Rethinking Seasonal Storage with a TT-Link

A Trans-Tasman Subsea HVDC Link as an Alternative to Hydrogen

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2025 EPOC winter workshop – 5 Sep 2025

New Zealand 2024 Dry Winter: Managed, Not Solved

To this day, the supply shortage has been managed with variable hydro and thermal reserves

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Hydro storage lake levels lower than usual, Transpower says

9:57 am on 1 August 2024

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Tight gas supply, low lake levels drive up wholesale power prices

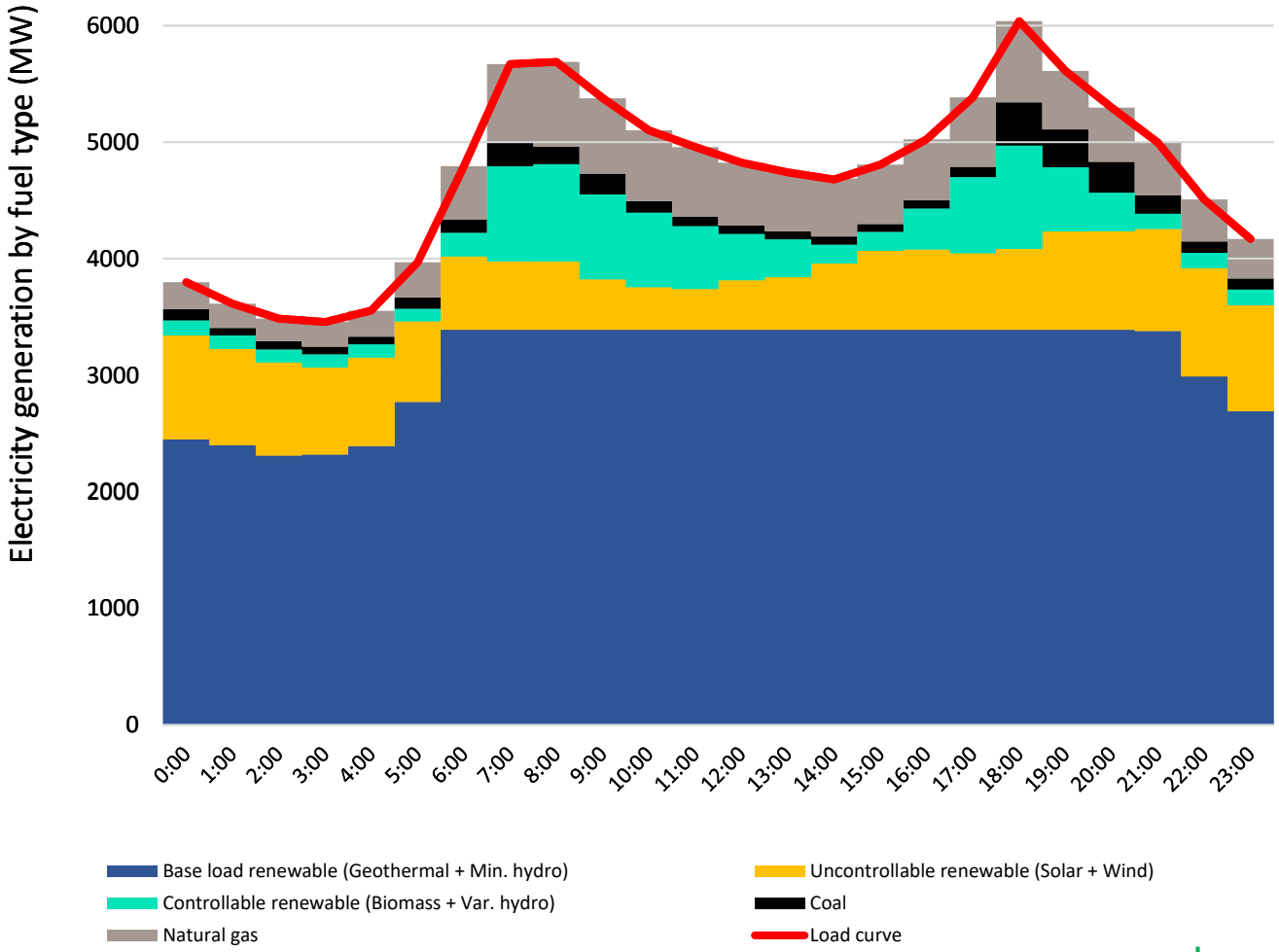
THE CONVERSATION

Academic rigour, journalistic flair

NZ energy crisis: electricity demand will jump as NZ decarbonises – can renewable generation keep up?

Published: August 27, 2024 7.56pm BST

Supply-demand plot: Aug. 29th, 2024



Source: Electricity Authority

1.1 Million Tonnes of Coal: NZ's Dry-Year Insurance for 2025

Gentailers (led by Genesis) agree to stockpile coal at Huntly Power Station

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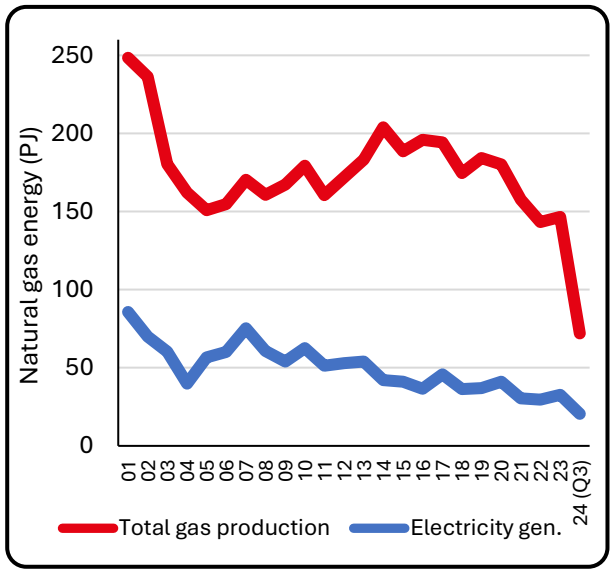
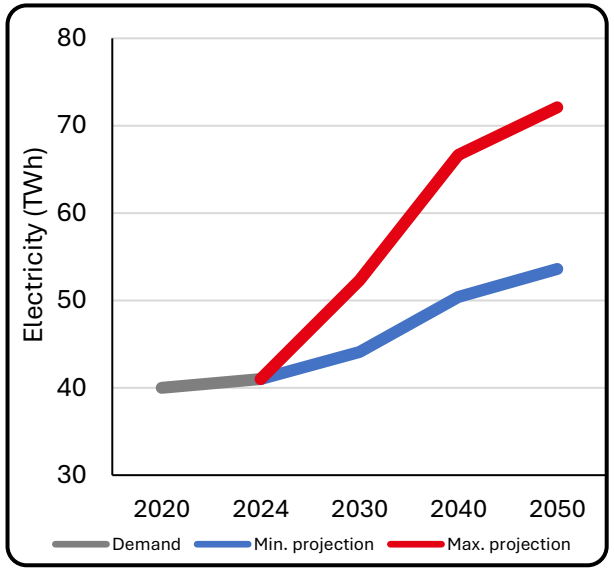
NEW ZEALAND / BUSINESS

Gentailers agree to stockpile coal at Huntly Power Station

11:39 am on 4 August 2025 Share this



Dwindling natural gas supply



Increasing demand (MBIE)

Solution: Onslow Lake Battery Project. **Failed** due to…

High estimated investment cost (~16 Billion NZD)

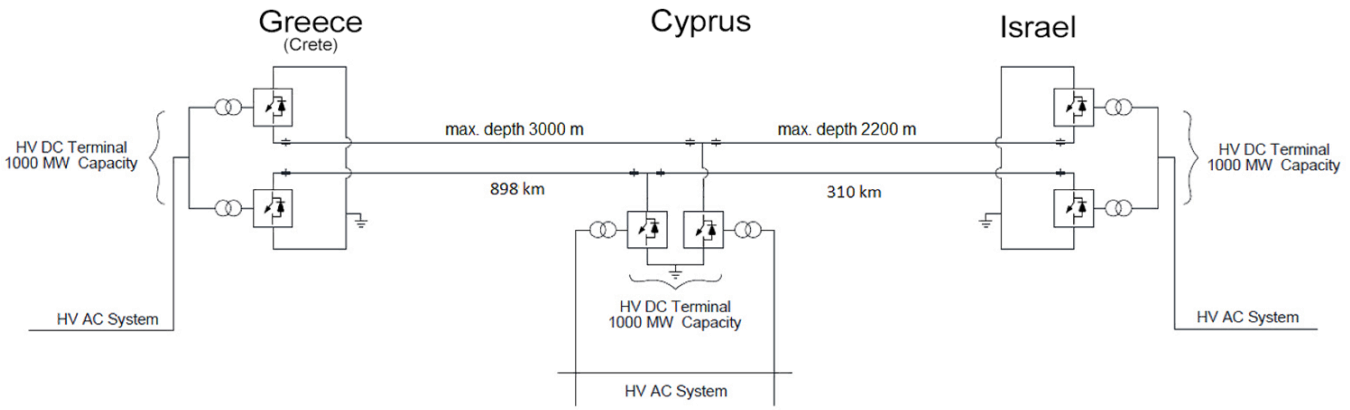
Higher round-trip losses

Source: Electricity Authority, Gas Industry co.

Virtual energy storage… over the ditch

An avant-garde energy transmission solution to solve the dry winter issues

Trans-Tasmanian HVDC link



** EuroAsia Interconnectors (Greece-Cyprus-Israel)*

TRL: Fairly high (7-8)

- Cables & converters: **9** (mature)
- Deep cable burial/laying: **9** (mature) – SAPEI HVDC link (IT)
- Long-distance cabling: **8** (beyond pilot tests) – Viking Link (DK-UK)

Source: Energinet, Nationalgrid, EuroAsia

How much are the per-flow losses for a TT-Link?

Quadratic loss curves for the operational and planned projects

$$\ell(q) = \ell_1 \cdot q + \ell_2 \cdot q^2$$

Quadratic in power linear in distance

$I^2R \rightarrow I \propto q, R \propto D$

q: Transmitted electricity (MW)

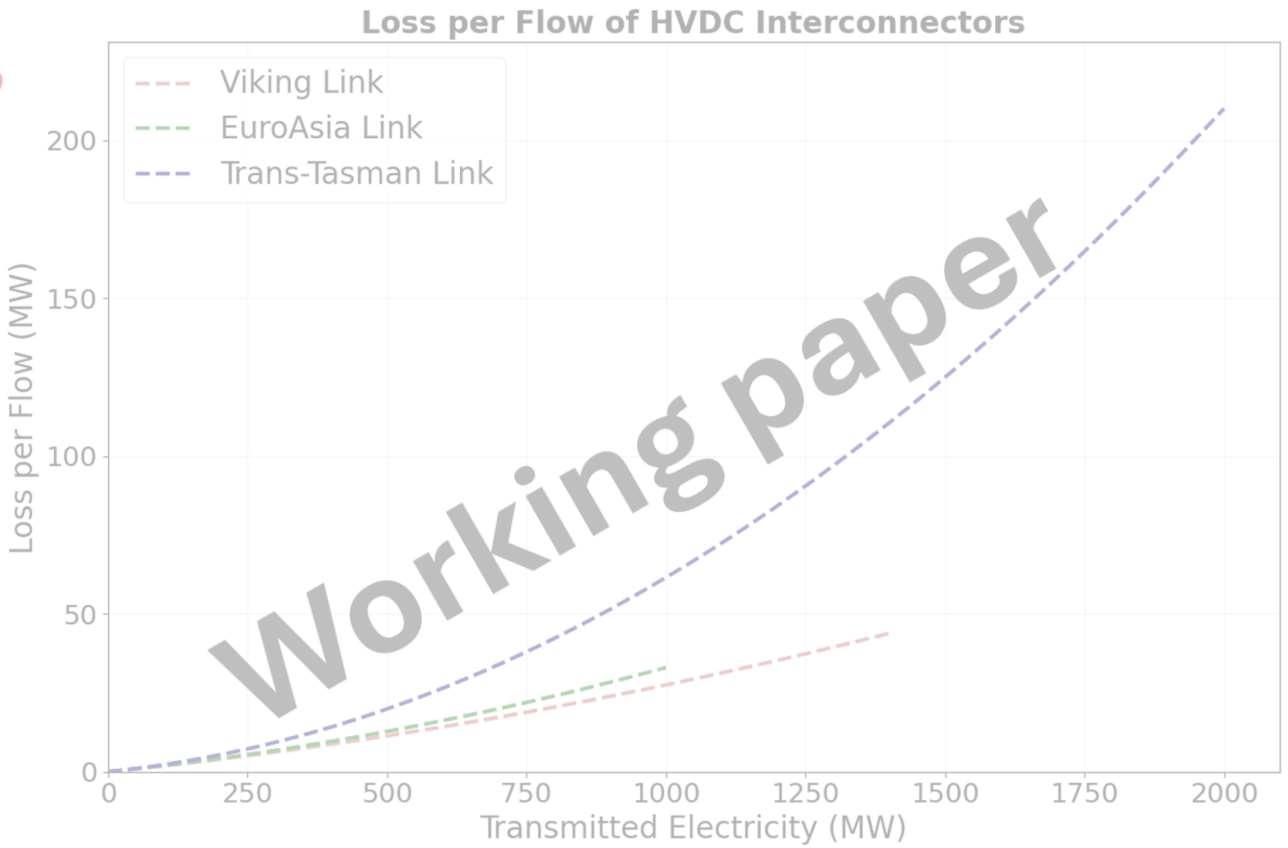
ℓ_1: Linear loss coeff. (1.8 % conversion losses)

** Fixed conversion loss (MW_{loss} per $MW_{transmitted}$) assumed to be near zero.*

$$\ell_2 = c_1 \cdot D$$

D: Distance (km)

c_1: Distance-based loss components



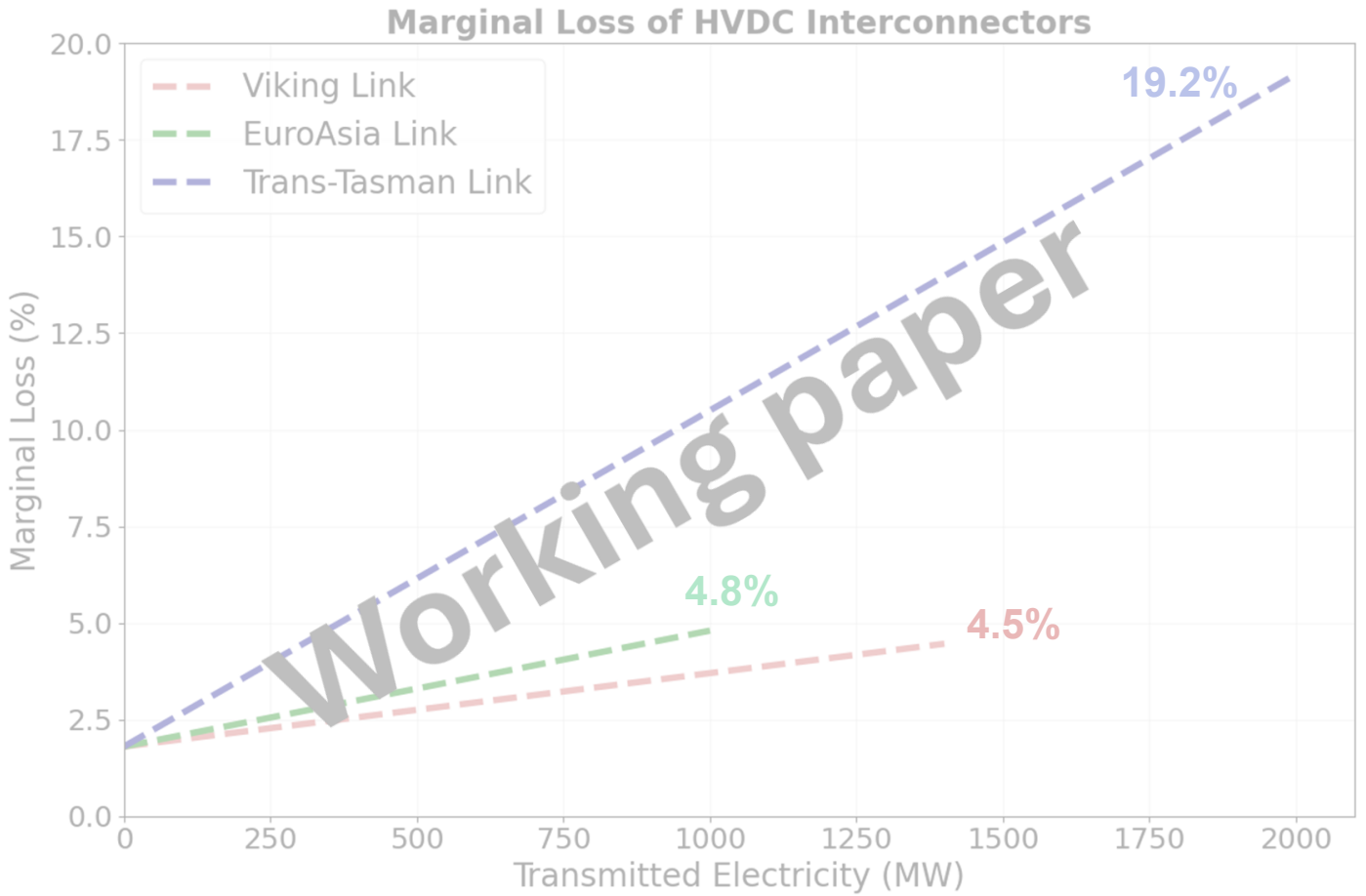
** Trans-Tasman Link losses are calibrated with the Viking Link.*

Source: Energinet, Nationalgrid

How much are the per-flow losses for a TT-Link?

Marginal loss curves for the operational and planned projects

$$\frac{d\ell(q)}{dq} = \ell_1 + 2 \cdot \ell_2 \cdot q$$

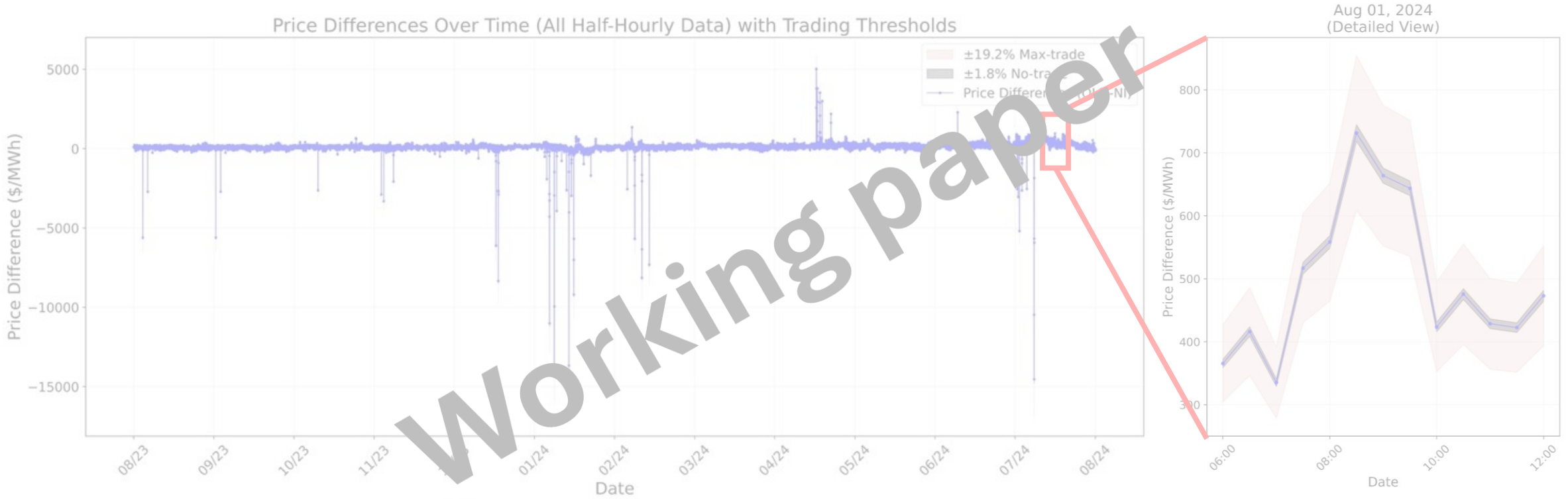


** Trans-Tasman Link losses are calibrated with the Viking Link.*

Source: Energinet, Nationalgrid

Observed electricity price differences

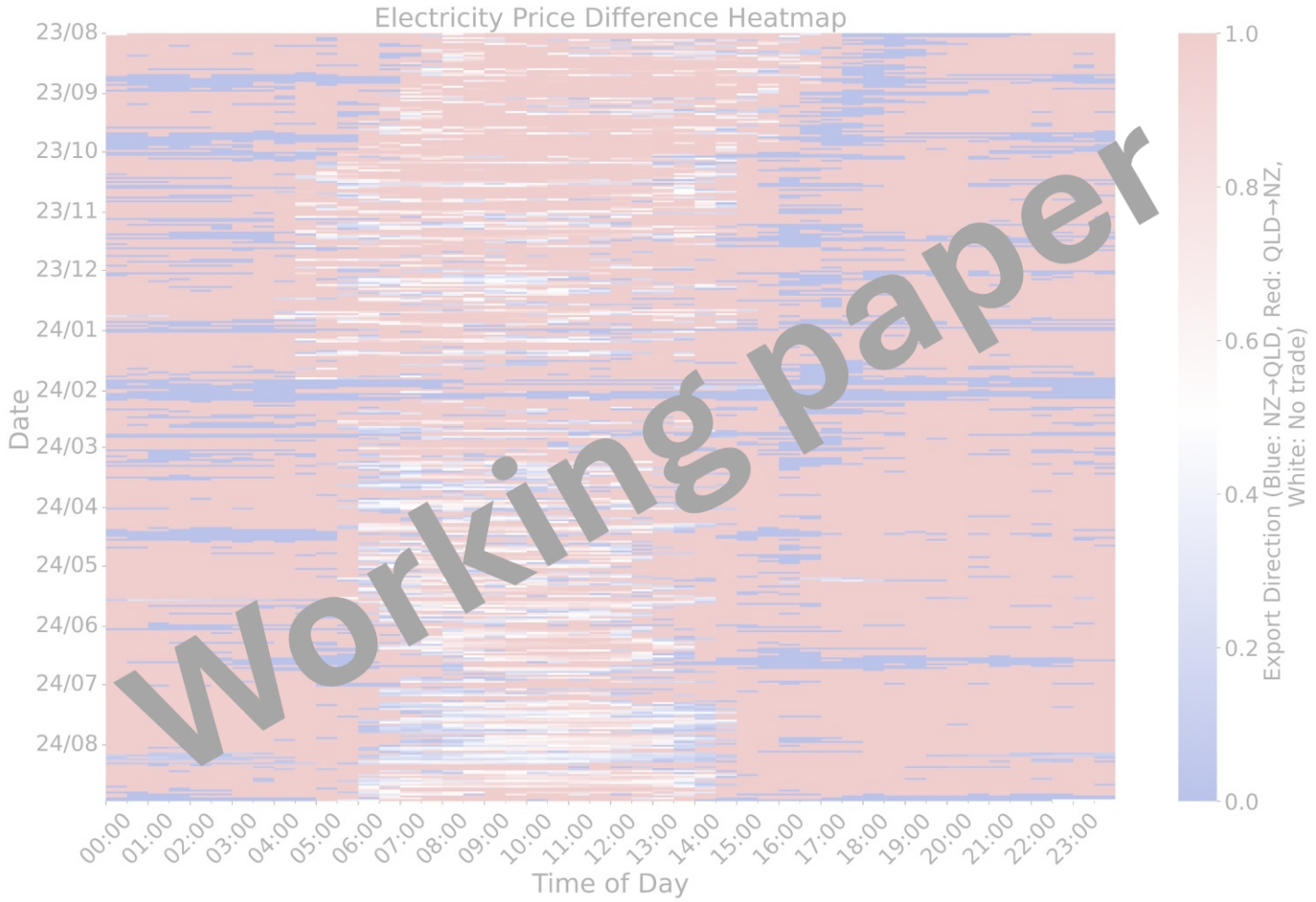
There is a potential for an energy arbitrage between the North Island (NI) and Queensland (QLD)



Source: Electricity Authority - EMI

Loss-adjusted price differences between NI and QLD

When can we export to QLD? When can we import? And when is it not economic to use the link?



Blue: NI cheaper (export from NZ),
White: Not suitable for trading,
Red: QLD cheaper (export to NZ)

Source: Electricity Authority, Australian Energy Market Operator (AEMO)

Our hybrid approach in a nutshell

When to import? How much a MWh from the link would cost? How the least-cost future system looks like?

- 1st step: Market price-based analysis (we've done this for QLD/NZ trade potential)

We assumed no market response; thus, we used the market data to get the upper bound for the analysis (potentially, over-estimating the benefits)

- 2nd step: Modelling using PyPSA-NZ (We're doing this for NZ – import-only)

Understanding system-level impacts of the TT-Link

Optimising the future energy system considering the presence of TT-Link using PyPSA-Earth framework

PyPSA-Earth-NZ Setup

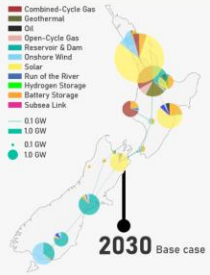
Preparation

Renewable timeseries and potentials (IRENA)
Infrastructure detection (OSM)
Weather data preparation (ERA5 satellite)
Data-driven demand forecast (e.g., SSP 2-2.6)
Fusion of datasets for optimization
Cleaning, processing, and preparation
Calibration with national statistics

PyPSA/atlite

Model setup

Transmission network
Substations and transformers
Carriers (production, storage)
Gas, heat, and H_2
Clustering configurations
Model validation
etc...



Generation capacity (GW) - 2020

	Hydro	Solar	Wind	Geothermal	Oil	Coal	OCGT	CCGT
Actual data (MBIE)	5.44	0.16	0.69	1.04	0.19	0.5	0.54	0.76
PyPSA-NZ	**5.29**	**0.00**	**0.73**	**1.05**	**0.15**	**0.75**	**0.45**	**0.79**
REMix-NZ	5.34	0.00	1.06	1.04	0.17	0.11	0.54	0.76
EP-ALISON-LUT	5.44	0.17	0.69	1.04	0.19	0.42	1.73	

Scenario: Trans-Tasman Link

Assumptions

Linked points:
South Auckland (NZ) to Northern Brisbane (AU - QLD)

Link distance: 2500 km

Assumed transmission capacity: 1-5 GW

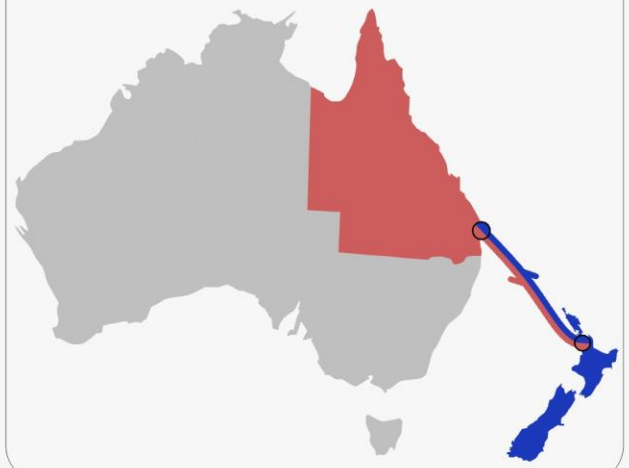
Transmission losses: 17 % (round-trip)

Capital expenditure: 493 EUR/MW/km

Project lifetime: +50 years

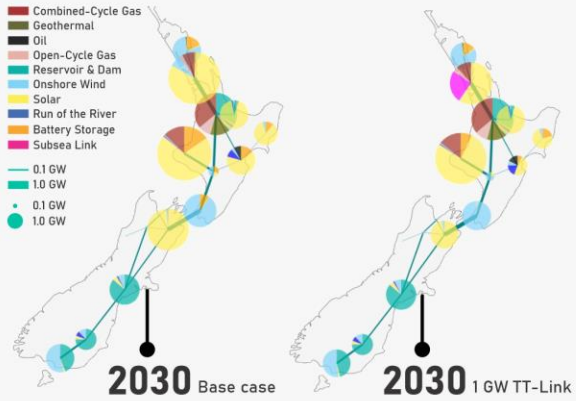
Discount rate: 5 %

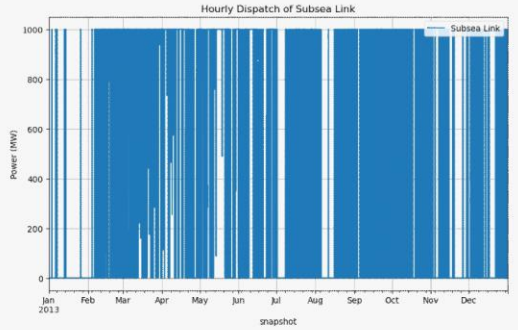
* Based on existing projects (e.g. Viking Link, North Sea Link)



Preliminary Results

Output

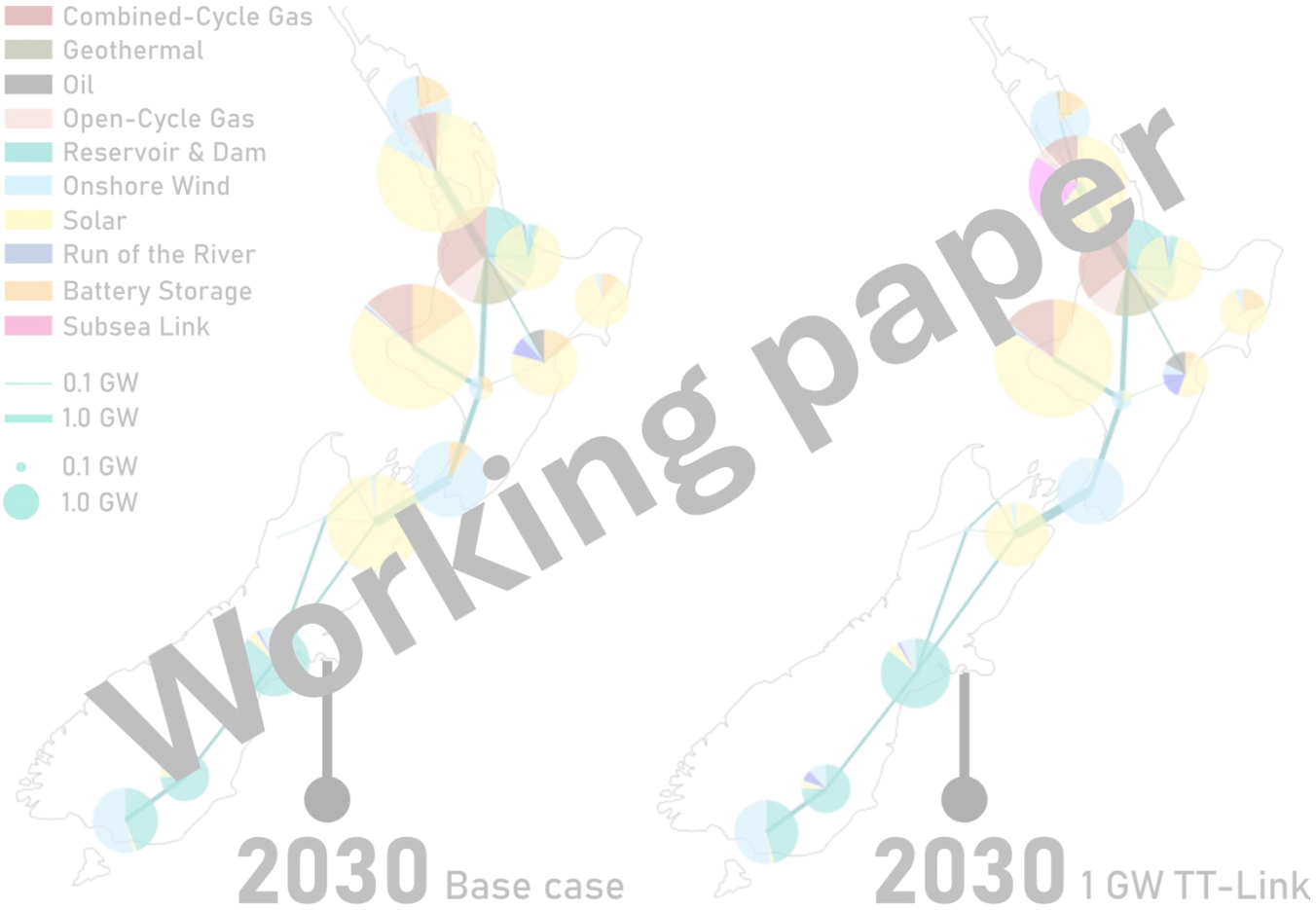


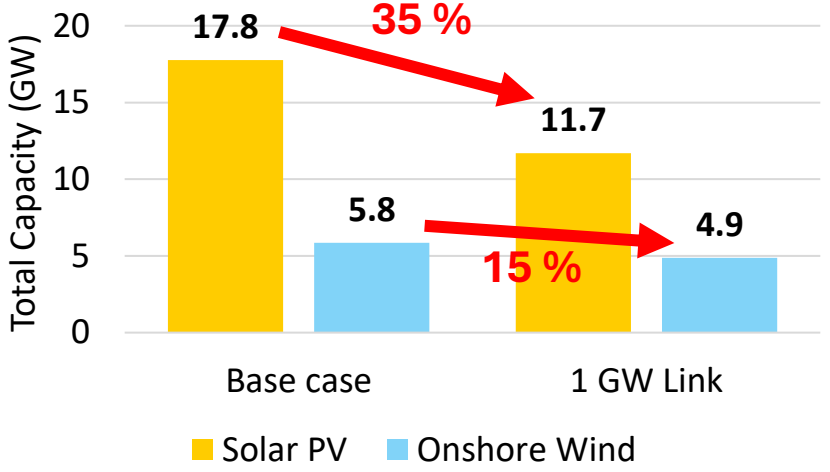


Vatankhah Ghadim H. "Breaking the Wall of Trans-Tasman Isolation". Falling Walls Lab Aotearoa New Zealand, Royal Society Te Apārangi, Sep 2024
Vatankhah Ghadim H. et al. "Too Little, Too Slow to Cope? New Zealand's Renewable Grid Needs a Rapid Scale-Up for Net-Zero". Working paper.

What does the 2030 system look like?

A 1-GW bi-directional TT-Link reduces the total grid investment requirements by 13% on average.





Overall GEP savings:

~ 440 Million EURs

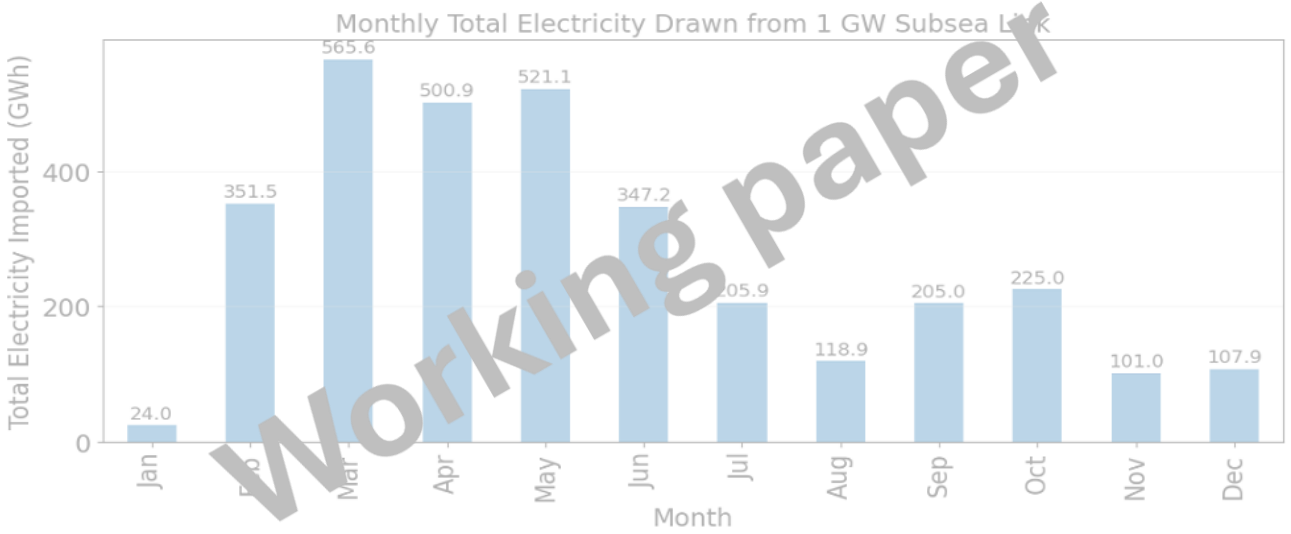
Required capital for TEP within NZ:

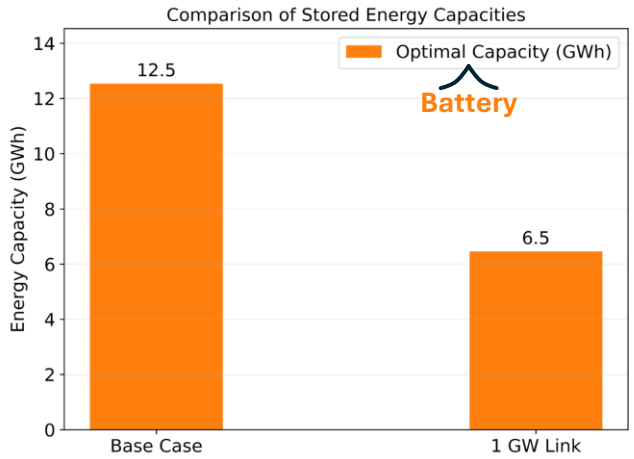
~ 245 Million EURs

Vatankhah Ghadim H., Peer R., Haas J. "How Can a Subsea Power Cable Provide Seasonal Storage? The Case for a Trans-Tasman HVDC Link", Working paper.

What does the 2030 system look like?

A 1-GW bi-directional TT-Link provides 0.7 TWh of virtual storage for New Zealand during winter.

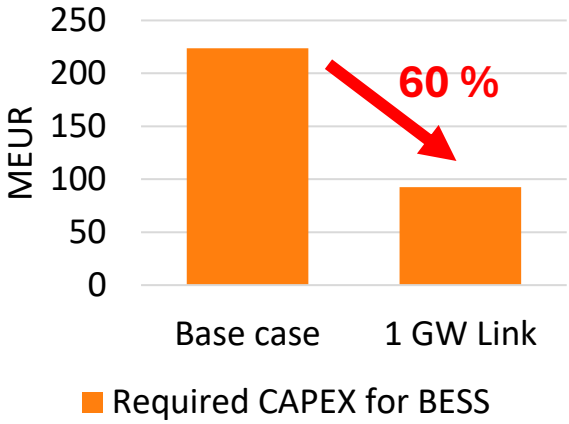




1 GW TT-Link operational stats:

- Utilisation rate: **0.3737**
- Average annual LCOE:

204.04 EUR/MWh



Vatankhah Ghadim H., Peer R., Haas J. "How Can a Subsea Power Cable Provide Seasonal Storage? The Case for a Trans-Tasman HVDC Link", Working paper.

1-GW or more? - What should we aim for?

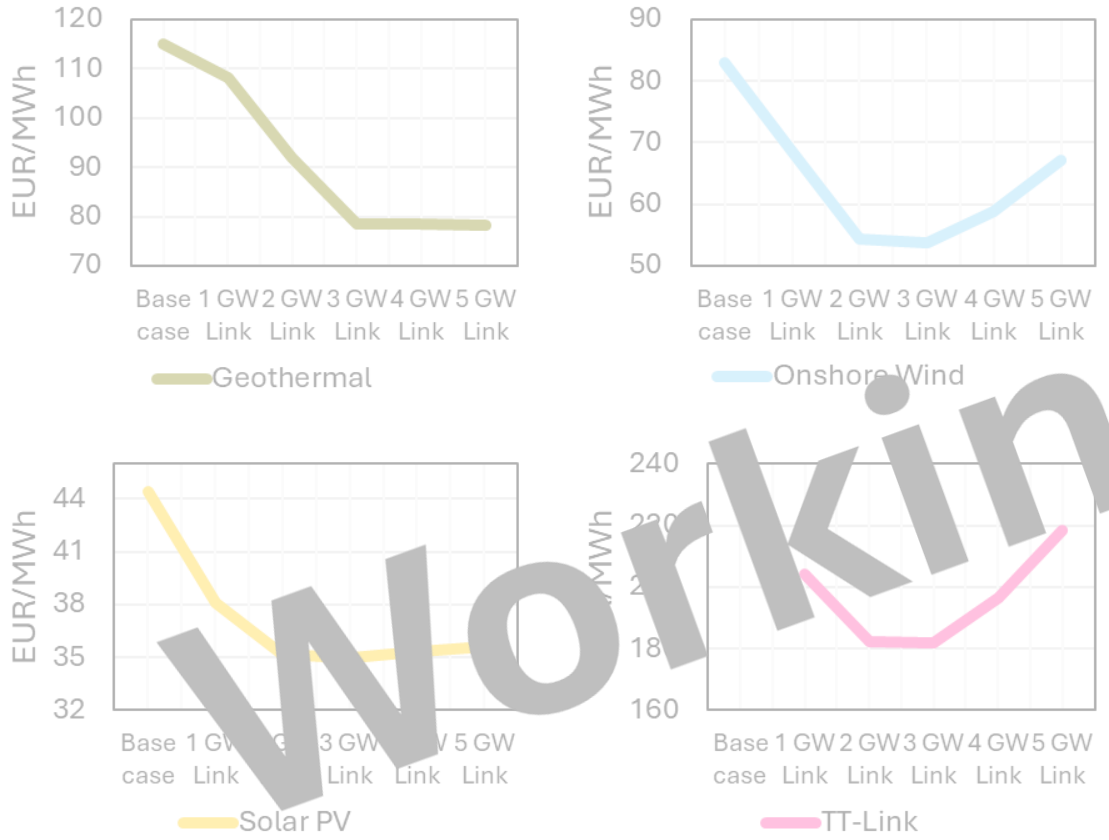
The highest utilisation rate (~42%) is recorded when there is a link with 2-3 GW capacity.

Vatankhah Ghadim H., Peer R., Haas J. "How Can a Subsea Power Cable Provide Seasonal Storage? The Case for a Trans-Tasman HVDC Link", Working paper.

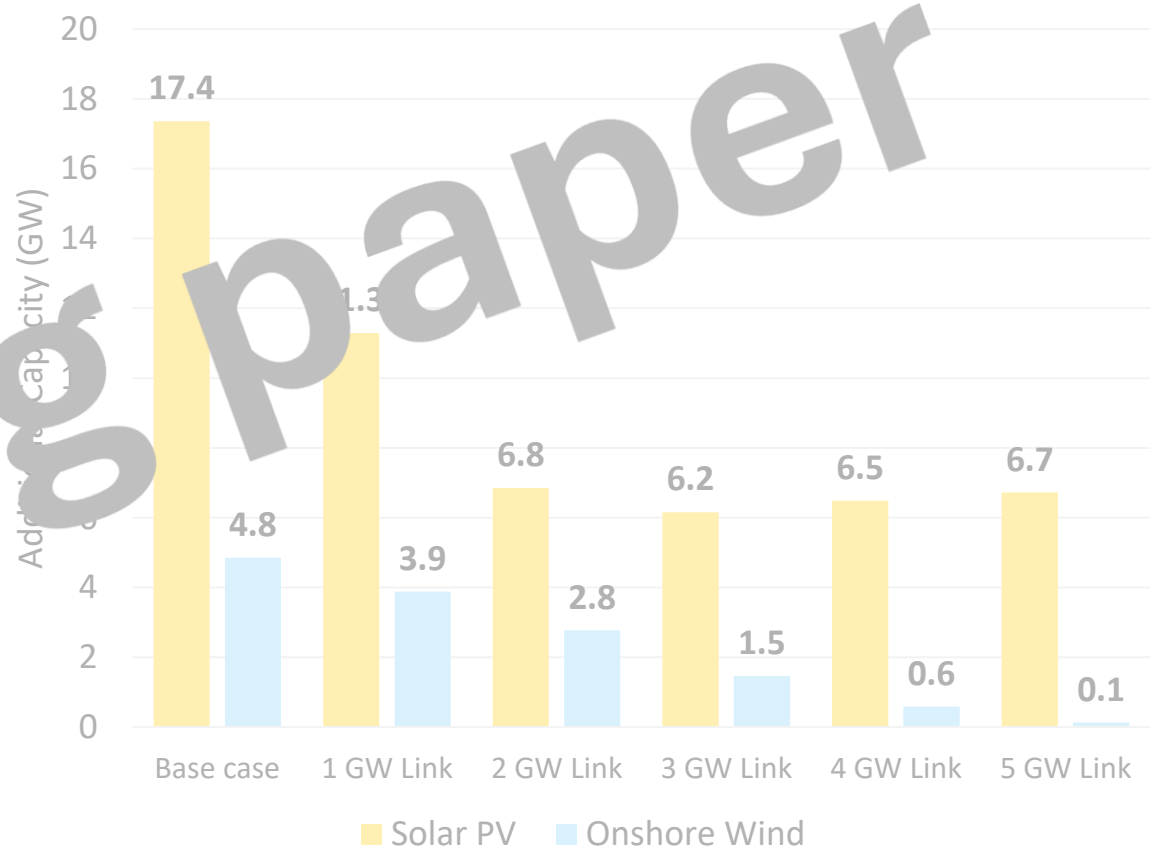
1-GW or more? - What should we aim for?

The lowest LCOE (~182 EUR/MWh) is recorded when there is a link with 2-3 GW capacity.

LCOE comparisons for different techs



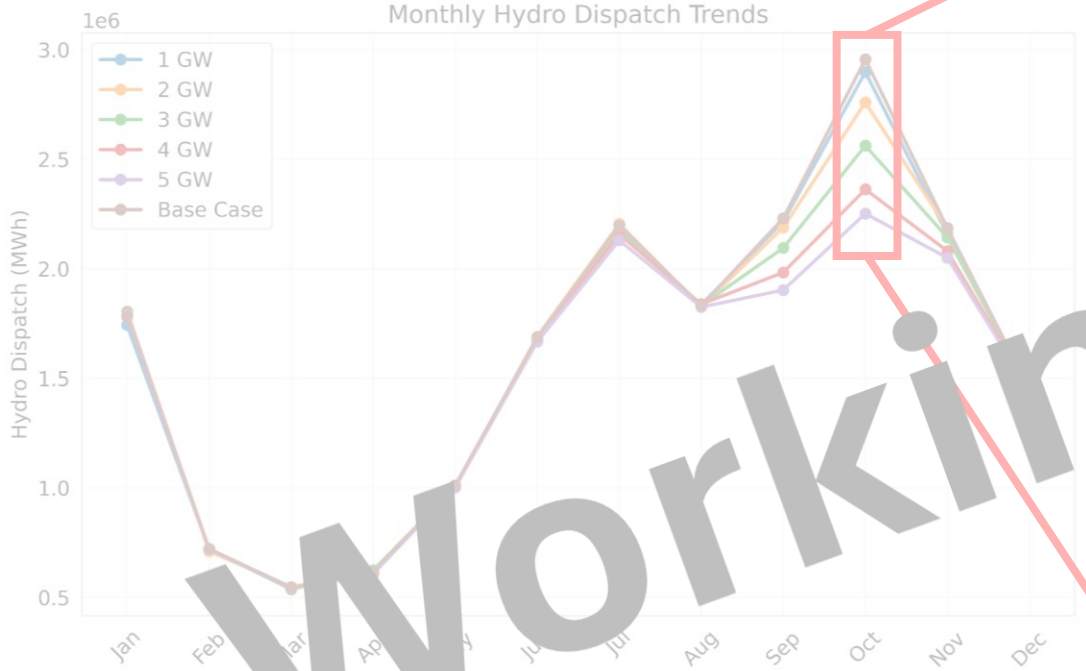
Solar and wind expanded capacity comparison



Vatankhah Ghadim H., Peer R., Haas J. "How Can a Subsea Power Cable Provide Seasonal Storage? The Case for a Trans-Tasman HVDC Link", Working paper.

What does the 2030 system operation look like?

A 2-GW HVDC interconnector provides an annual hydro use offsetting by around 215 GWh.



Vatankhah Ghadim H., Peer R., Haas J. "How Can a Subsea Power Cable Provide Seasonal Storage? The Case for a Trans-Tasman HVDC Link", Working paper.

Further details to be included…

What improvements does the PyPSA-NZ model need?

Overall simplifications:

1) No price response from QLD (infinite elasticity – the investment response would be in a way that maintains the current price patterns – disequilibrium?).
2) NZ load forecast is based on the SSP 2-2.6 scenario (no response to price changes induced by link investment).
3) Simplified assumptions on the line configurations (based on the operational cases globally).
4) Improving hydro modelling in PyPSA.

Potential refinements on the current hybrid modelling approach:

1) Assuming the elasticity using the market bid/offer curve for NZ (decrease profitability)
2) Increasing the volatility in the market (increase profitability)

Q&A

Thanks for your attention!