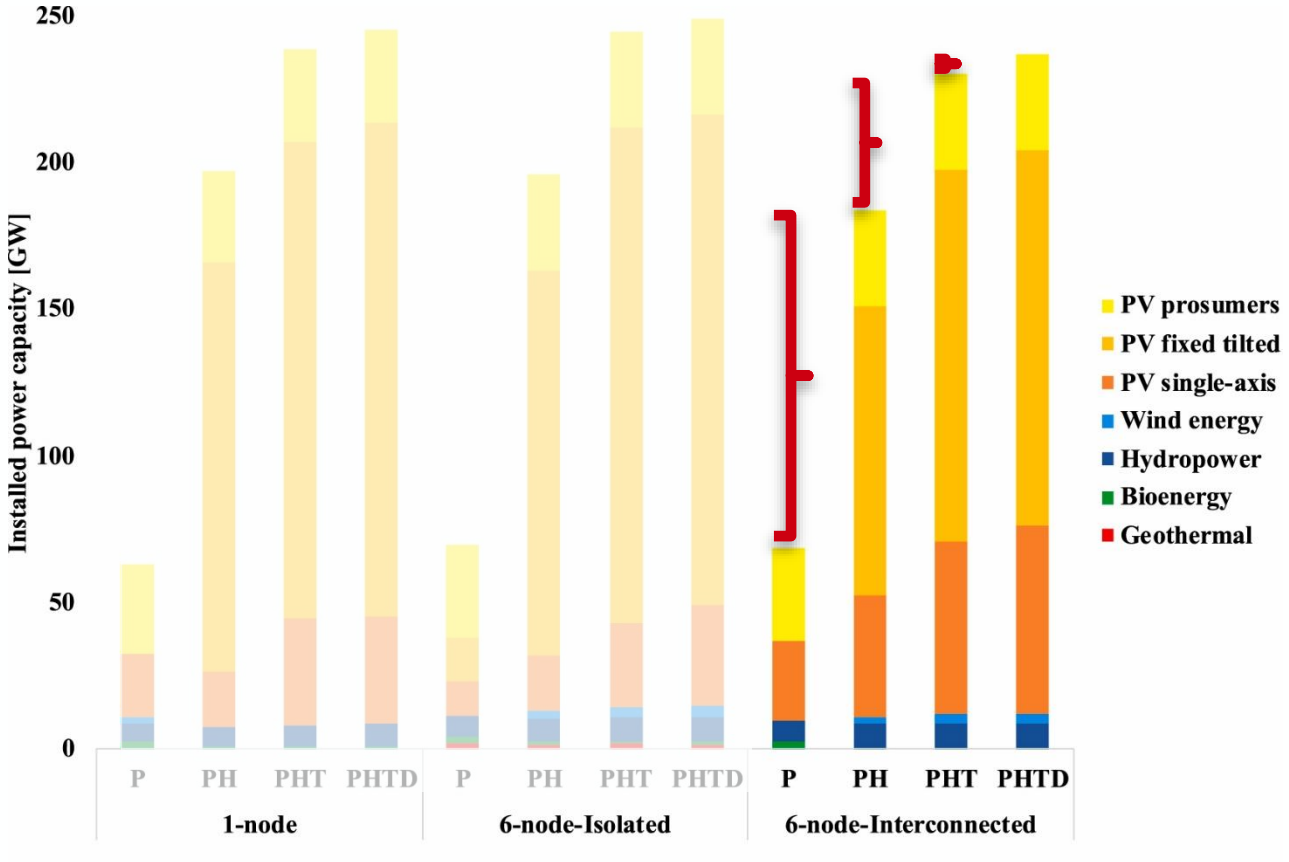
Upcoming plots only end state 2050



Osorio-Aravena et al (inc. Haas and Breyer): Synergies of electrical and sectoral integration: Analysing geographical multi-node scenarios with sector coupling variations for a transition towards a fully renewables-based energy system. Energy 2023

Does sector-coupling matter?

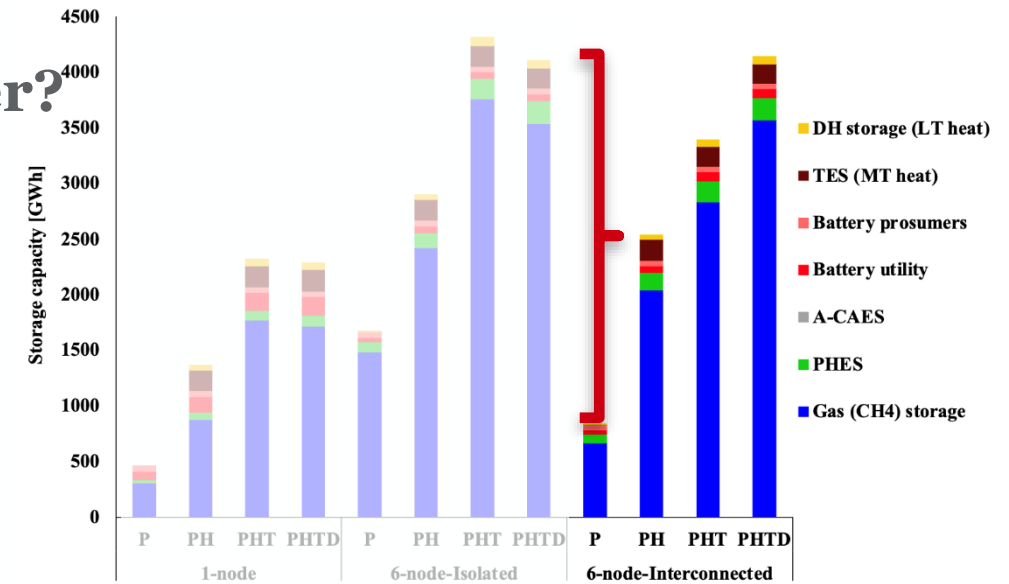
Inc. heat and transport = **4x** generation

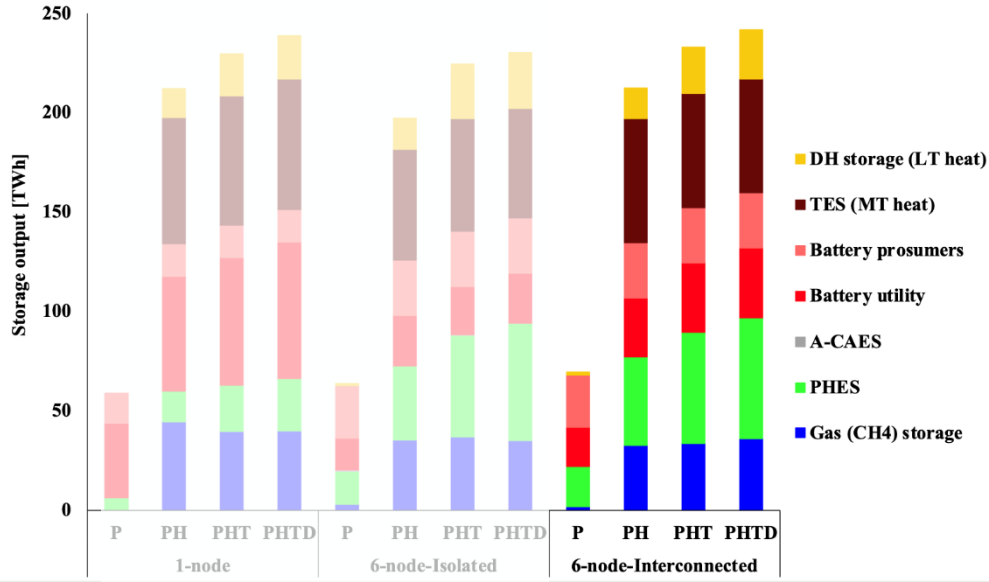


Osorio-Aravena et al (inc. Haas and Breyer): Synergies of electrical and sectoral integration: Analysing geographical multi-node scenarios with sector coupling variations for a transition towards a fully renewables-based energy system. Energy 2023

Does sector-coupling matter?

Also 4x storage!

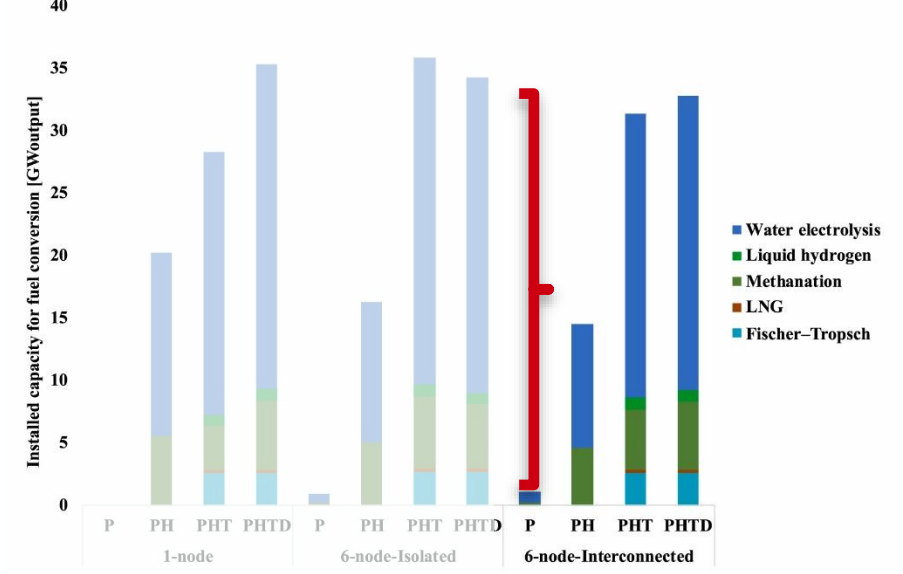


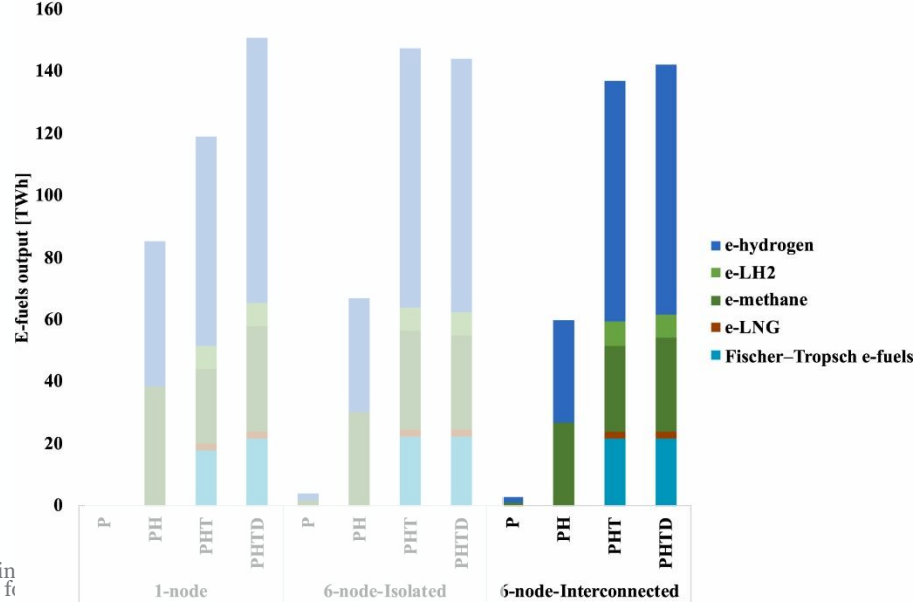


Osorio-Aravena et al (inc. Haas and Breyer): Synergies of electrical and

Does sector-coupling matter?

>15 GW for electrolyzers!
(without export ambitions)



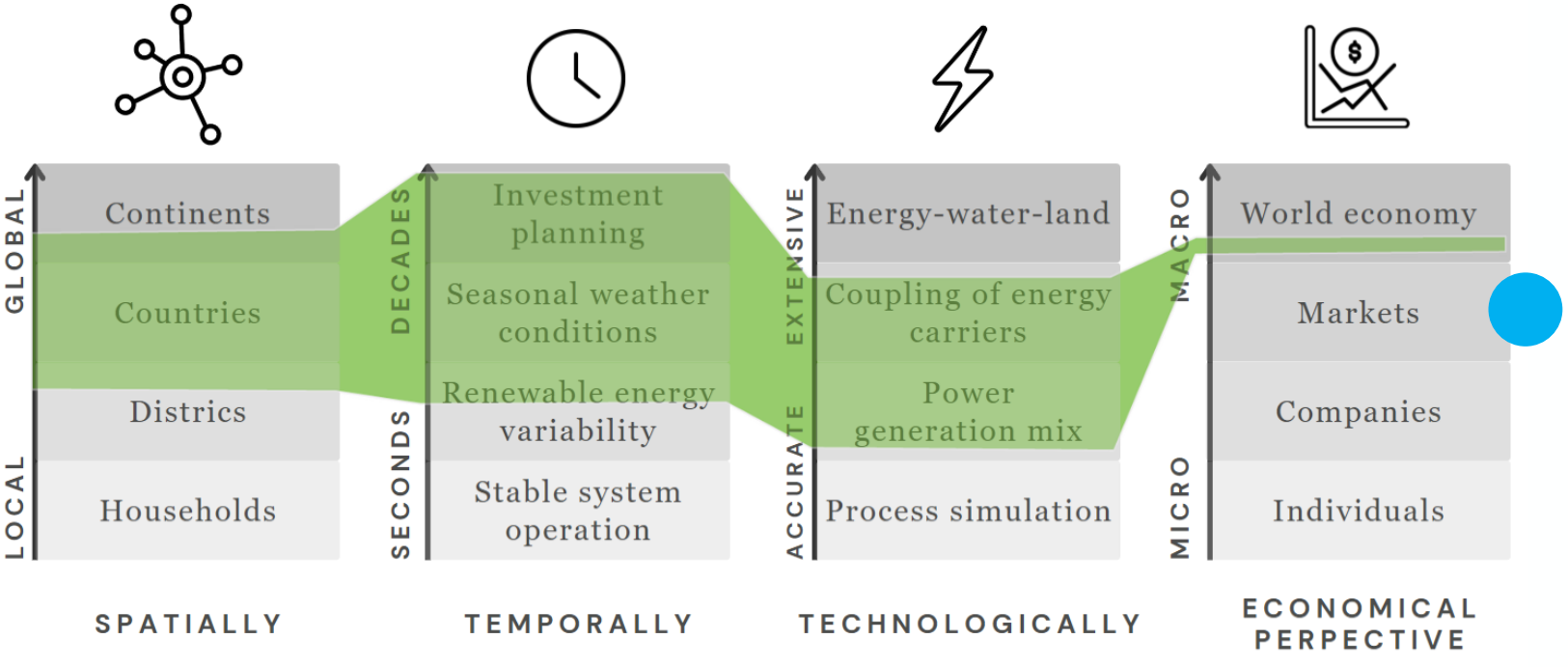


Osorio-Aravena et al (inc. Haas and Breyer): Synergies of electrical and sectoral in
variations f

Are we getting the costs right?

Tools for expansion planning are inherently limited

=> Modelling gaps!

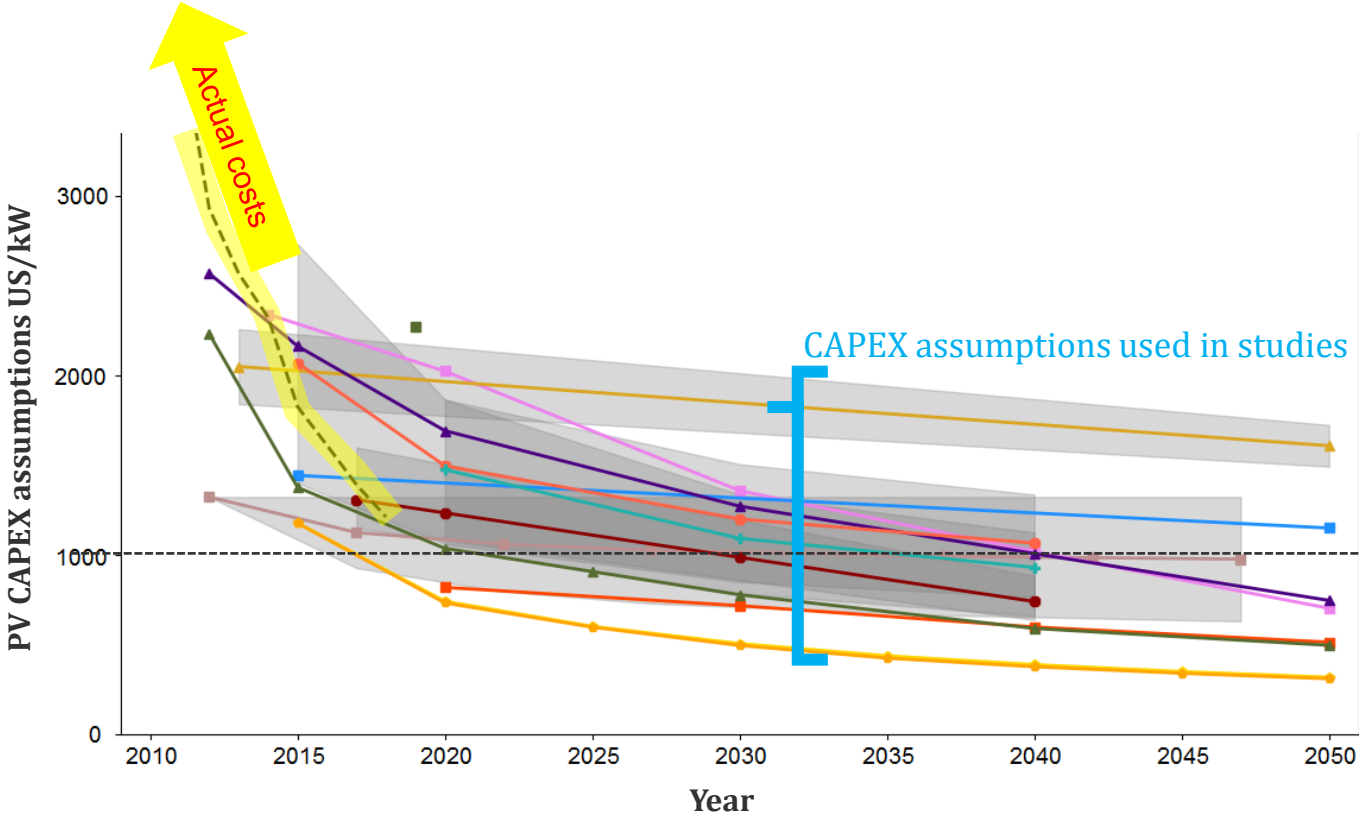


Typical scope of energy system optimization tools

Cao, Haas, et al: "Bridging granularity gaps to decarbonize large- scale energy systems— The case of power system planning" Energy, Science and Engineering 2021

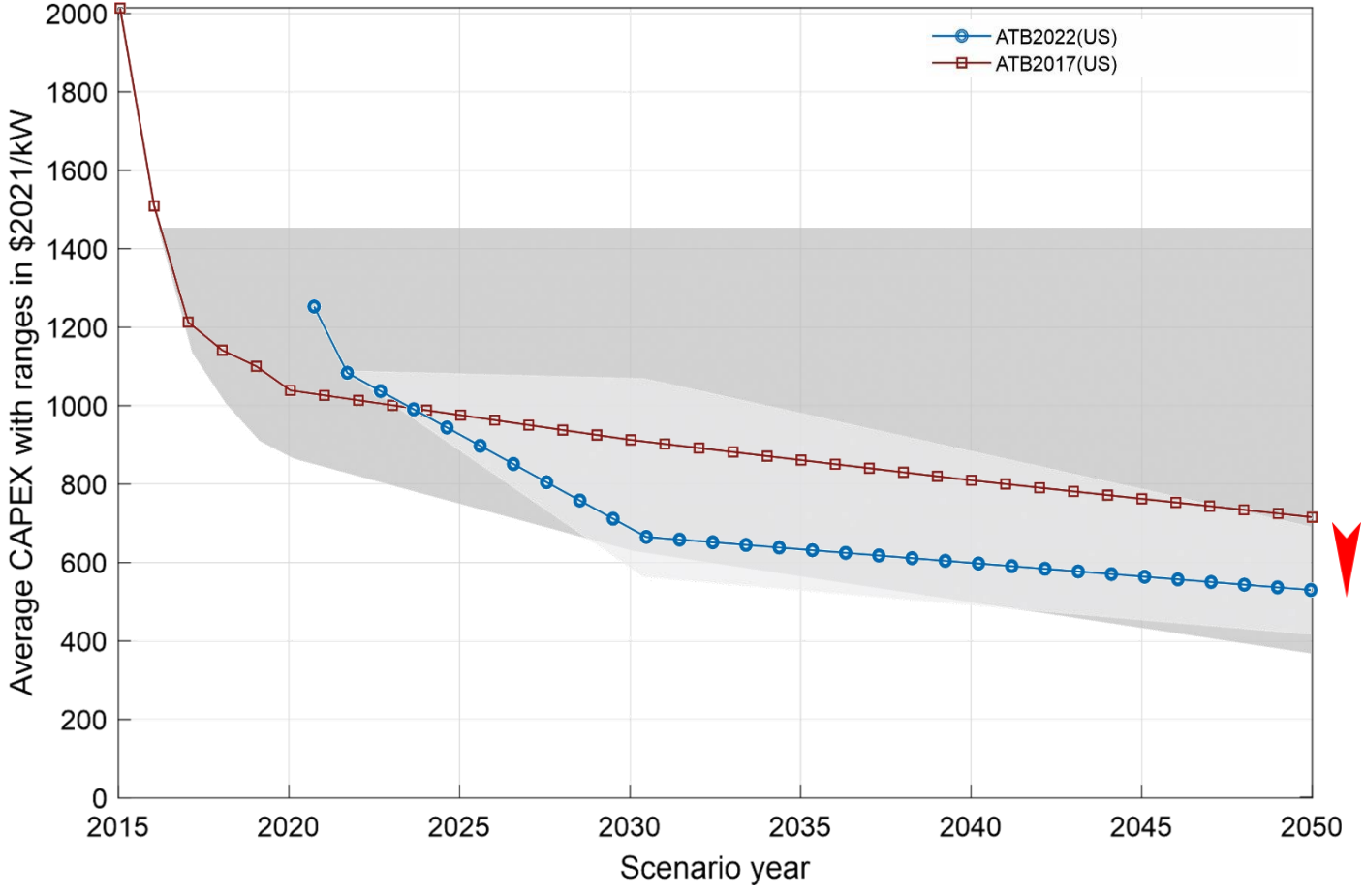
We keep on underestimating the cost decline of clean tech

… misinforming decision makers



Mengzhu Xiao, Tobias Junne, Jannik Haas, Martin Klein Plummeting costs of renewables - Are energy scenarios lagging? Energies 2021

Utility PV cost assumptions, revised down by 15%

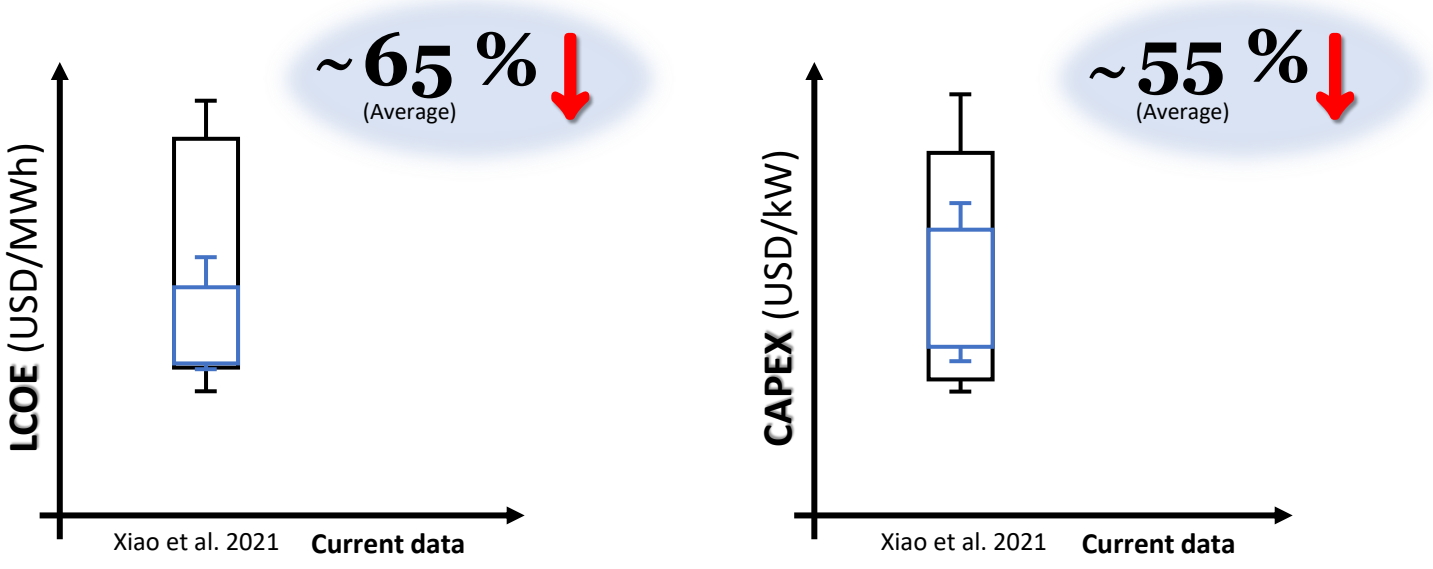


~15 %
(Average)

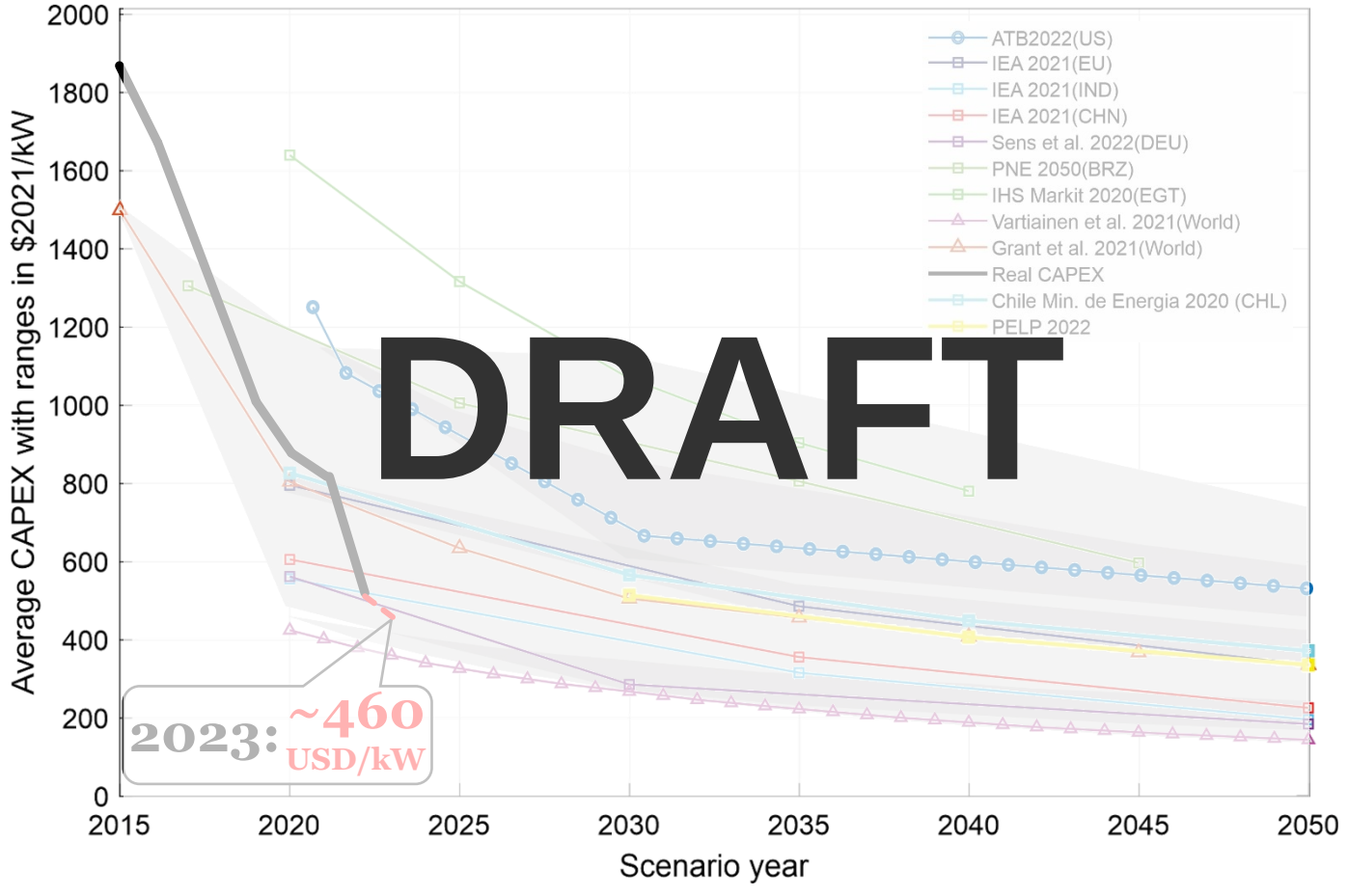
Vatankhah Ghadim, Haas, Peer at el: How low can you go? Re-assessing cost projections for renewable technologies. To be submitted to Energy.

Utility PV cost assumptions

Projections for 2050



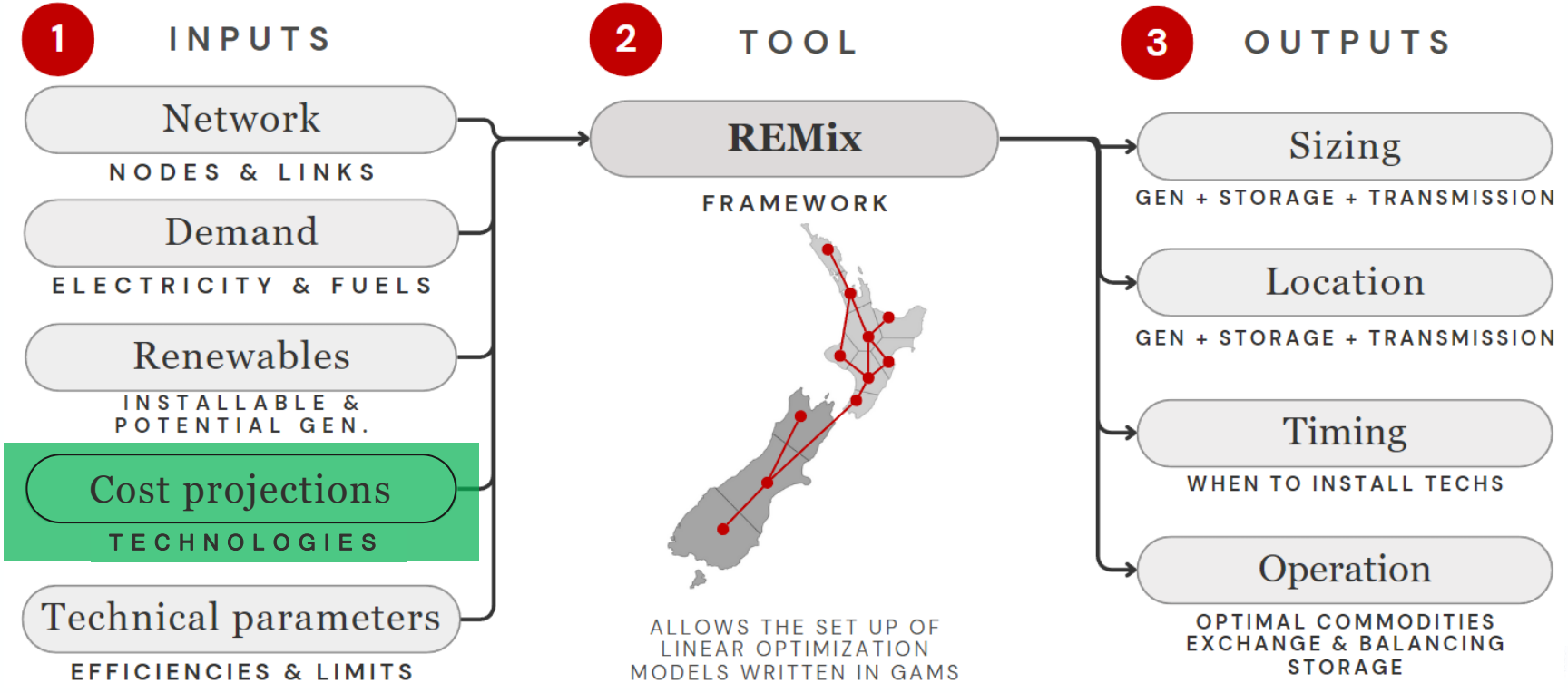
Cost assumptions: most studies still overestimate costs



Vatankhah Ghadim, Haas, Peer at el: How low can you go? Re-assessing cost projections for renewable technologies. To be submitted to Energy.

What is the purpose of the cost projection analysis?

=> Inputs to NZ energy system modelling

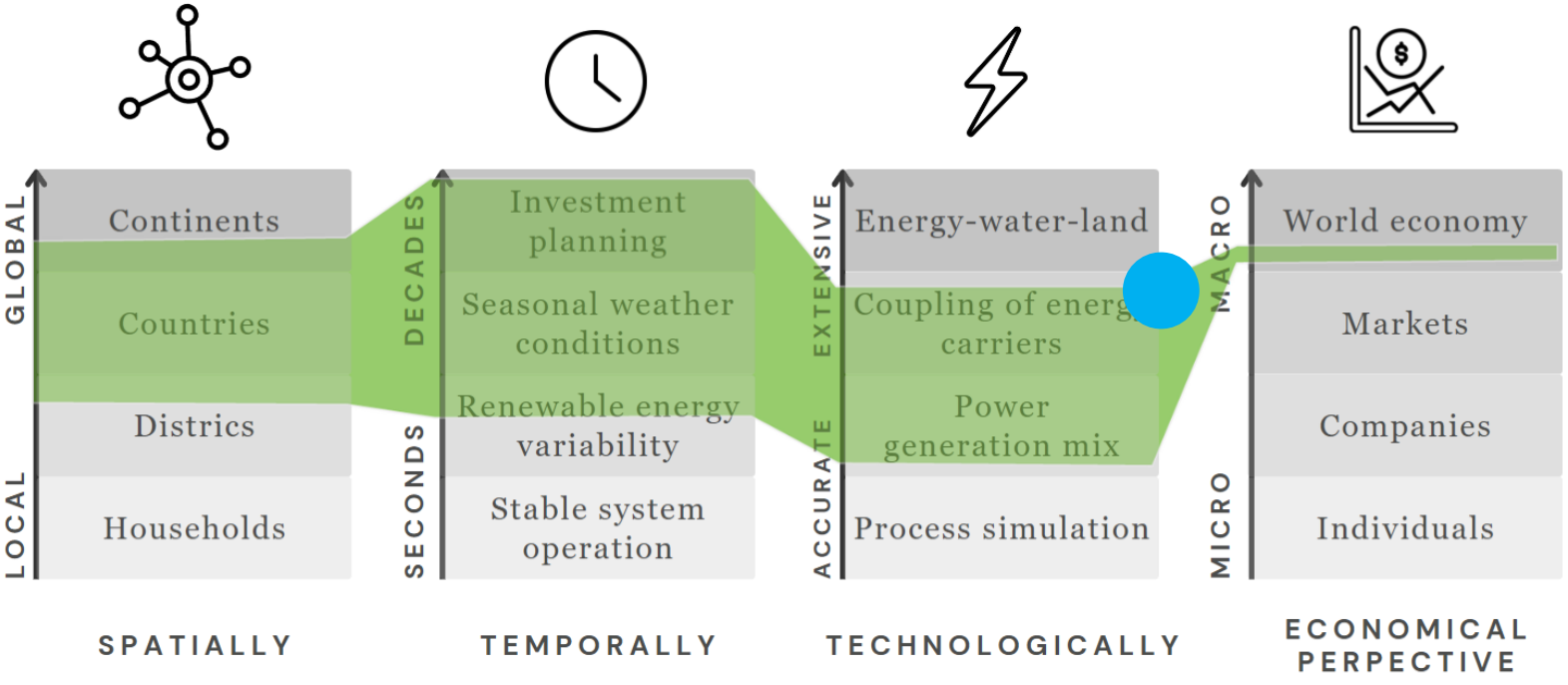


HINT

NZ-German platform for Hydrogen Integration

Tools for expansion planning are inherently limited

=> Modelling gaps!

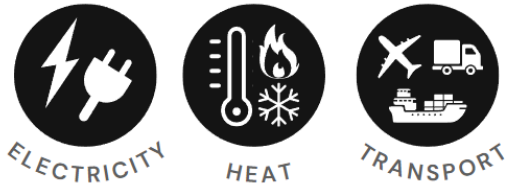


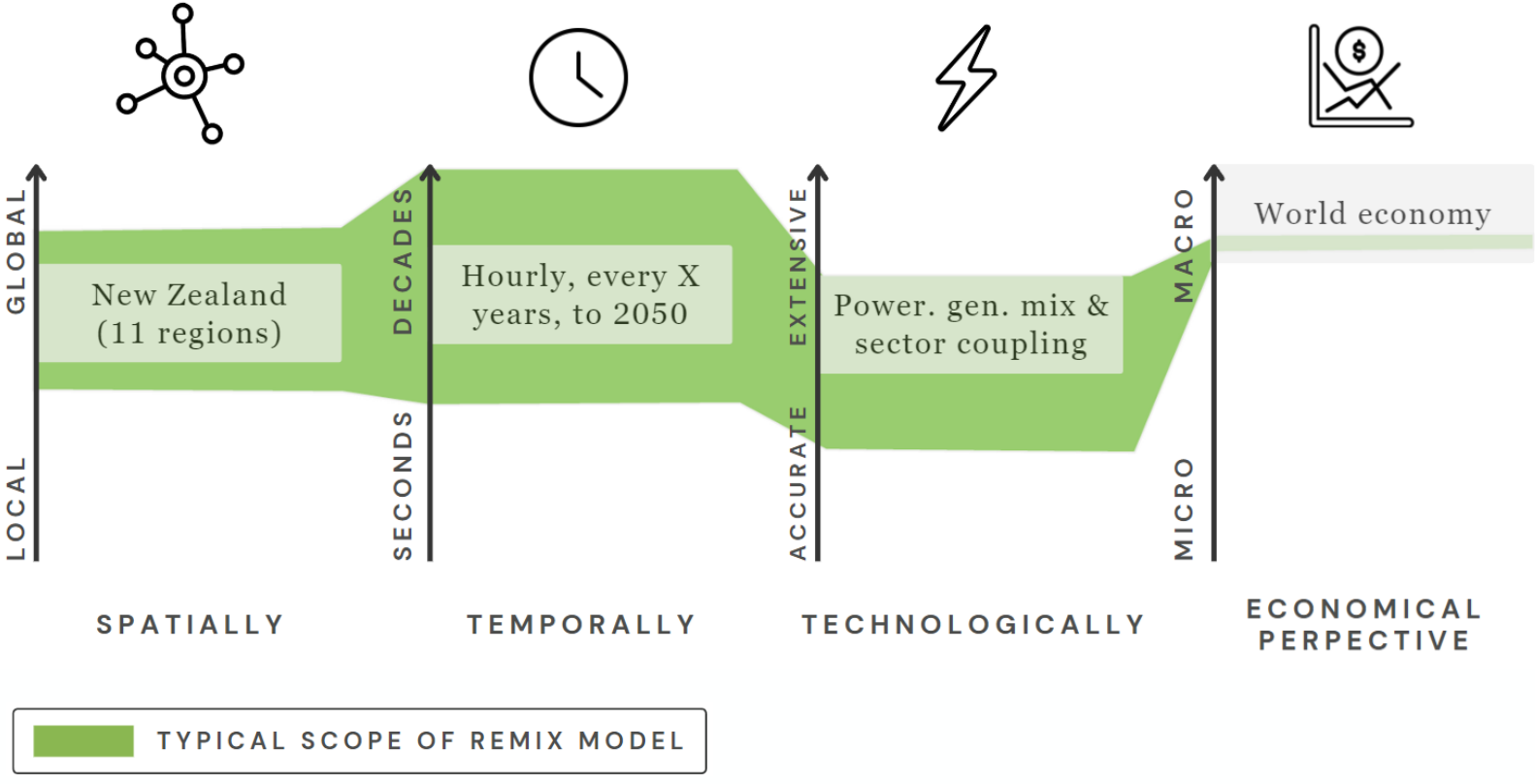
Typical scope of energy system optimization tools

Cao, Haas, et al: "Bridging granularity gaps to decarbonize large- scale energy systems— The case of power system planning" Energy, Science and Engineering 2021

Scope of Research

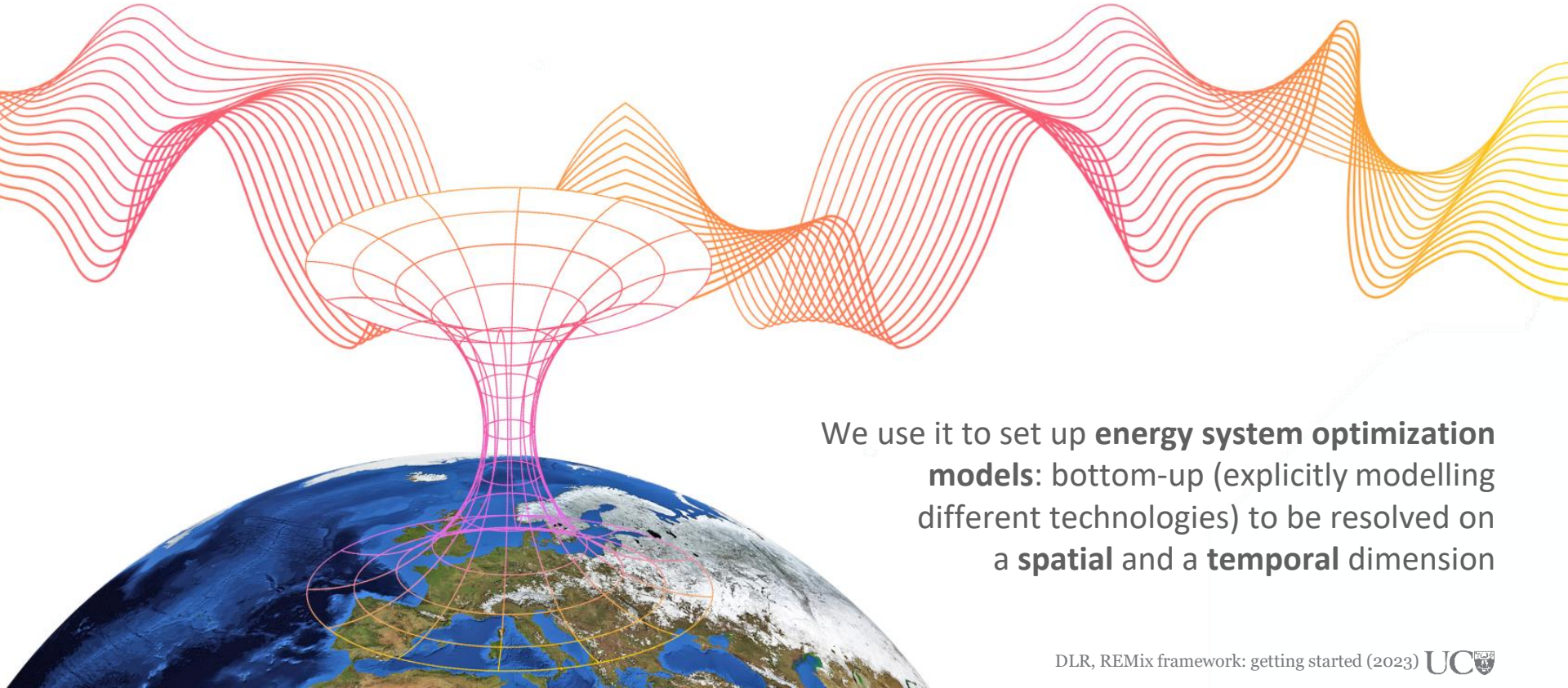
Integrated multi sector energy modelling





REMix Framework

Renewable **e**nergy **mix** for a sustainable energy supply



We use it to set up **energy system optimization models**: bottom-up (explicitly modelling different technologies) to be resolved on a **spatial** and a **temporal** dimension

REMix for New Zealand

Electricity Sector Modelling

DLR

1 INPUTS

- **Network** — NODES & LINKS
- **Demand** — ELECTRICITY & FUELS
- **Renewables** — INSTALLABLE & POTENTIAL GEN.
- **Cost projections** — TECHNOLOGIES
- **Technical parameters** — EFFICIENCIES & LIMITS

2 TOOL

REMix

FRAMEWORK

ALLOWS THE SET UP OF LINEAR OPTIMIZATION MODELS WRITTEN IN GAMS

3 OUTPUTS

- **Sizing** — GEN + STORAGE + TRANSMISSION
- **Location** — GEN + STORAGE + TRANSMISSION
- **Timing** — WHEN TO INSTALL TECHS
- **Operation** — OPTIMAL COMMODITIES EXCHANGE & BALANCING STORAGE

DLR, REMix framework: getting started (2023)

REMix model overview

- Main model language GAMS
- Comprehensive energy system modelling framework
- Flexible spatial, temporal & technological scope
- Capacity expansions and dispatch of all infrastructures
- System integration of power, heat, gas, transport sectors

Active development

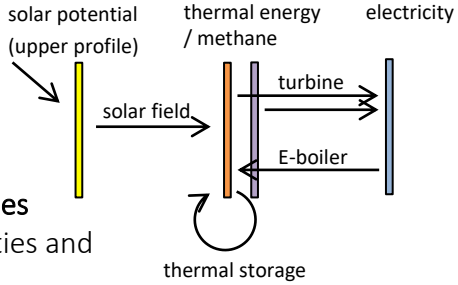
- Testing framework and merge approvals to ensure stability from previous version developed over 10 years
- Development over the last two years

Multi-activity converters

- Linear combinations
- Partial and minimum loads

Multi-input multi-output activities

- Free definition of commodities and accounting variables



Power grid

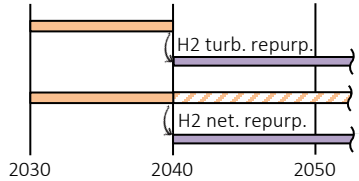
- LOPF power angles and Kirchhoff formulation
- Security constrained transmission expansion planning

Gas sector modelling

- Pipeline and storage repurposing for H_2
- Hydrogen admixture for methane networks

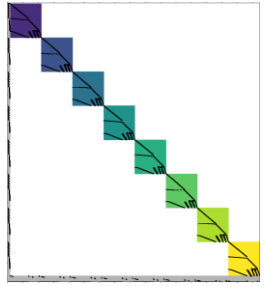
System transformation pathways

- Limited and perfect foresight
- Carbon budgets



MIP capacity expansion and unit commitment

Multi-criteria optimization



Resilience and outage modelling

- Rolling horizon with multiple outage events

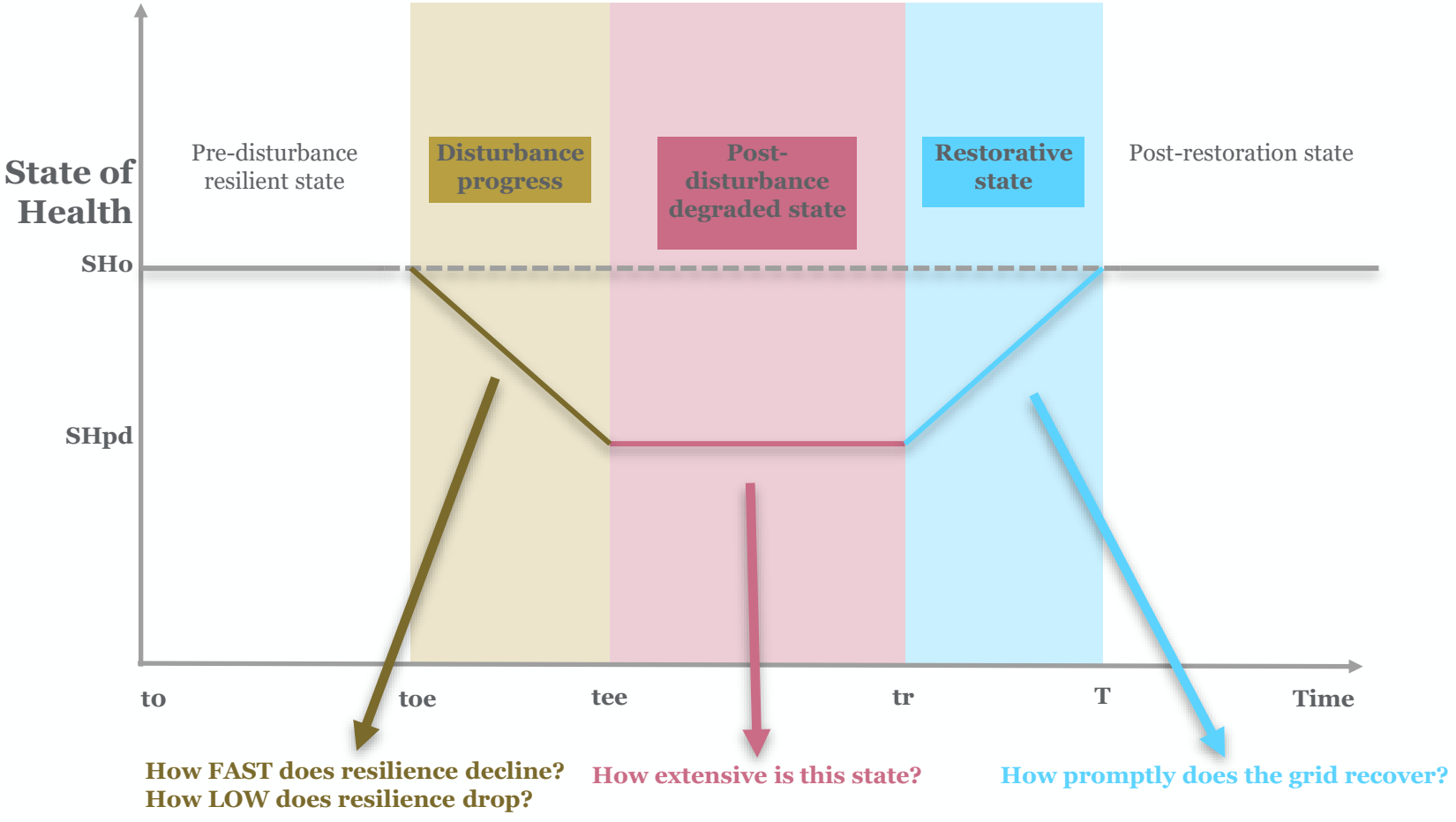
Modelling to generate alternatives methods

HPC ready via PIPS-IPM++ link

- EMP reformulation for stochastic optimization

Resiliency Modelling

Resilience



M. Panteli, P. Mancarella, D. N. Trakas, E. Kyriakides, and N. D. Hatziargyriou, "Metrics and Quantification of Operational and Infrastructure Resilience in Power Systems", IEEE Transactions on Power Systems, vol. 32, no. 6, November 2017.

Resilience assessment

Phase 1

Geographic profiles

Hazard characterization

- Spatiotemporal threat modelling
- Empirical data and simulation of thousands scenarios

Phase 2

Fragility-driven approach

Vulnerability asessment of system components

- Time and hazard dependent failure probabilities
- Fragility-based assessment

Phase 3

Power system analysis

System response

- Spatio-temporal impact assessment
- Component and region criticality assessment

Phase 4

Probabilistic recovery

System restoration

- Operational and infrastructure restoration and recovery modelling

M. Panteli, D. N. Trakas , P. Mancarella, and N. D. Hatziargyriou, “Power Systems Resilience Assessment: Hardening and Smart Operational Enhancement Strategies”, Proceedings of the IEEE, vol. 105, no. 7, pp. 1202 1213, July 2017.

M. Panteli, P. Mancarella, C. Pickering, S. Wilkinson, and R. Dawson, “Power System Resilience to Extreme Weather: Fragility Modelling, Probabilistic Impact Assessment, and Adaptation Measures”, IEEE Transactions on Power Systems, vol. 32, no. 5, September 2017.

M. Panteli, R. Moreno, A. Martinez Cesena and M. Pierluigi. (2022). Flexibility and Resilience in Future Low-Carbon Energy Systems.

Resilience: Phase 1 and 2

Earthquake Modelling

HAZUS Methodology

PGA

Intensity of the earthquake at the surface of a given point in the map

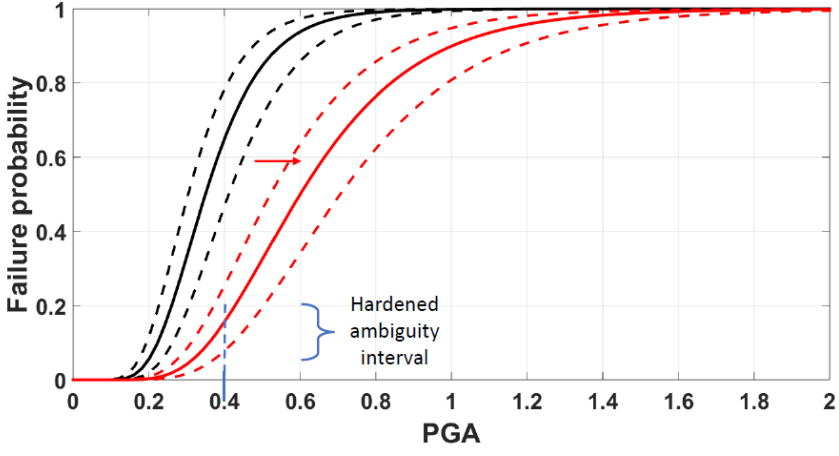
$$\ln PGA = 6{,}36 + 1{,}76M - 2{,}73\ln(R + 1{,}58\, e^{0{,}608\, M}) + 0{,}00916\, h$$

M intensity magnitude in the Gutenberg-Richter scale

R distance between the earthquake coordinates and the location of each power system component [km]

h focal depth in the epicenter [km]

Fragility Curves

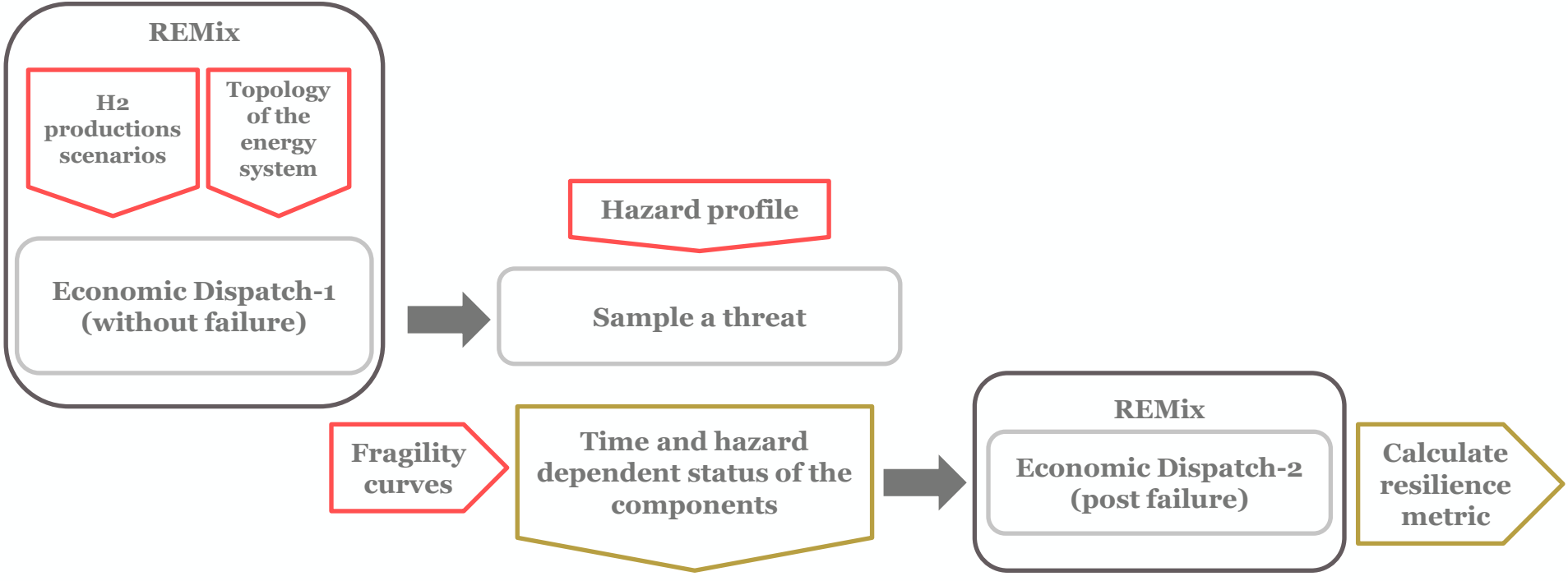


C. B. Crouse Ground-Motion Attenuation Equations for Earthquakes on the Cascadia Subduction Zone. Earthquake Spectra, May 1991, Vol. 7, No. 2, pp. 201-236.

Lagos, Tomas & Sacaan, Rafael & Navarro-Espinosa, Alejandro & Ordonez, Fernando & Rudnick, Hugh & Moreno, Rodrigo. (2017). Designing Resilient Power Networks Against Natural Hazards.

Resilience and REMix: Phase 3 and 4

The Sequential Montecarlo Procedure for Resiliency Model



Application: Earthquakes in Chile

"From Reliability to Resilience: Planning the Grid Against the extremes"

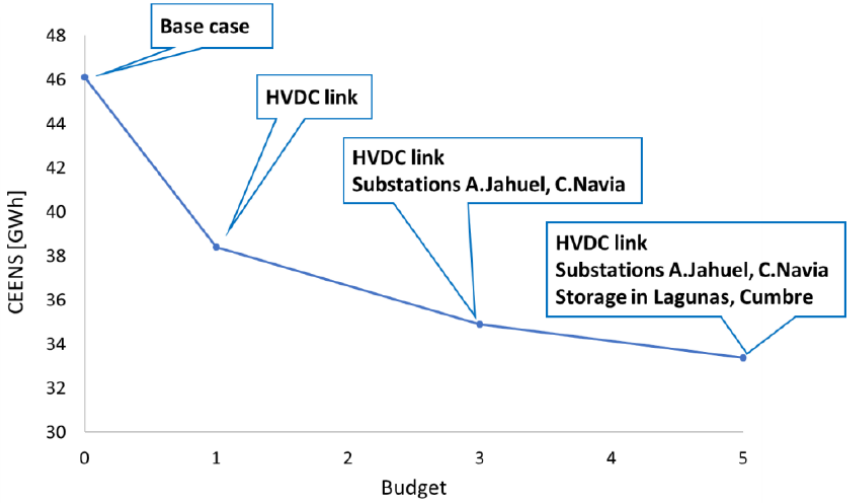
Results:
Optimal portfolio solutions for resilience enhancement for different budgets.

Reliability

Rank	Enhancement	EENS [MWh]
1	L: HVDC link	348
2	L: Laberinto - Cumbre	392
3	L: Ciruelos - Pichirropulli	523
4	L: Cautin - Charrua	580
5	L: Ciruelos - Cautin	617
6	Ss: Crucero	696
7	Ss: C. Navia	696
8	Ss: A. Jahuel	696
9	Ss: Charrua	696
10	Base case	696

Resilience

Rank	Enhancement	CEENS [GWh]
1	L: HVDC link	38
2	Ss: C. Navia	43
3	Ss: A. Jahuel	43
4	Ss: Charrua	44
5	Ss: Crucero	45
6	L: Laberinto - Cumbre	46
7	L: Ciruelos - Cautin	46
8	L: Cautin - Charrua	46
9	L: Ciruelos - Pichirropulli	46
10	Base case	46



The **best possible insurance to the main system load center** against the occurrence of large earthquakes.

R. Moreno et al., "From Reliability to Resilience: Planning the Grid Against the Extremes," in IEEE Power and Energy Magazine, vol. 18, no. 4, pp. 41-53, July-Aug. 2020, doi: 10.1109/MPE.2020.2985439.

Bottoms up! Planning cities

Energy system optimisation for cities and industries

FLEXIGIS-H_2

- **GIS-based**
- **open-source**
- **high-resolution optimization** of green hydrogen integration at district and industry level
- calculate **demand and generation potential** of renewables and H_2

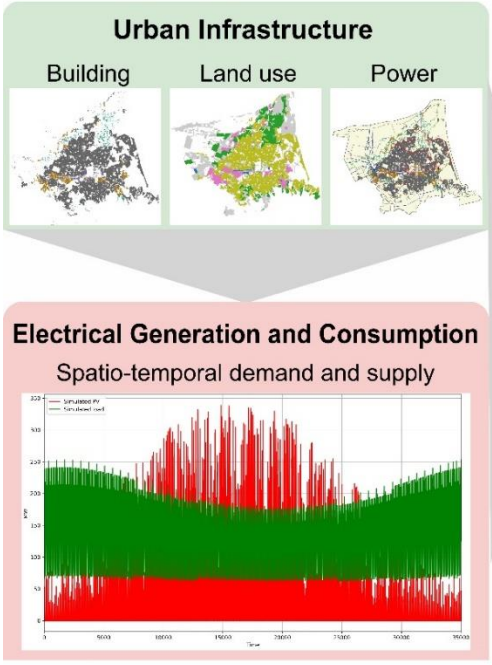
6 Scenarios

H_2 integration: **yes / no** for:

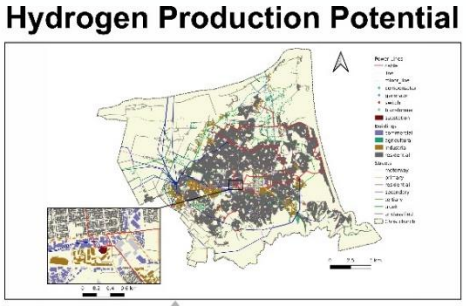
- Reference - 2023
- Future - 2030
- Future - 2050

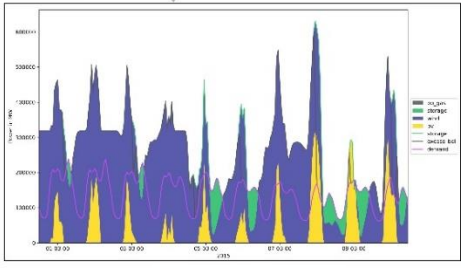
Use-cases

residential heating | process heat | seasonal storage | fertiliser



Linear Optimisation



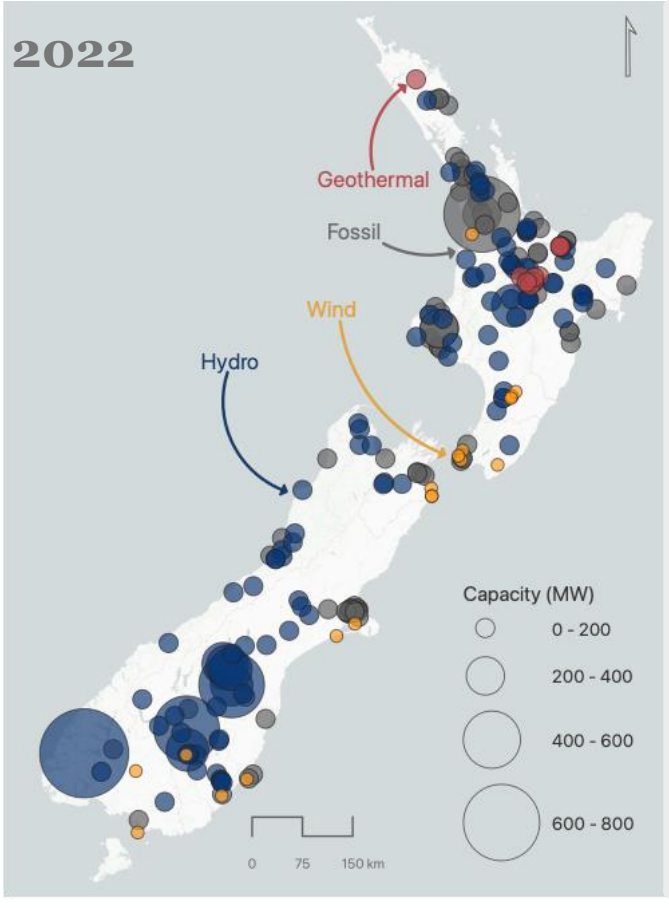


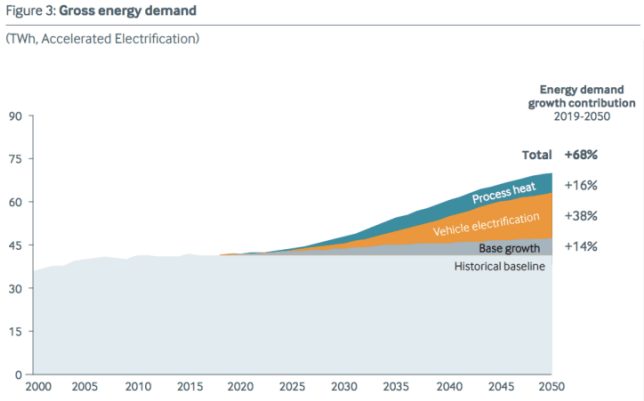
Operation

Based on: Alhamwi et al., 2019, Development of a GIS-based platform for the allocation and optimisation of distributed storage in urban energy systems

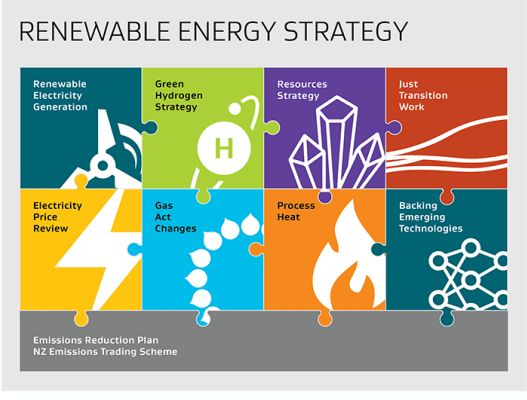
Thinking beyond carbon

Evaluating the non-carbon trade-offs of NZ's near-term energy futures





Policy commitments & alternative energy pathways



Impacts on:
- land
- water
- materials
- access
- equity

Newsroom; NZ MBIE

Outro

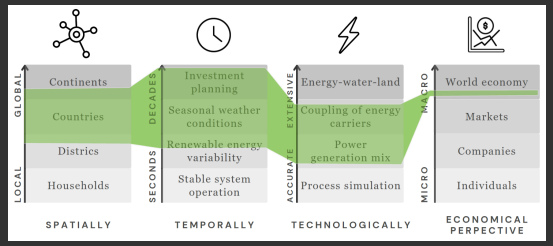
Upcoming conferences

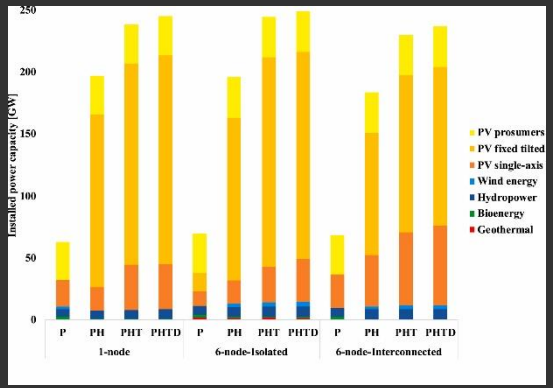
2nd New Zealand Hydrogen Symposium

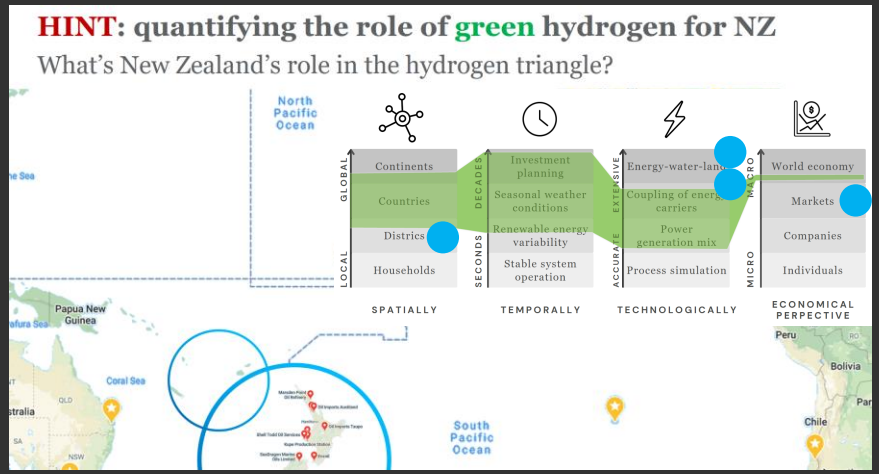
31 Jan-2 Feb 2024, Wellington
Special session on “Hydrogen energy systems”

4th LA SDEWES Conference

Sustainable development of water energy systems
14 -17 Jan 2024, Vina del Mar
Special Session on “Integrated Energy Systems”


GLOBAL
Continents
Countries
Districts
LOCAL
Households
DECADES
Investment planning
Seasonal weather conditions
Renewable energy variability
SECONDS
Stable system operation
EXTENSIVE
Energy-water-land
Coupling of energy carriers
Power generation mix
ACCURATE
Process simulation
MACRO
World economy
Markets
Companies
MICRO
Individuals
SPATIALLY
TEMPORALLY
TECHNOLOGICALLY
ECONOMICAL PERPECTIVE


Installed power capacity [GW]
250
200
150
100
50
0
P
PH
PHT
PHTD
1-node
6-node-Isolated
6-node-Interconnected
PV prosumers
PV fixed tilted
PV single-axis
Wind energy
Hydropower
Bioenergy
Geothermal


HINT: quantifying the role of green hydrogen for NZ
What's New Zealand's role in the hydrogen triangle?
North Pacific Ocean
Papua New Guinea
Coral Sea
South Pacific Ocean
Peru
Bolivia
Chile
GLOBAL
Continents
Countries
Districts
LOCAL
Households
DECADES
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Seasonal weather conditions
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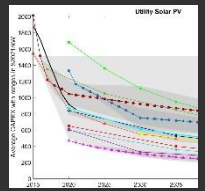
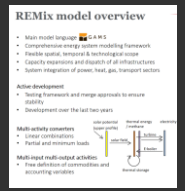
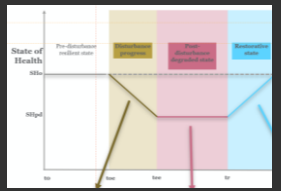
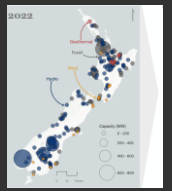

Utility Solar PV


REMix model overview


State of Health


2022

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

SERG serg.co.nz

Sustainable Energy Research Group

PV yield
Mai
Int. PhD
Haas/Breyer

Green farming systems
Hadi
PhD
Haas/Peer

NZ energy plan
Rafaella
PhD
Haas/Peer

Pacific Islands
Akash
PhD
Haas/Peer

Green farming scenarios
Sam
MSc
Haas/Gallardo

Urban systems
Stella
PhD
Haas/Peer

Sustainable transport
Cong
Postdoc
Keyvan/Haas

Deep uncertainty
Matias
Int. PhD
Palma/Haas

H2 co-impacts
tba
PhD
Peer/Haas

Resilient systems
Melissa
Int. MSc
Moreno/Haas

Water-energy plan
Patrick
Int. PhD
Nowak/Haas

C negative geotherma
Karan
PhD
Peer/Dempsey

Resilient systems
Maddy
PhD
Peer/Haas

Energy game theory
Francisco
Int. PhD
Feijoo/..Haas

Ranking Civil: 11th ARWU, 54th QS, 24th QS employers' reputation

Research

- Energy systems optimization
- Transitions pathways
- Lifecycle assessments
- Planning for carbon negativity

Study

- Master of Engineering in Renewable Energy
- Doctorate on Renewable Energy

Always looking for outstanding PhD students. UC scholarships!

jannik.haas@canterbury.ac.nz
Director of Programmes in Renewable Energy