NZ Battery Project

Technical Reference Group Meeting

21 September 2021 – Online

MAHI TAHI
BETTER TOGETHER

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Today's programme

No	Time	Item	Lead
1.	9.30am – 9.35am	Welcome / Karakia	Adrian Macey and Hoani Langsbury
2.	9.35am – 10.15am	Project news update • Project status update past and future milestones	Andrew Millar and Carl Walrond
3.	10.15am – 11.30am	**Workstream 1** – Lake Onslow update • Progress update on the Environmental and Geotechnical engineering investigation tender and next steps. **Workstream 3** – Non hydro options – next steps	Sam Treceno, Carl Walrond and Bridget Moon
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8.	1.45pm – 2.30pm	NIWA scientists - Freshwater update	s 9(2)(a)
9.	2.30pm – 3.00pm	Q&A Summary	Adrian Macey

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NZ Battery Project update

MINISTRY OF BUSINESS,
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For this session:

Purpose of this session

- Give you an overall project status update and cover off the current workstreams underway
- What have we completed over the past 6 weeks
- What is coming up over the next 6 weeks

What we want from you

- This is for your information but please provide feedback or observations

Last 6 weeks' milestones

Lake Onslow pumped hydro

- Finalising procurement and contracting process for the Lake Onslow environmental, engineering and geotechnical investigation. Aim to commence by end-September. **Samuel will update you on this later today**
- Worked closely with landowners in the Lake Onslow inundation area to seek their approval for land access for environmental and cultural fieldwork. **Maria will update you on this later today**

Other pumped hydro

- Peer reviewed our identification and screening process for alternative pumped hydro sites (as well as modification of existing hydro assets). Minister briefed.

Non hydro options

- Kicked off procurement of technical investigations into non hydro options . ARUP undertaking the drafting of a Technical Scope of Work.

Market interactions and implications

- Kicked off procurement for further economic modelling of the different dry-year risk management options. This includes an extension of Concept Consulting's gross economic benefit analysis.

Next 6 weeks' milestones

- Issue updated project plan and schedule, including revised timeline, scope and milestones.

Lake Onslow pumped hydro

- Work underway on Lake Onslow environmental, engineering and geotechnical investigations.
- Visit Central Otago to introduce landowners the chosen Supplier.

Other pumped hydro

- Initiate engagement with iwi, environmental NGOs and affected gentailers of our alternative pumped hydro sites, as well as modification of existing hydro assets.

Non hydro options

- Initiate procurement for a desktop level engineering assessment on non-hydro options.

Market interactions and implications

- Further development of operational governance models.

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Lake Onslow feasibility study update

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Purpose

Purpose of this session

- To update you on the outcome of the tender process for the engineering, environmental and geotechnical investigation, and provide you an overview of the work that this investigation will entail.

What we want from you

- This is for your information, but please provide feedback or observations.

Next steps from here

- Subject to negotiations, we expect work to be underway by the end of this month.

Why are we doing these investigations?

Lake Onslow pumped hydro

Is a pumped hydro scheme at Lake Onslow technically, economically, commercially, and environmentally feasible?

Can any adverse impacts or risks be effectively managed or mitigated?

- Cabinet agreed to fund the NZ Battery Project to **identify the best option** or options for managing dry year risk in a highly renewable electricity system.
- Engineering, geotechnical and environmental **investigations** of a pumped hydro scheme at Lake Onslow **will assess its feasibility**
- This investigation is **a key input for Phase 1** of the NZ Battery Project, as it will provide us with design elements and options that will allow us to assess the technical, commercial and environmental feasibility of a Lake Onslow pumped hydro scheme. This **information** will also help form a credible **cost estimate and construction schedules**, on which to make a decision to progress into Phase 2.

MĀIA
BOLD & BRAVE

PAE KAHURANGI
BUILD OUR FUTURE

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PONO ME TE TIKA
OWN IT

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What is the scope of this work?

- The scope covers the majority of the technical areas and it is divided in two parts:

Phase 1A: A predominantly desktop-based technical study that will identify the options for the key parameters for the design and configuration of the pumped hydro scheme, and will select the optimal design configuration for more detailed engineering design and geotechnical de-risking.

Phase 1B: A focused technical study, including drilling boreholes, which will provide further engineering detail on the optimal design configuration.

- The remaining areas, such as the assessment of the environmental values, historic heritage values, Ngāi Tahu values, and the archaeological values of the Lake Onslow area, have work already underway.

How did we procure this work?

We have followed a multi-stage procurement process that reflects the complexity of this investigation

Development - scope of work [April – May] → Release - Advance Notice of a contract opportunity [14 May] → Release - Request for Proposals (RFP) [10 June] → Combined Supplier briefing session [14 June] → Individual Supplier briefings sessions [18 June]

Figure 1. Outline of procurement process until the closing date of the RFP.

What process did you follow to evaluate suppliers?

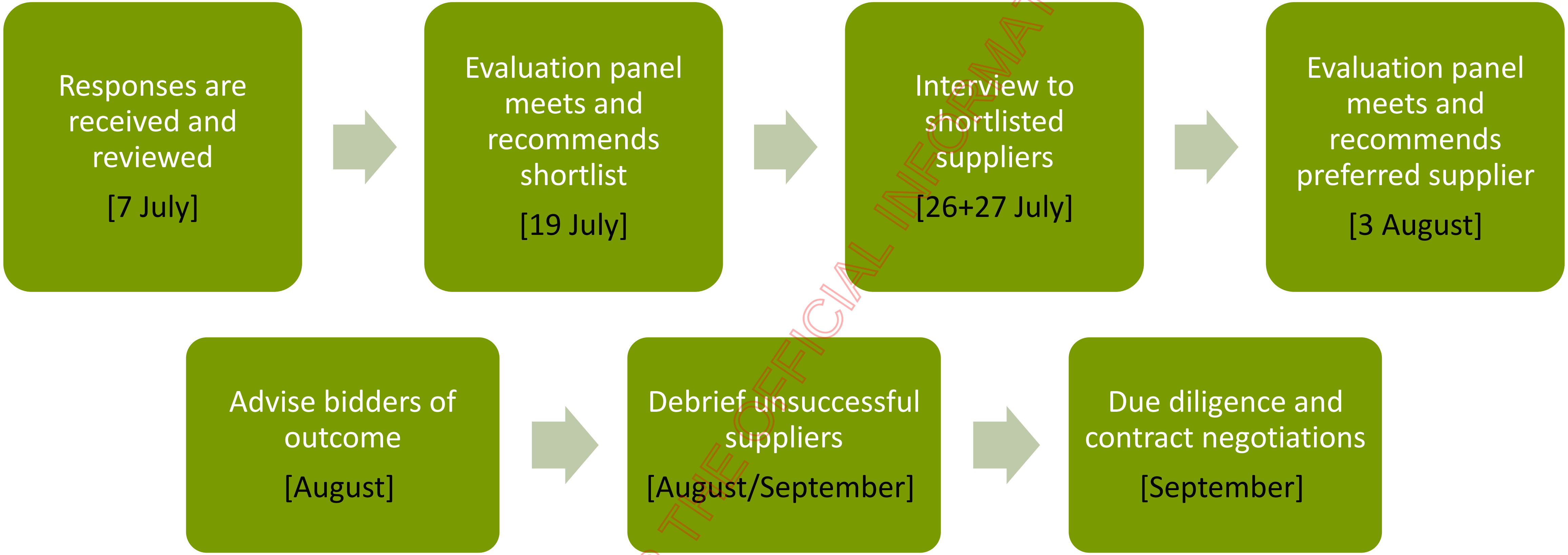

Figure 2. Outline of evaluation process followed from the closing date of the RFP.

How did we ensure a robust process?

We worked to ensure the procurement process was fair, transparent and attractive to prospective tenderers.

<u>TENDER PROCESS:</u>

- commissioned WSP (an engineering consultancy) to draft the **technical scope of works** as it was involved in early studies of Lake Onslow.
- obtained an **expert review** of the tender documents.
- issued an **advance notice** of a contract opportunity letting suppliers know that we would shortly be going to market.

<u>EVALUATION PROCESS:</u>

- **evaluation panel** consisted of five members, including three external experts.
- an **external cost estimator** (Bond CM) was engaged to review the pricing from respondents and
- an **external project planner and scheduler** (Inovo Projects) reviewed how realistic the tenderer's programme's timelines were.

The entire procurement process was independently audited. An external probity advisor (PwC) attended all meetings and made sure that any probity concerns were addressed.

What were we looking for?

We were looking for a trusted advisor. A strong and robust team with a collaborative approach to deliver the best public value.

- Price was not be a weighted criterion. Instead, price was taken into account in determining overall value-for-money over the whole-of-life of the contract.

We evaluated tender responses based on their ability to deliver on a complex investigation & experience in:

- recent feasibility studies and successful execution/construction of relevant **large scale projects**.
- in New Zealand conditions and geology, including tunnelling in New Zealand (especially **schist**).
- **Environmental/consenting**, specifically working with Central Otago District and Regional Council,
- working with Ngāi Tahu or other **Treaty Partners** on large infrastructure projects,
- working **with landowners and local communities** on large infrastructure and environmental studies, and
- working with many environmental **sub-contractors**.

How many tender responses did you receive?

We received five compliant proposals.

- All were consortia
- Big infrastructure providers
- Teamed up with overseas pumped hydro/hydro expertise
- And NZ environmental/planning consultancies
- And NZ geotech expertise

Selected Supplier

This consortium:

- **90 per cent New Zealand-based** personnel with a strong local Otago presence and a project office in Wellington,
- personnel with **extensive experience in all areas of the feasibility study** and in recent relevant pumped hydro projects such as Snowy 2 (Australia) and the North Bank Hydro Project (Waitaki Valley),
- key members were involved in the design and construction of the Clyde Dam and landslide stabilisation programme, bringing region specific expertise, **lessons learnt and advice on schist**, geology, active faulting, tectonics and seismic hazard,
- provided an **ambitious but feasible timeline and schedule** both Phase 1A and 1B of this investigation,
- demonstrated **great understanding of the potential consent and permit requirements**, providing a robust approach to consenting the required fieldwork,
- provided evidence of **experience of working with iwi and stakeholders**, and
- scored the highest overall in the weighted criterion and submitted pricing that demonstrated good value for money.

Next steps

- Award Contract (late Sep)
- Kick-off workshop (early October)

Engineering and Geotechnical

- Desktop study (modelling and analysis) plus some topographic surveying.
- Multi criteria analysis (MCA).
- Resource consent for geotechnical programme.

Environmental

- Negotiate access with landowners for environment and cultural values fieldwork.

Stakeholder engagement

- Introduce Teviot/Rox landowners and community to providers.

Summary

This session was an update of progress

- We have chosen a prefer supplier to deliver the engineering, geotechnical and environmental investigations of a pumped hydro scheme at Lake Onslow.
- We expect to finalise contract negotiations this week.

It was mainly for your information

- But please provide feedback or observations.

There'll be more for you to engage once we have on-boarded the preferred supplier

- What would you like to hear in the next TRG meeting?

Non Hydro option update

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Purpose

Purpose of this session

- To update you on the non-hydro options progress and next steps

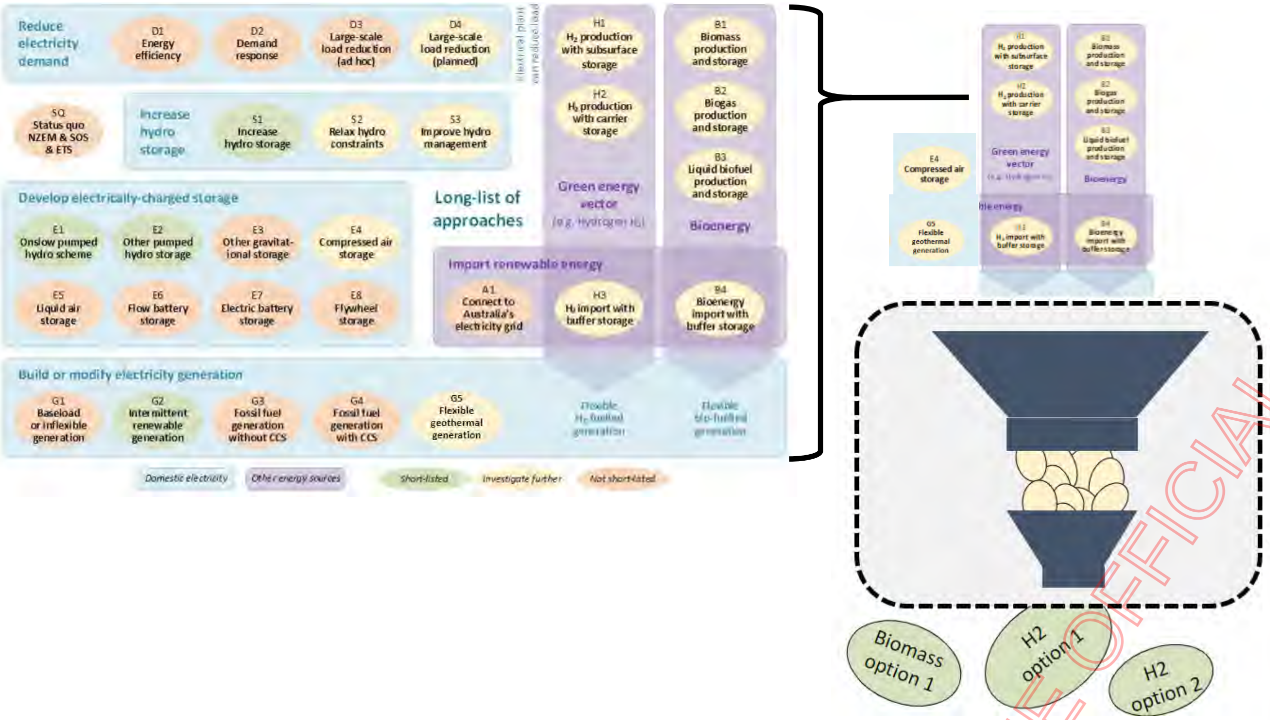
What we want from you

- This is for your information, but please provide feedback or observations.

Next steps from here

- We will be procuring a party to undertake the feasibility study into other technologies
- Key decision point before year-end on options to investigate in detail

Where we left off…



Options		
	Approach	Fuel production / source Fuel transport Fuel storage Electricity generation
	Infrastructure required	Distinguish new and existing
	Site	Site requirements for production / transport / storage / generation Optimal site(s) in NZ Alternative sites
	Scale	Efficient scale Economies of scale & linearity of costs with scale
	Flexibility	Ability to vary output (years) Constraints on flexibility
	Alternatives	Key alterative design options Trade-offs considered
Costs	For fuel / transport / storage / generation • Capex -> feed into LCOS • Opex -> feed into LCOS Size / scale limits and breakpoints	

Markets and risk assessment		
	Timeframes	Now -> 2030 -> 2040 -> 2050 -> beyond
	Technology	Maturity of technology Rate of cost decline Redundancy risks / competitive tech
	Markets	Maturity of markets (domestic / international) Competing uses Supply / demand balance incl seasonality 'Green' (req'd) vs 'blue' vs 'brown'
	Technical issues	Engineering challenges Storage risks Safety assurance
	Environmental issues	Impacts on water (use, discharge) Impacts on air (emissions incl. greenhouse, pollutants) Impacts on land (use, discharge)
	Social issues	Construction workforce Operational workforce
Next steps	Key uncertainties remaining Further work recommended	

What's happened since…

- Went out to market for someone to prepare a scope of work
  - Competitive but limited pool
- Procured ARUP Ltd in mid-August

- ARUP finished up last week:
  - Peer reviewed our high-level screening
  - Drafted scope of work for technical investigations

ARUP peer reviewed our short-listing

- Red / Amber / Green:
  - Security of supply
  - Renewable
  - Feasible - Technology readiness level, geographical constraints, proven commercially
- Largely affirmed our conclusions
- But no easy options
- Recommended we add two options back in to provisional short-list

Liquid air:

+	-
Energy dense, geographically flexible, simple supply chain, safe	Needs co-located heat sink/source, low efficiency, not proven at scale

Flow batteries:

+	-
Zero-discharge, geographically flexible, environmentally friendly(?)	Tank / land required, technology readiness, a distributed solution

ARUP drafted a scope of work to investigate short-listed options

- Recommended three tasks:
  - Option selection
  - Feasibility:
    - Concept design (A)
    - Cost/risk assessment (B)
  - Option assessment & further development:
    - Multiple criteria analysis (A)
    - Concept design and implementation (B)

Heavy filtering → Option selection

Deep dives → Feasibility

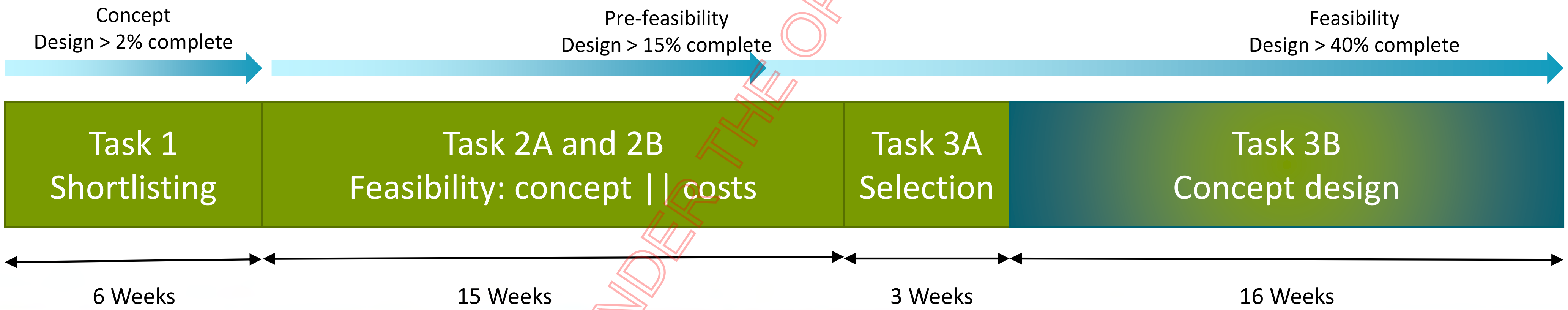
Ranking → Option assessment & further development

Feasibility (Concept design (A), Cost/risk assessment (B)):
- This is the big cost
- Providing numbers helps to quote
- Provisionally said we want 2-3 at end

Optional extra → Concept design and implementation (B)

Task 3B module reflects our desire for detail

- Initially drafted for a light piece of work
    - Timeframe is short
    - Doubted the market could achieve more through higher resourcing
    - Doubted detail that can be achieved given technology maturity
- Revised scope of work to be more ambitious (+/- 50% cost estimate)
- But module 3B a step-up (+/- 30% cost estimate)



And also…

- Been continuing to engage with industry and other stakeholders
  - Genesis on biomass
  - Meridian/Contact on interruptible demand / hydrogen production
  - Eavor on closed-loop geothermal

Where to from here…

- Continue to engage with industry…

- Preparing for procurement of a party to execute the scope of work
  - Bit of a process to go through
  - High-value contract, so several steps involved
  - Trying to turn around as quick as we can

- Timeline should mean 'option selection' done this year
  - Will be a key point for TRG input
  - Will be feeding info in preparation

Purpose

This session was an update of progress

- ARUP largely agreed with our short-list but recommended flow batteries and liquid air too
- ARUP drafted a scope of work involving 3 key tasks and an optional extra

It was mainly for your information

- But please provide feedback or observations.

There'll be more for you to engage with soon

- We will be procuring a party to undertake the feasibility study into other technologies
- Key decision point before year-end on options to investigate in detail

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Stakeholder update

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Purpose

Purpose

- Provide you with an update on engagement to date
- Show progress on engaging landowners on access for Lake Onslow fieldwork

What we want from you

- Your feedback on our approach and stakeholders we're engaging with
- Is there more we should be doing?
- How else can we support or facilitate engagement on fieldwork?

Next steps

Take your feedback on board and continue with engagement

Government & political

Mana whenua & iwi @ national level

Investors & financial institutions

Gentailers

Other energy generators

Electricity network providers

Electricity retailers

Electricity users

ENGOs

Academia and Crown Research Institutes

General public

Media

s 9(2)(f)(iv)

s 9(2)(f)(iv)

[redacted]

s 9(2)(f)(iv)

[redacted]

s 9(2)(f)(iv)

ENGOs

- Scoping a workshop in October/November
- Provide update on Lake Onslow fieldwork schedule
- Include DOC & NIWA in discussion
- Fish & Game – update to governance scheduled end-September

ENGOs

- Environmental Defence Society
- Greenpeace
- Forest & Bird
- Fish & Game
- NZ Climate Action Network

s 9(2)(f)(iv)

Lake Onslow: Access for Environmental & Cultural Fieldwork

- Advice from WSP on access process and industry best practice
- Next step to negotiate land access for environmental and cultural fieldwork and sign access agreements
- Some landowners have already indicated they’ll provide access
- Concerns shared about uncovering environmental values
- s 9(2)(b)(ii) – requirement to align geotech programme to farming operations
- Teviot Valley Business Register to be shared with fieldwork providers

s 9(2)(b)(ii)

What we want from you

- Your feedback on our approach and stakeholders we're engaging with
- Is there more we should be doing?
- How else can we support or facilitate engagement on fieldwork?

Next steps

- Negotiate access agreements for environmental and cultural fieldwork
- Continue industry engagement
- Meet with ENGOs on environmental fieldwork for Lake Onslow
- Share Teviot/Roxburgh business database with fieldworkers
- Contractors and fieldworkers to receive project information and guidance on relationships around Lake Onslow
- Introduce Teviot/Rox landowners and community to upcoming geotech providers
- Stakeholder engagement for other hydro sites (or defer)

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NIWA update

Purpose

Purpose

- Provide you with context on previous work in this area **(Malcolm)**

- NIWA update on solar, wind and hydro inflows correlations and changes with climate **(**s 9(2)(a) **NIWA)**

What we want from you

Hear your feedback on our approach

Next steps

Take your feedback on board

Summary

- 30 + years work in this area (hydro inflows change as climate changes? Are they correlated with wind?
- Early work focused on hydro inflows – indicative & caveated
- More sophisticated modelling over time
- More and better data
- Leading to firmer conclusions
- As wind generation added wind was also looked at....

  - Windier and wetter in S & W
  - Drier and calmer in N & E
  - More rain, less snow
  - Backed up by some observations in recent decades – more winter inflows in S as rain instead of snow

- As solar grows we also need to consider it....
  - Important as may influence the size of the Battery

Variable Renewable Generation

- Prior studies focused on two Qs:

1. What impacts will climate change have on renewables gen:

    - changes in quantity, seasonality, variability/volatility
    - most studies = changes to hydro inflows under climate change scenarios

2. Is renewable gen correlated? e.g. wind & hydro inflows

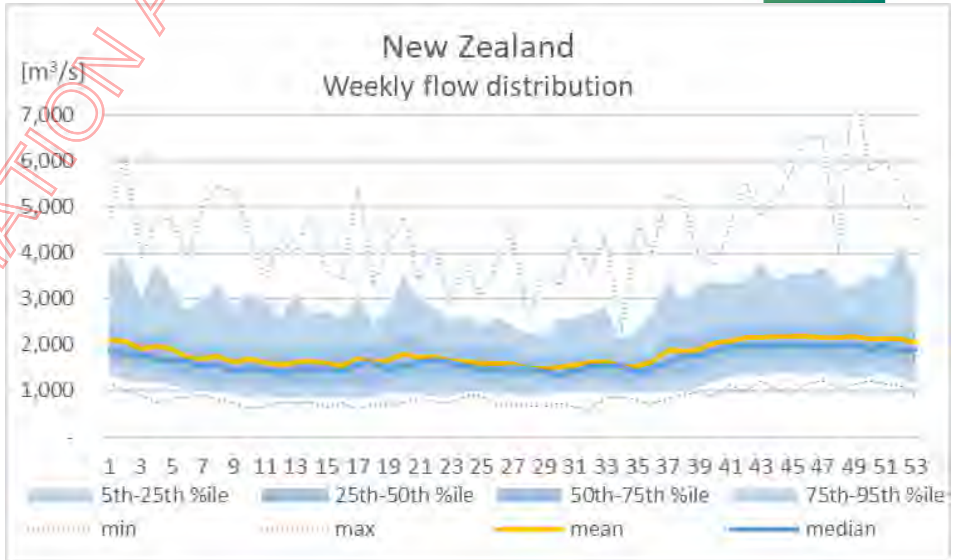
- Both Qs are relevant to Battery project = potentially impact size of storage solution

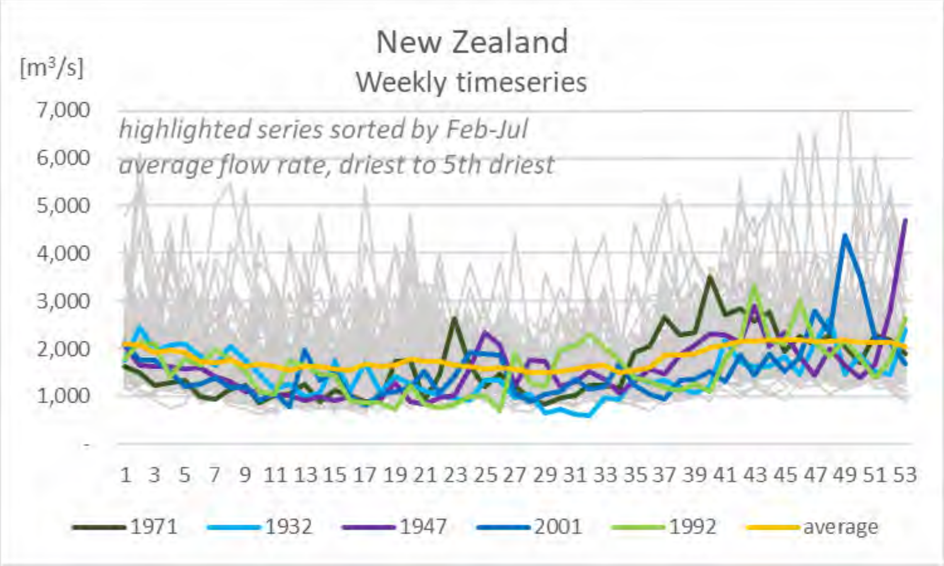
What matters?

1. Hydro = risk is dry
inflows vary = daily, weekly, seasonally, annually and more….
   - "dry- year" appears when inflow deficits really matter
   - variability managed = hydro storage & burning coal & gas

2. Wind = risk is calm
   - Variability = intermittent = under an hour and up to week(s) for windy/calm periods.
   - firmed by hydro which can vary output quickly for hours/days sustained levels for longer durations = week(s)

3. Solar = risk is cloudy
   - Most variation from time of day and seasonality is deterministic, day/night, winter/summer, but there is the more uncertain impacts of weather – dry/calm/cloudy?





Why does correlation matter?

- We need to build of a lot of new intermittent renewable generation
- correlation, seasonally and diurnally, may require changes to the size of a Battery solution.

- + correlation = more use of Battery

- – correlation = new gen compliments existing storage & NZ Battery storage = may reduce size of Battery

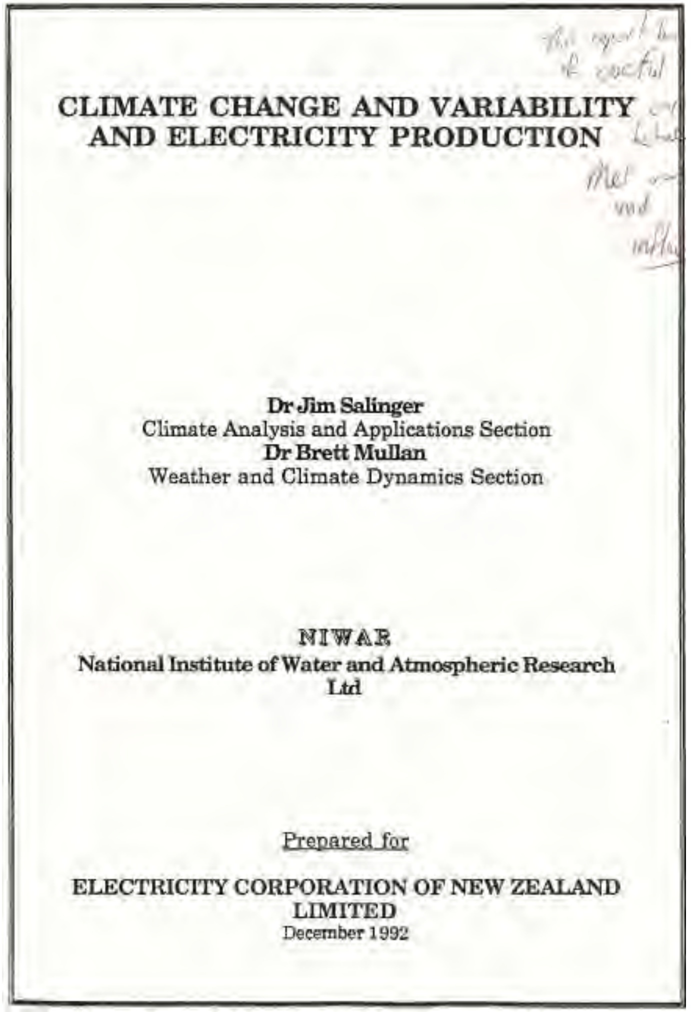
- s 9(2)(f)(iv)

As we become more dependent on sun and wind correlations with them become more important....

s 9(2)(f)(iv)

Waitaki Inflows – NIWAR 1992

- Lake Pukaki & (Pukaki, Tekapo & Ohau combined), on annual and seasonal basis
- Correlated natural inflows with circulation indicies and regional temperature.
- Simulated climate under climate change scenario, with a General Circulation Model, to calculate future circulation indicies and estimate regional temperature.
- Apply correlations established in first step to estimate potential impacts on inflows.
- Circulation indicies representing Norwest flow conditions and regional temperature were found to best explain inflow variation to Pukaki & Waitaki system on both annual and seasonal bases.


CLIMATE CHANGE AND VARIABILITY
AND ELECTRICITY PRODUCTION

Dr Jim Salinger
Climate Analysis and Applications Section
Dr Brett Mullan
Weather and Climate Dynamics Section

NIWAR
National Institute of Water and Atmospheric Research
Ltd

Prepared for

ELECTRICITY CORPORATION OF NEW ZEALAND
LIMITED
December 1992

Waitaki Inflows – NIWAR 1992 – Cont…

- Climate/inflow relationships developed from historical data allowed a preliminary analysis of impacts of the climate change scenario simulated in the GCM.
- Preliminary findings = inflows to Pukaki and Waitaki increased in the climate change scenario modelled, driven largely by increased temperature predicted but advised these results should be treated with caution.
- More westerlies and norwesters which bring more rain in total to Waitaki system

CLIMATE CHANGE AND VARIABILITY AND ELECTRICITY PRODUCTION

Dr Jim Salinger
Climate Analysis and Applications Section
Dr Brett Mullan
Weather and Climate Dynamics Section

NIWAR
National Institute of Water and Atmospheric Research Ltd

Prepared for

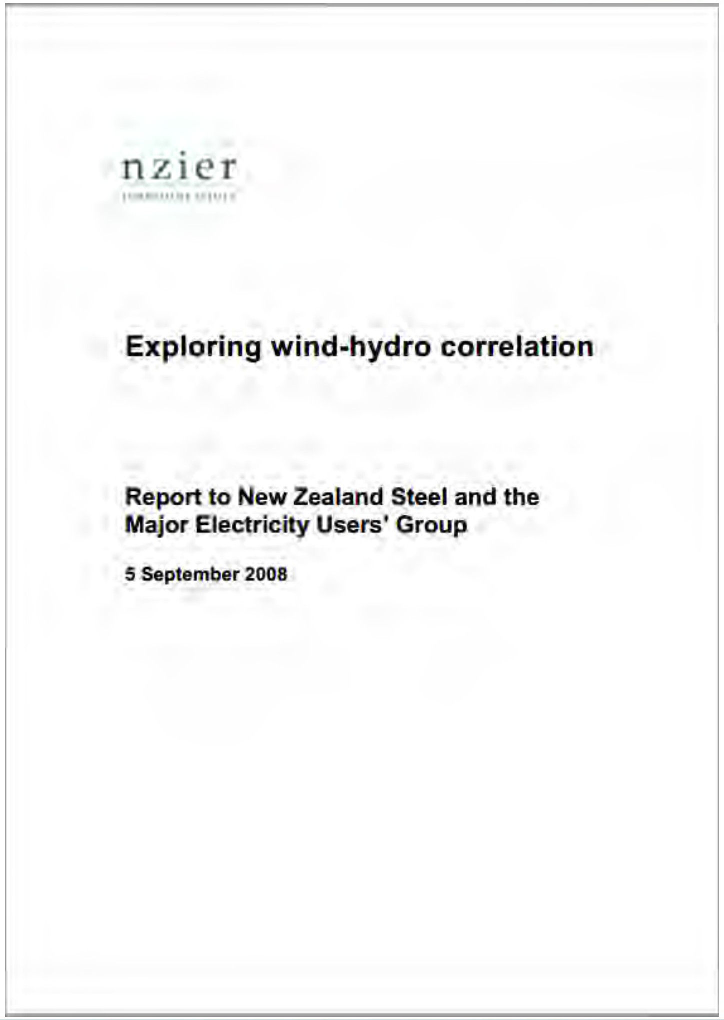
ELECTRICITY CORPORATION OF NEW ZEALAND LIMITED
December 1992

Wind-hydro variation & correlations NZIER 2008

Analysed wind speed data for 4 distributed sites, 6 hydro storage levels and 1 wind generation site. Conclusions grouped into;

- Magnitude of variation
  - Wind speeds vary significantly, by month and by year.
  - Wind speeds vary less than lake levels, between months & between years.
  - Wind generation varied more than wind speeds at sites selected.

- Timing of variation
  - Considerable overlap when wind speeds highest.
  - Wind generation generally highest when wind speed highest.
  - Hydro lake levels more diversified three highest at same time and other three lowest at that time.


nzier

Exploring wind-hydro correlation

Report to New Zealand Steel and the Major Electricity Users' Group

5 September 2008

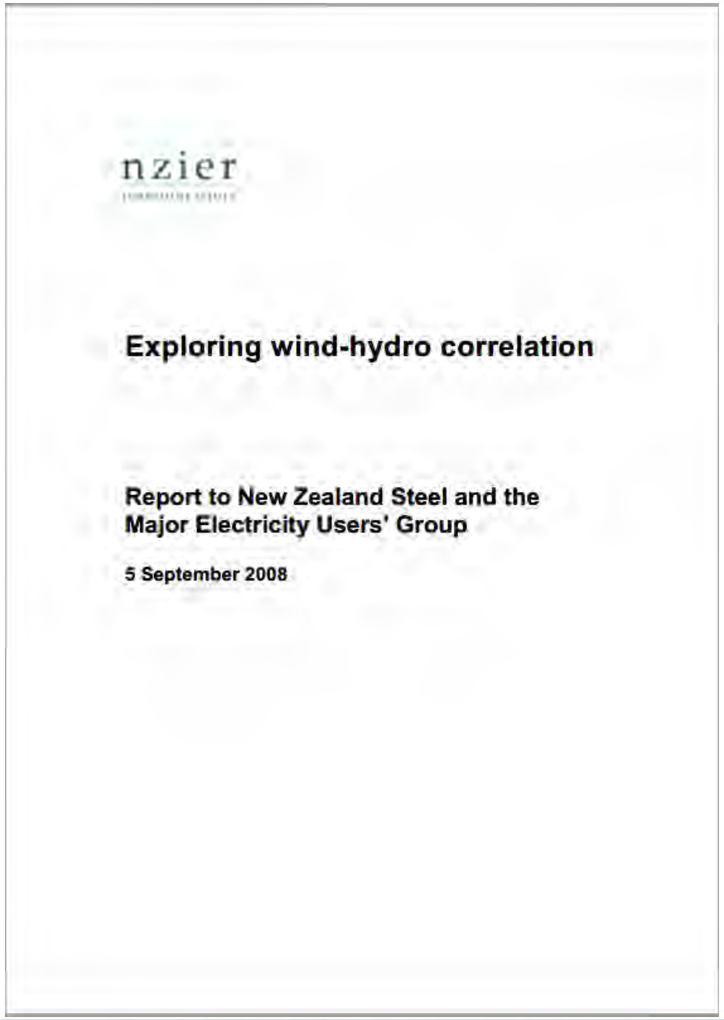
Wind-hydro variation & correlations NZIER 2008 – Cont…

- Correlations – within & between data series
  - Wind speeds correlated (for the four sites considered).
  - Positive correlation between three lake levels which are negatively correlated with other three.
  - Wind speeds and wind generation positively correlated with three lake levels & negatively correlated with other three.

- Concluded that there is some complementarity between wind and hydro resources – at least for the wind resources analysed

- Crude early days analysis

As some wind is negatively correlated with inflows use your hydro storage when its calm and distribute your wind geographically


nzier

Exploring wind-hydro correlation

Report to New Zealand Steel and the Major Electricity Users' Group

5 September 2008

Correlation: wind gen & hydro inflows – 2010

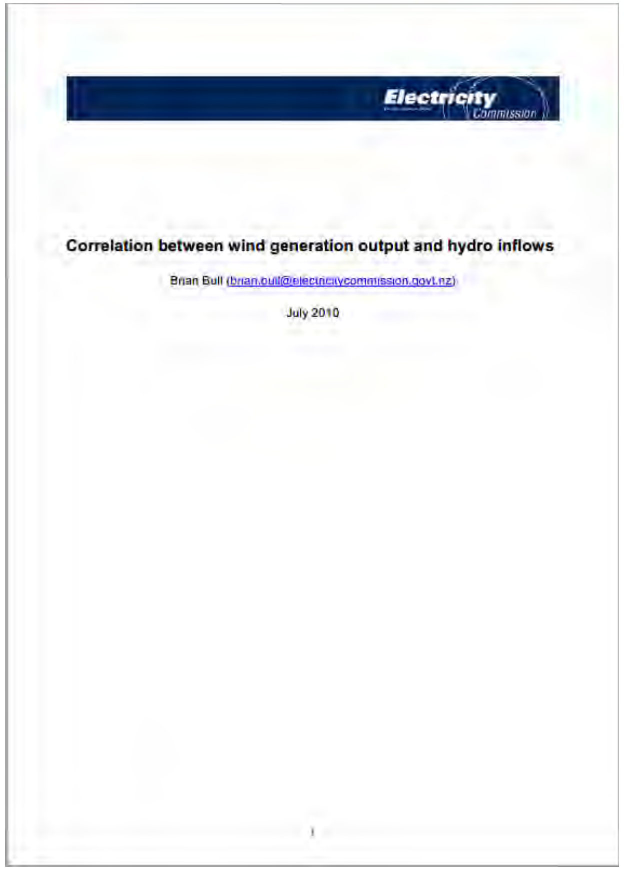
- What is relationship between wind gen and hydro inflows?
- Concerns that wind gen may be low in dry years – i.e. wind and hydro correlated = security of supply in a dry year
- Seasonal wind also correlated with hydro inflows? – both potentially lower in winter = economics of wind investment

- 19 year section of the available inflow data
- Compared to an artificial, 19 year, wind flow data set comprising an amalgam of generator development wind flow data, actual wind farm generation data and NIWA Climate Database wind records, for 12 distributed sites.

- wind flow data found to have seasonality,
- heightened wind gen in Oct- Jan
- least in the period April to July.

- moderate correlation between hydro inflows and wind generation, across most sites, with the exceptions being Northland & Taranaki.

“dry period” likely to be a calm period, with implications for security of supply


Electricity Commission

Correlation between wind generation output and hydro inflows

Brian Bull (brian.bull@electricitycommission.govt.nz)

July 2010

Jen Purdie climatologist working at Meridian 2019

Use suite of models to provide climate change adjustment factors for hydro inflow and wind flow data.

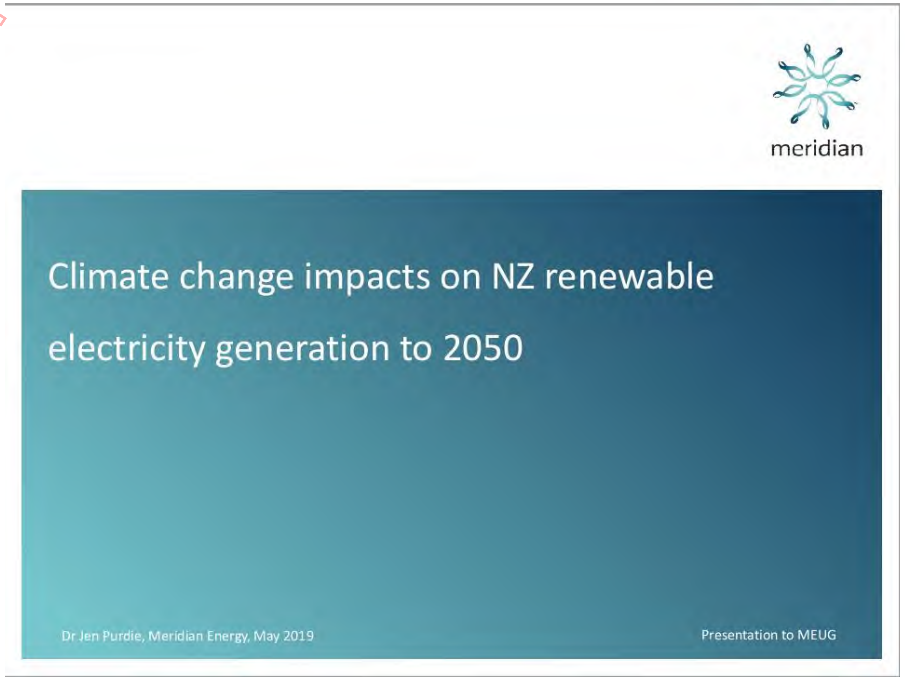
- Global Circulation model - mid-range emissions.
- NIWA regional downscaling model – rainfall/wind leads to;
  - Seasonal adjustments to wind flows.
  - Seasonal rainfall changes + increased rainfall volatility.
  - Plus snow-pack changes & snow melt modelling.
- New wind flow data sets.
- Seasonal adjustments to hydro inflows – new hydro inflow data sets.

Modelled changes to hydro inflows (mid-range emissions scenario)

- Total annual inflows to major South Island storage catchments, plus seasonal changes – winter/summer
- Similarly for North Island hydro storage at Lake Taupo.

Modelled changes to wind flows (mid-range emissions scenario)

- Annual and seasonal changes for selected wind regions in North & South Island.



Climate change impacts on hydro inflows – Jen Purdie

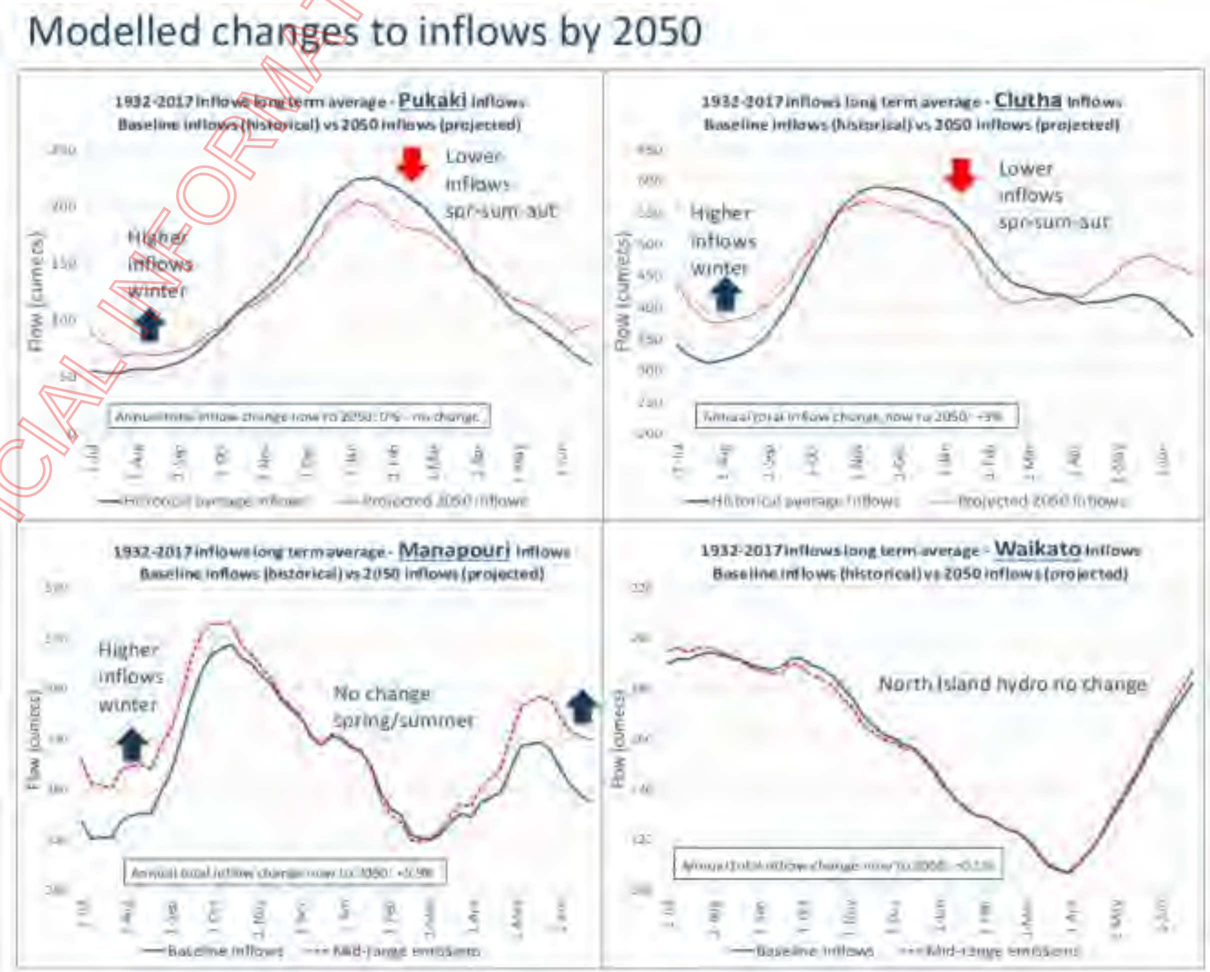
Modelled changes to hydro inflows (mid-range emissions scenario)

- Total annual inflows to South Island catchments; no change to Pukaki, increases to others.

Plus seasonal changes;

- Higher winter inflows to South Island catchments (Waitaki & Clutha & Manapouri catchments).
- Lower spring-summer-autumn inflows to South Island catchments.
- Driven in part by less snowpack, snowmelt more precipitation falling as rain instead of snow

- North Island hydro; no change to annual total or regional inflows.

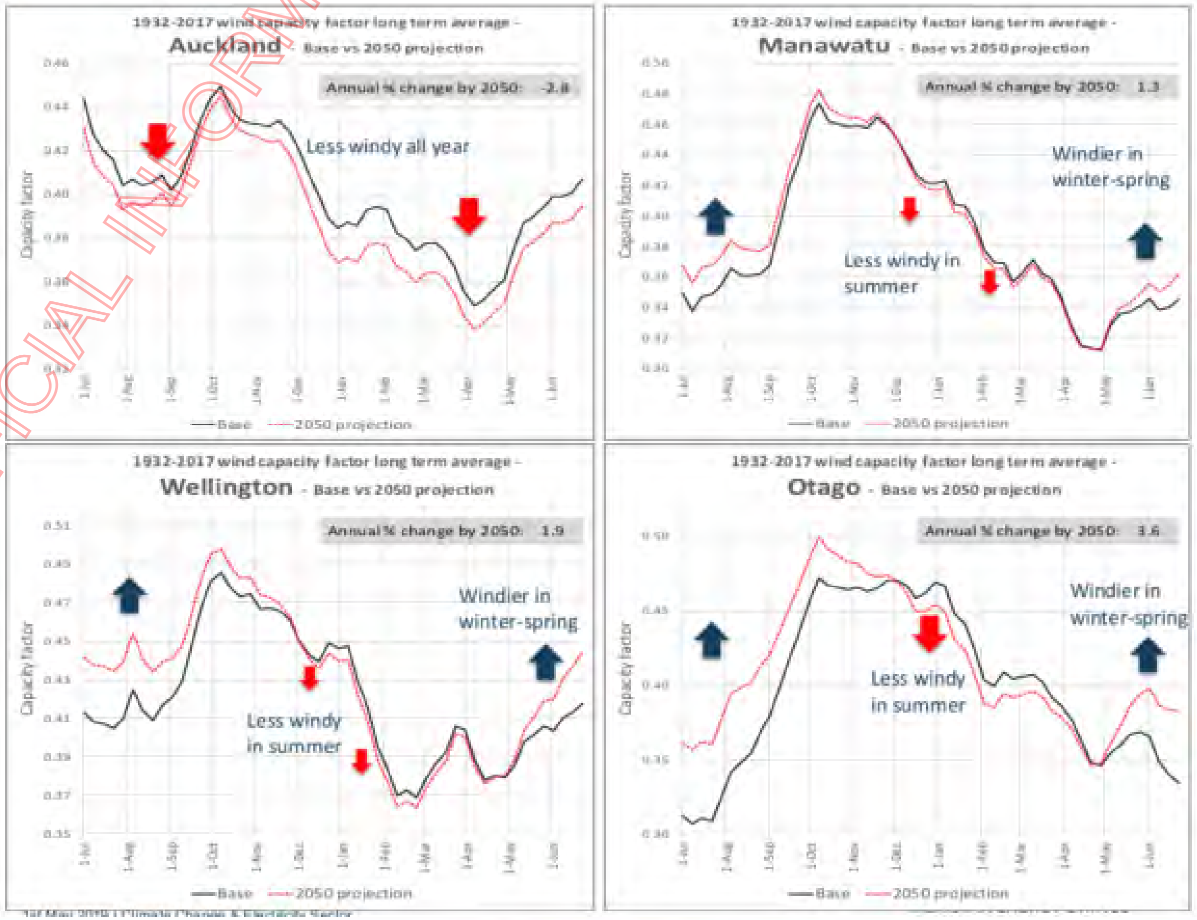


Climate change impacts on wind generation capacity factors – Jen Purdie

Modelled annual changes to wind flows (mid-range emissions scenario)

- Less windy overall in Northland, Auckland & Waikato wind flows
- All South Island and lower North Island see increased wind, greatest increase for Otago.
- Seasonal changes.
    - Upper North Island decline across all seasons for Auckland, Waikato & Northland decrease in winter, otherwise unchanged.
    - South Island & lower North Island; all regions windier in winter, slightly less windy otherwise.

Modelled changes to wind farm capacity factor



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[redacted]

Model Inputs used for Problem One – Concept & John Culy

- 80+ years of historical, daily hydro flow data available for existing hydro (and potential) schemes.
- 18 years of synthetic satellite data for hourly, regional wind data (19 sites/regions).
- 18 years of synthetic satellite data for hourly, regional solar data (regions distributed across the country).

Captures correlations between hydro inflows, wind flows and solar for the 18 year overlap.

Assumes historical series are a reasonable representation of future series – i.e. climate change impacts not assessed.


concept JC

Estimated gross benefits of NZ Battery options

21 May 2021

Version 4.0

Summary

- Work in this area for over 30 years (what will happen, are they correlated?)
- Early work indicative & caveated
- More sophisticated modelling
- More and better data
- Leading to firmer conclusions
- Results generated with relatively high level of confidence
- Windy and wetter in S & W
- Drier and calmer in N & E
- Backed up by some observations in recent decades – more winter inflows in South as rain instead of snow

- So we asked NIWA to use NESI to see what the future held for inflows, sunshine and wind flows …..and were they correlated?

NIWA update – early insights into the current work underway

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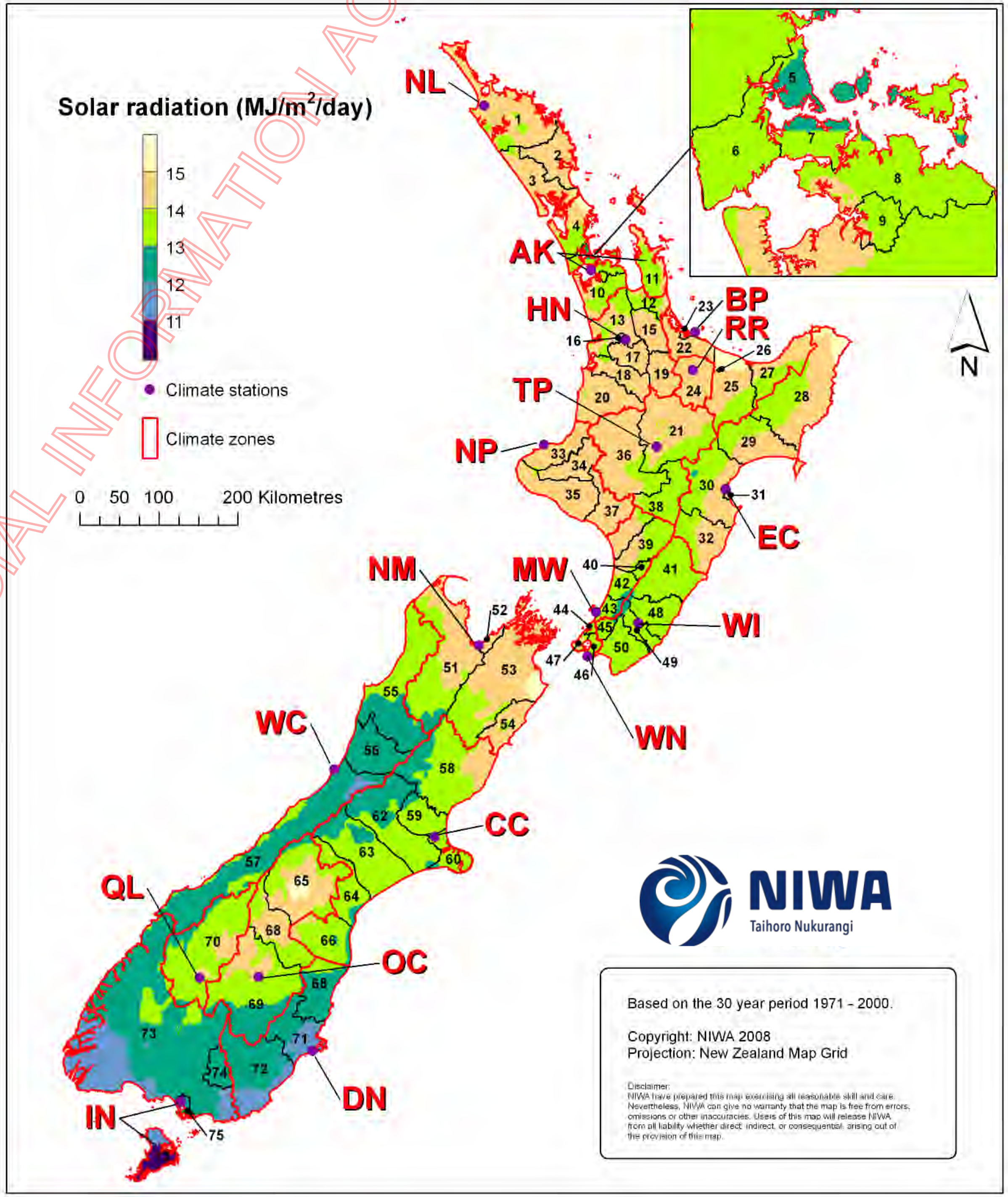
Solar Energy

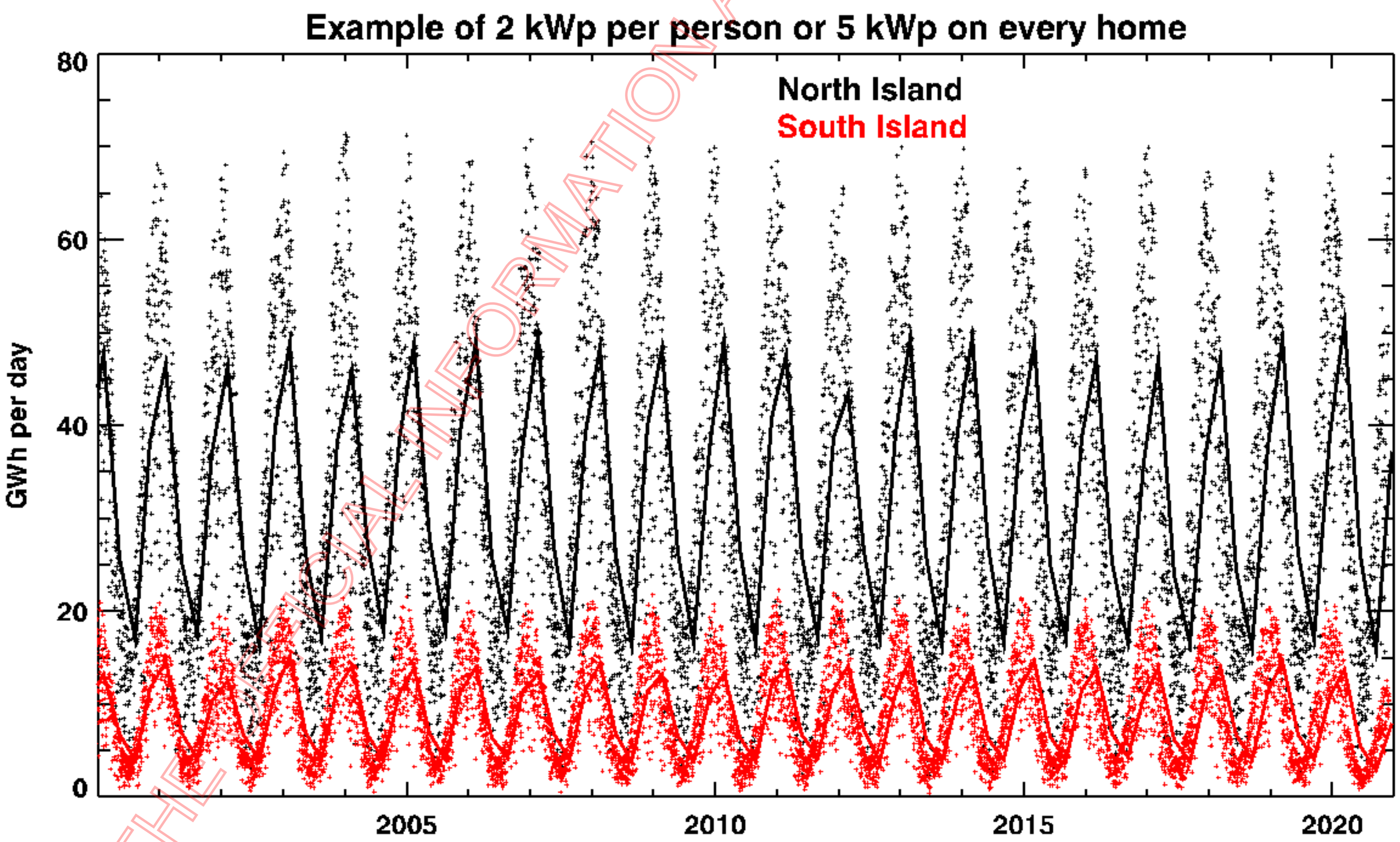
- **Solar radiation data from 18 climate zones**
- **Zones weighted by TLA population**
- **Solar < 0.5% of NZ generation at present**
- **In last 6 months, 10 solar farms announced, for more than 2% of NZ supply**
- **Past analysis on hourly data from CliDB**
- **Simulations of past (1981-2005) and 4 future (2031-2070) scenarios with 6 models**
- **Simulations are just daily, so analysis here is just of global horizontal irradiance (GHI)**



Solar Energy

Example scenario:
A 5 kWp system on every house, or fewer large systems on commercial buildings and solar farms, supplies 15 TWh per year, or 1.7 GW average power.

Variation by hour and by season is far greater than from year to year.



- **Any aggregation beyond hourly must assume some storage system**
- **For now, buffering is via hydro**
- **When solar fraction increases, storage in EV and hydrogen is expected**

Global Energy Sources and Reserves

IEA-SHCP-Newsletter Vol. 62, Nov. 2015 – draft

- **To the extent that the whole world moves to renewable energy, solar will be dominant**
- **IEA recently acknowledged over 50% of generation in 2050 will be solar**
- **IEA also noted (Oct 2020): Solar is now 'cheapest electricity in history'**

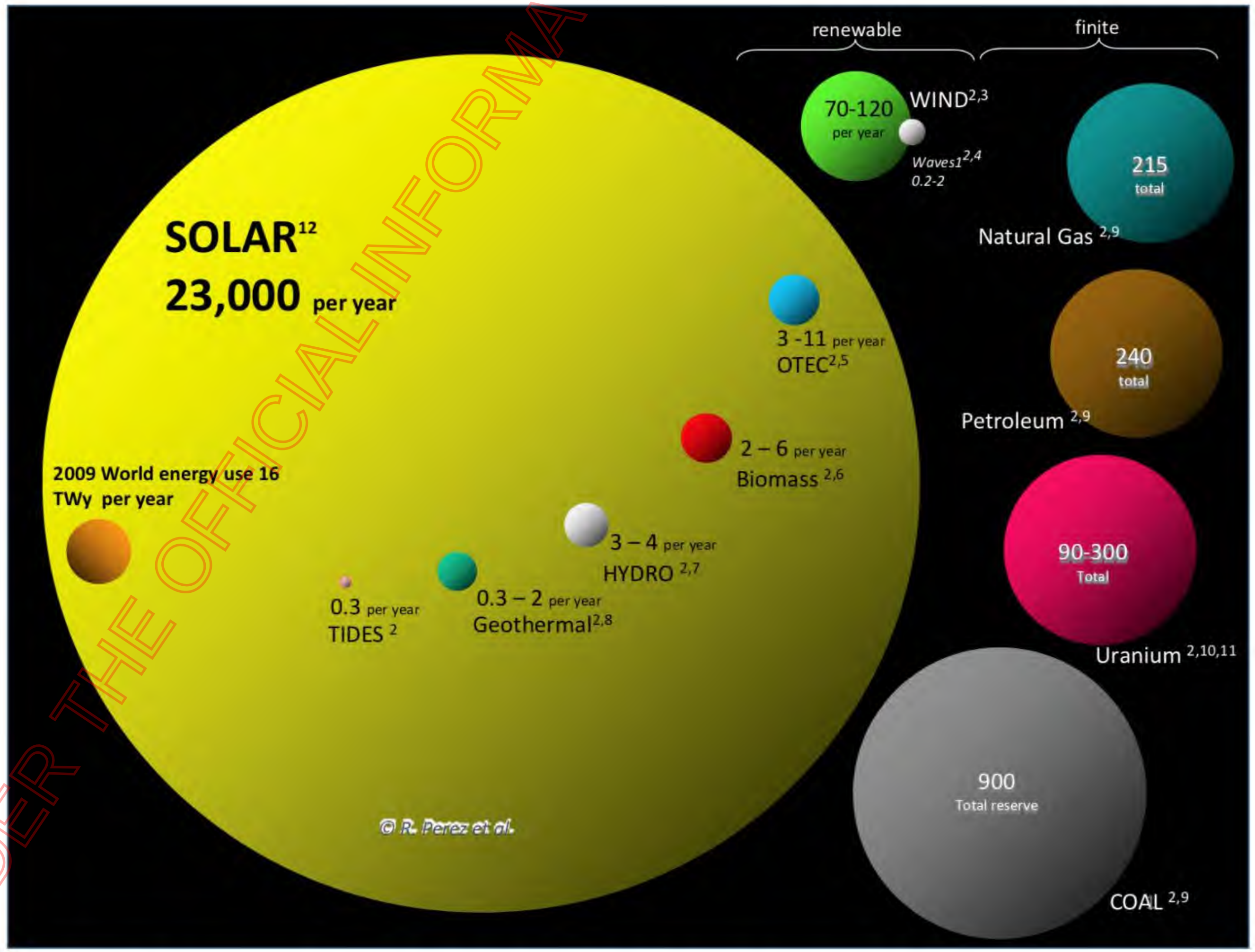


Figure 1: *2009 Estimate of finite and renewable planetary energy reserves (Terawatt-years). Total recoverable reserves are shown for the finite resources. Yearly potential is shown for the renewables.*

Aotearoa Solar Energy

At present, solar energy supplies < 0.5% of NZ electricity; all rooftop solar.

In six months, 10 solar farms have been announced, adding > 2% to NZ supply within two years.

By 2030, it could by 20%.

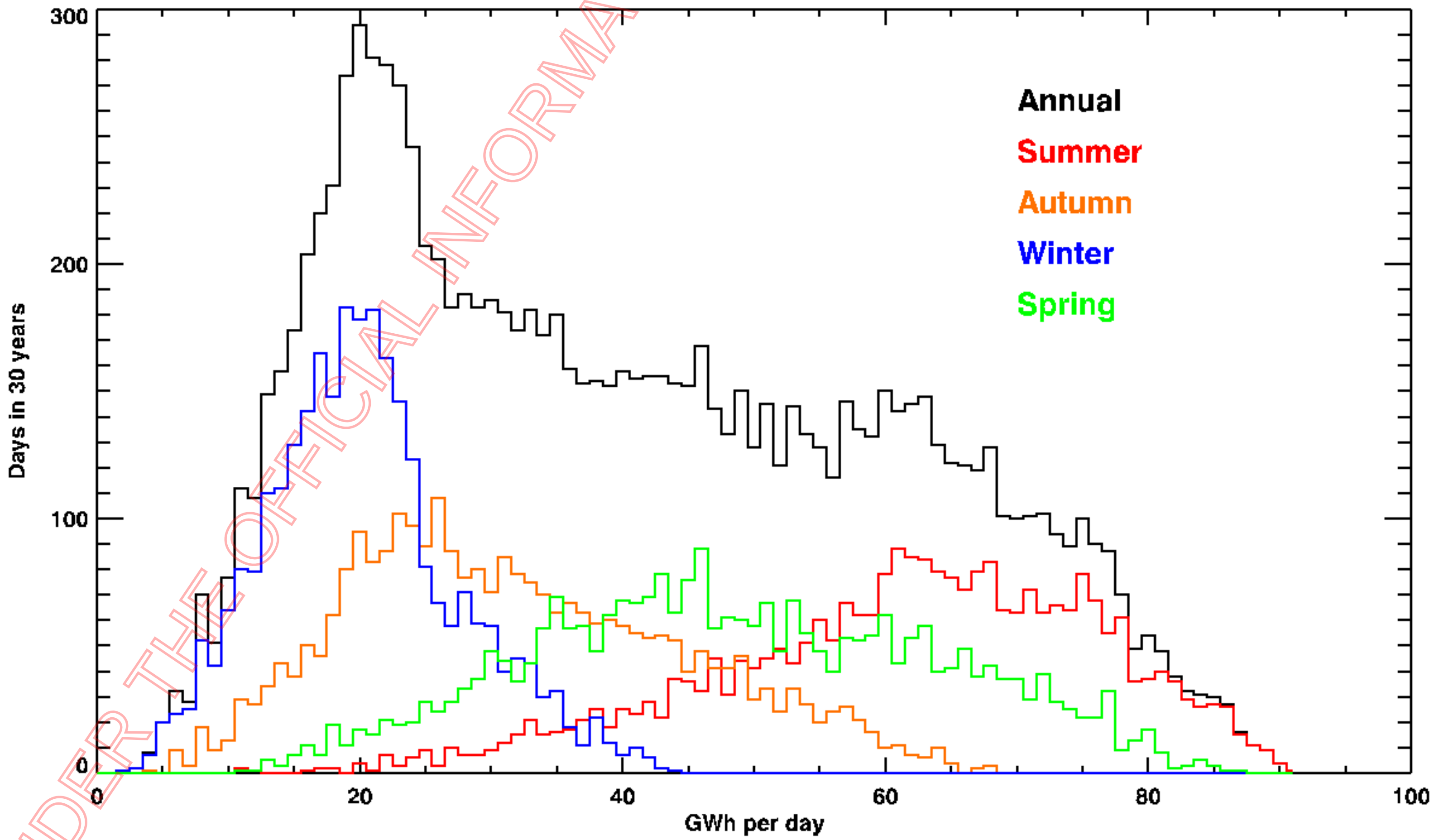
The one constraint will be short-term storage
- **Battery EV – 2 million x 50 kWh = 100 GWh for V2G or V2B**
- **Hydrogen – produced for transport, available for electricity generation**

Interseasonal storage
- **EV batteries not relevant**
- **Hydrogen will be, at cost of conversion and storage**
- **Solar sized for autumn and spring means large excess generation in summer**

Measured GHI 1990-2021

Historical distribution by season for the example scenario of 10 GW peak solar generation capacity.

The distributions are the basis of comparison for past (RCP10) models of 1981-2005.



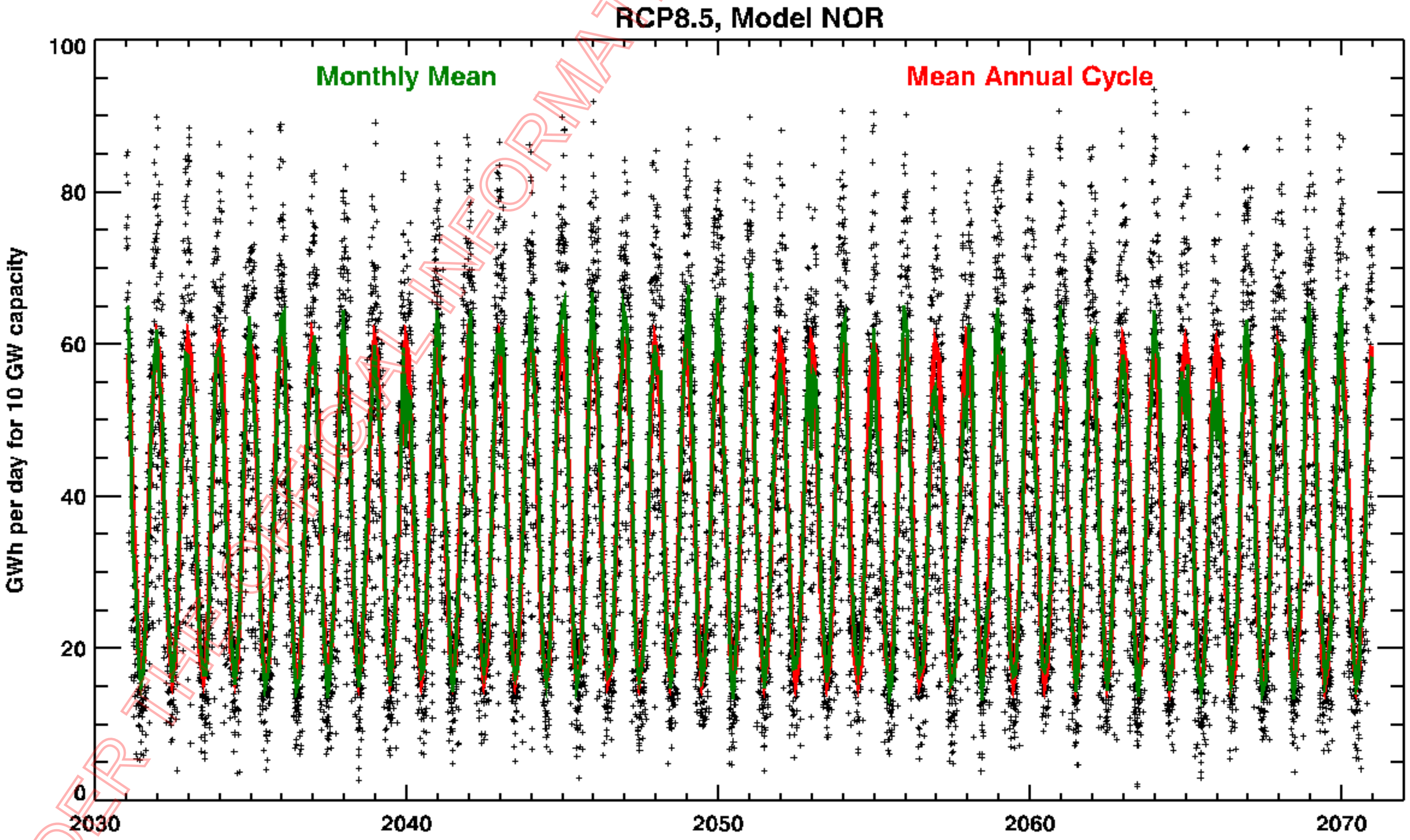
Modelled GHI 2031-2070

Because of the dominant annual cycle, monthly means (green) for all scenarios and models are fitted (red) with

Constant + Trend + Cycle (6-par)

The residuals (green – red) are analysed for patterns of difference from an average year.

The trends in all models are small (< 0.5% per decade) and inconsistent between models and scenarios.



Modelled GHI 2031-2070

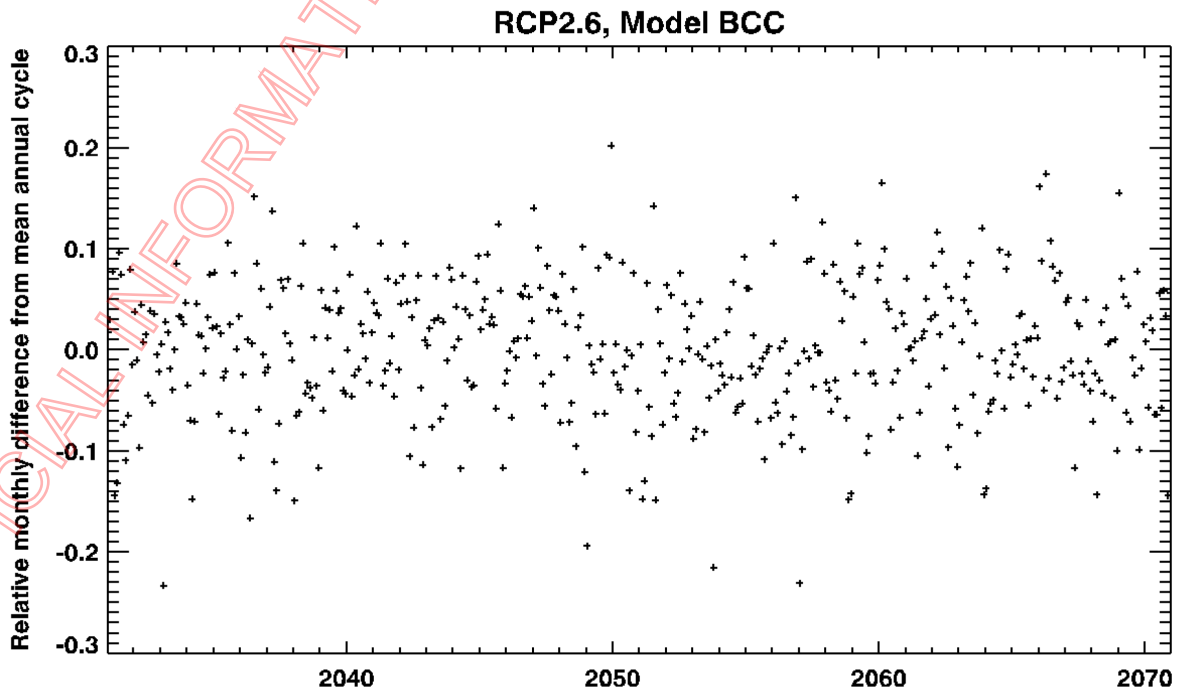
The monthly residuals as a fraction of the annual cycle are uniform (homoscedastic) over time.

The autocorrelation at one month lag = 0.072

It measures the likelihood that an above- or below-average month will be followed by one of the same type.

Correspondingly, we expect little correlation (or anticorrelation) with other forms of generation.

Solar generation can be treated as naturally variable around the dominant cyclicity.



Hydro-power

- **Current analysis based on MHD dataset and raw non bias corrected inflow simulations**
- **Climate change driven dataset to follow same rules and calculation as MHD**
- **Power potential conversion factor under climate change**
  - **Identical to the one provided by WSP**
  - **Assumes 1cumec~1MW for riverine sites (valid assumption?)**
- **Spatial split :**
  - **North and South Island**
  - **East/West**
  - **12 datasets**
- **Temporal split analysis to match wind dataset :**
  - **2020-2050**
  - **2030-2060**
  - **2041-2070**

Hydro-power- MHD

- **MHD Dataset splits in “natural” – forced – potential**
  - **Natural – Inflows that can be reproduced by the New Zealand Water Model (NZWaM)**
  - **Forced – inflows that cannot be reproduced by NZWaM (e.g. transfer between catchment – TPD, or using transfer through pipe flow – Coleridge/Mangahao)**
  - **Potential: natural riverine flow sites that could be developed**

- **MHD Temporal split in 3 periods:**
  - **Pre 86**
  - **Hindcast: 86-05**
  - **Nearfuture: 06-17**

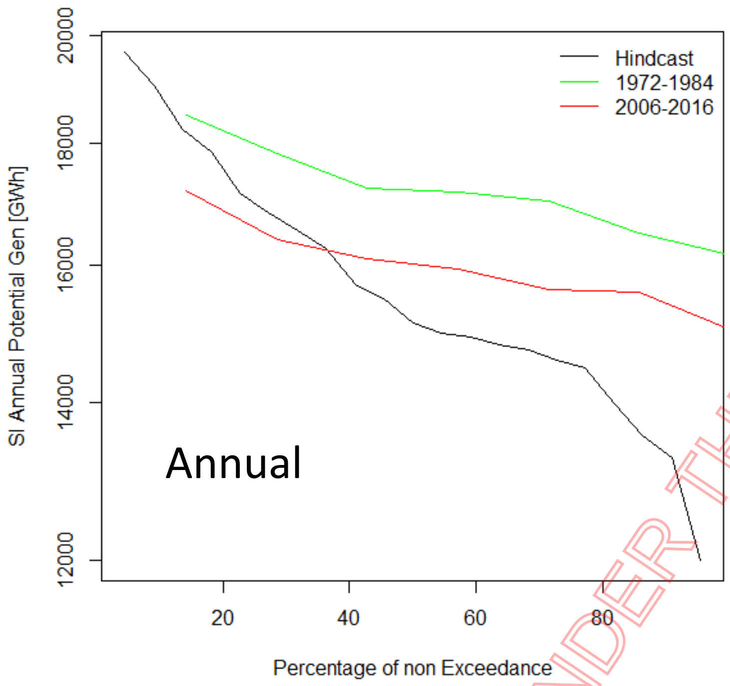
-

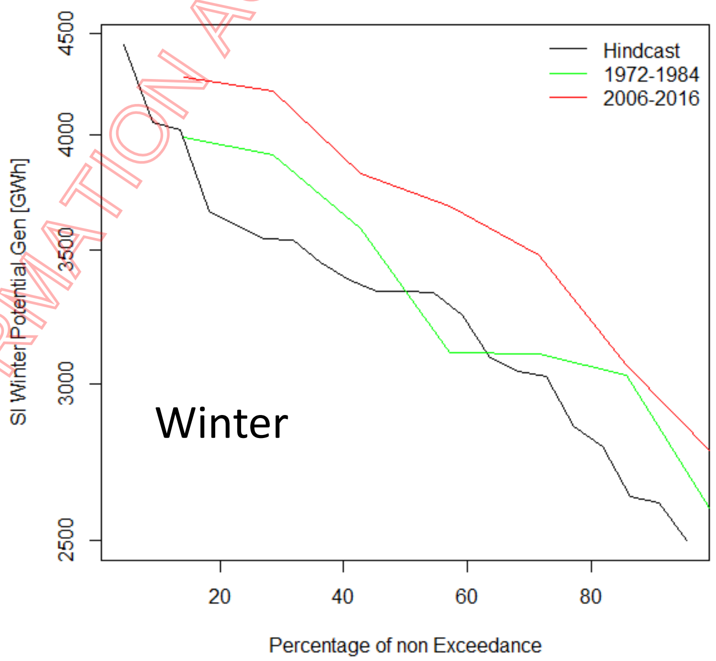
Hydro-power- MHD

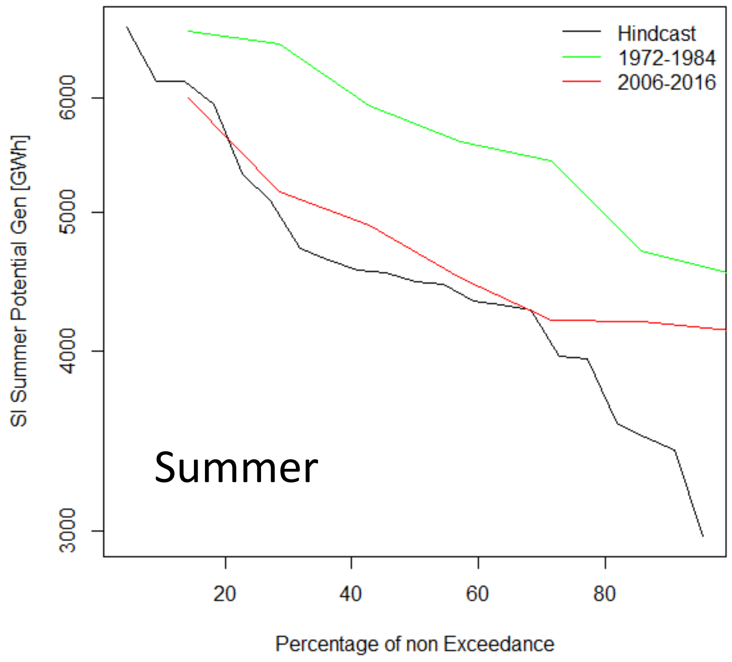
- **Work completed**
  - **MHD dataset pot-processing to natural and potential datasets using R**
    - **South-West : only potential sites**
    - **South-East:**
      - **Natural: Waitaki +Hawea-Clyde+ Manapouri system**
      - **Potential: Waiau-Wairau-Hurunui**
    - **North-East**
      - **Natural : Waikaremoana**
      - **Potential: Ngaruroro**
    - **North West**
      - **Natural: DSTaupo system without TPD**

Hydro-power - MHD

- **South Island- Generation**



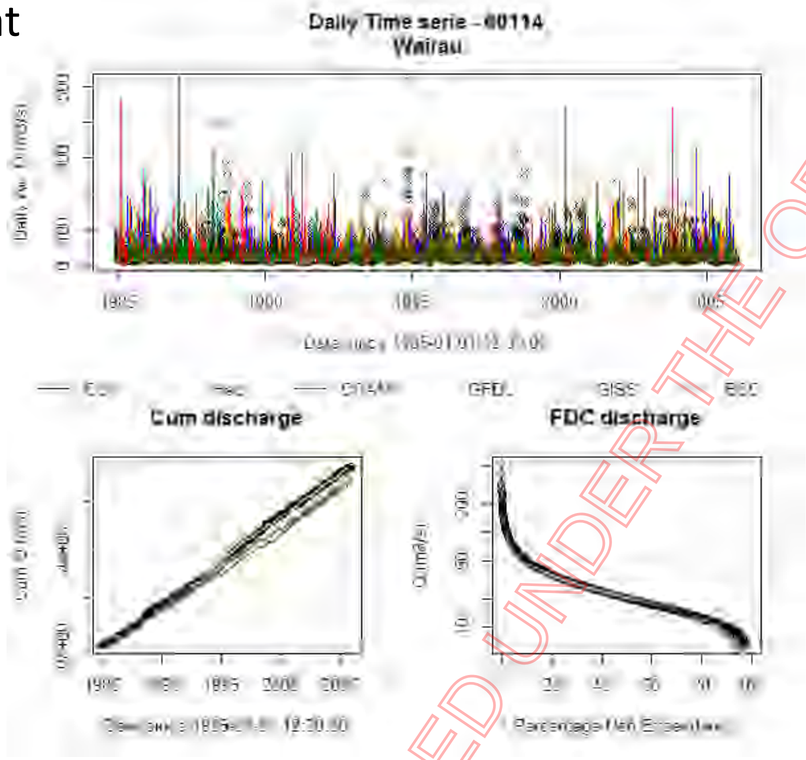




Hydro-power- CMIP5 driven

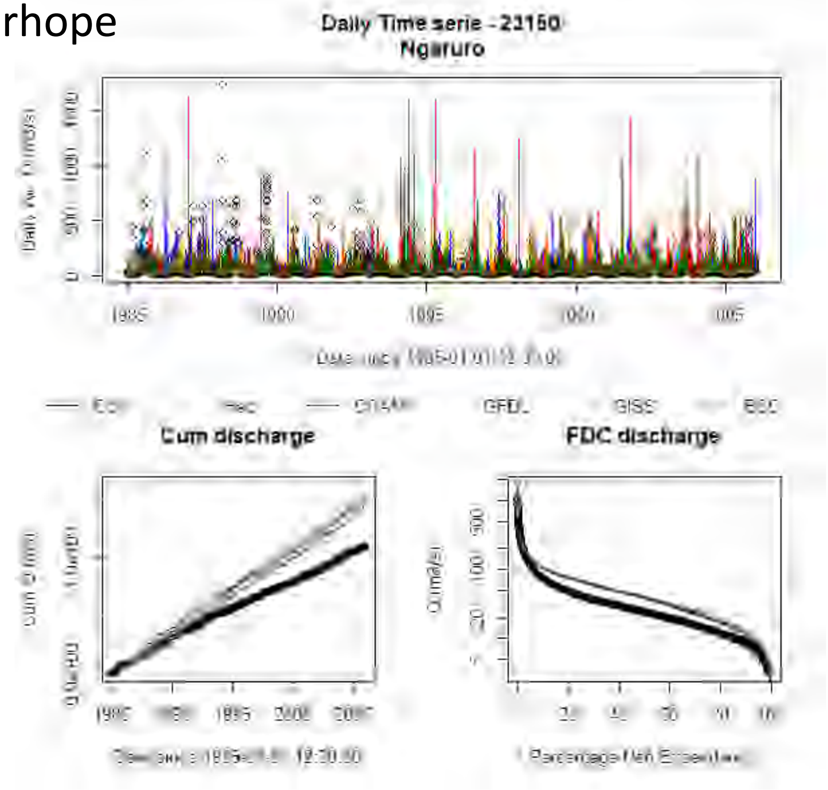
- **Simulations completed from 1971 to 2098 for raw uncorrected simulations**
- **Bias correction on water balance and Flow duration curve – Precipitation-Evaporation and cryospheric processes (not completed yet)**

Wairau @ DipFlat



Increase Prec

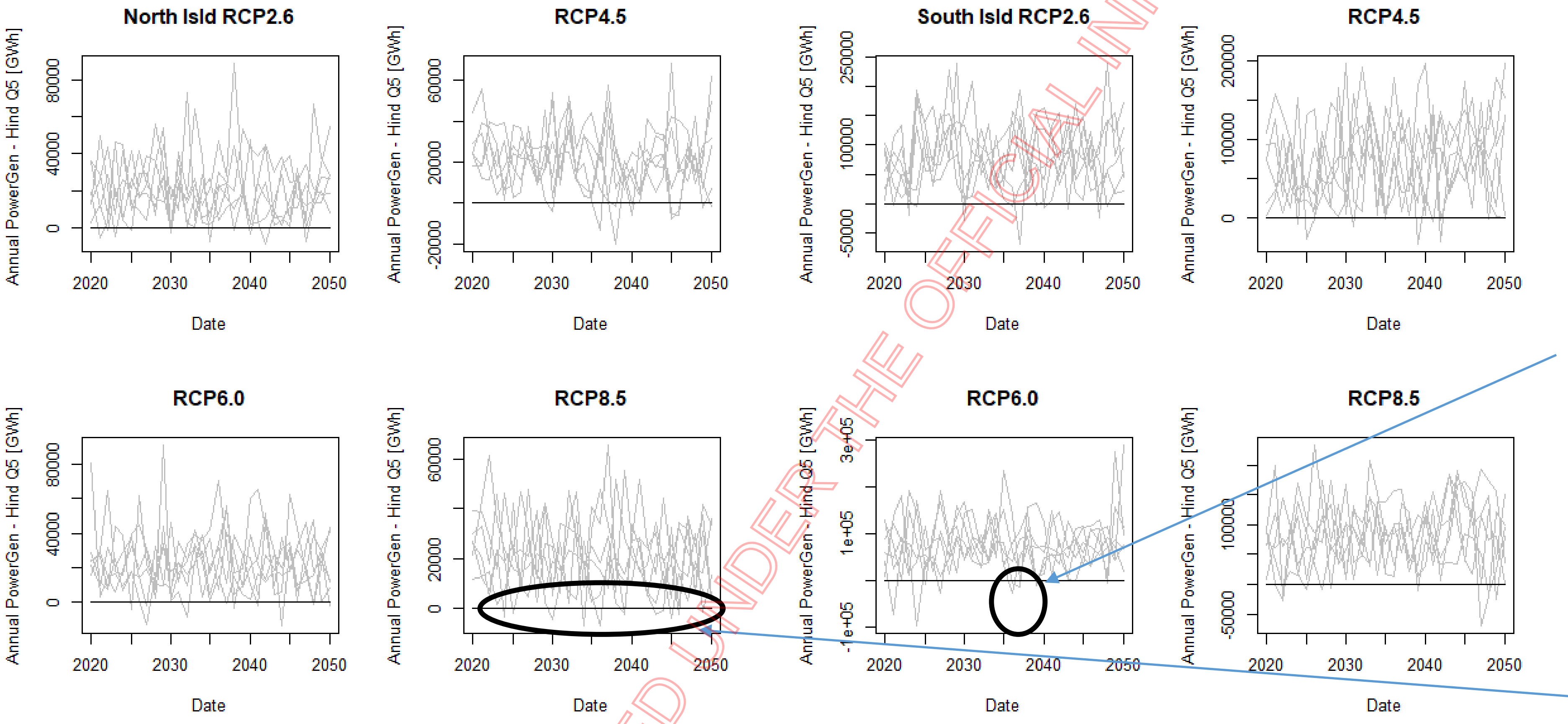
Ngaruro@Chesterhope



Reduce Prec

Hydro-power- CMIP5 driven

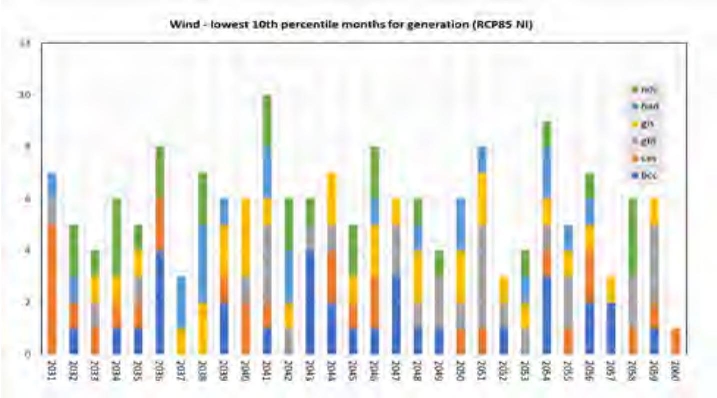
- **2020-2050- looking at existing system**
- **Power Generation Threshold at 5ercentile of hindcast (GCM specific) [Annual time scale]**



Consecutive years with no generation in SI

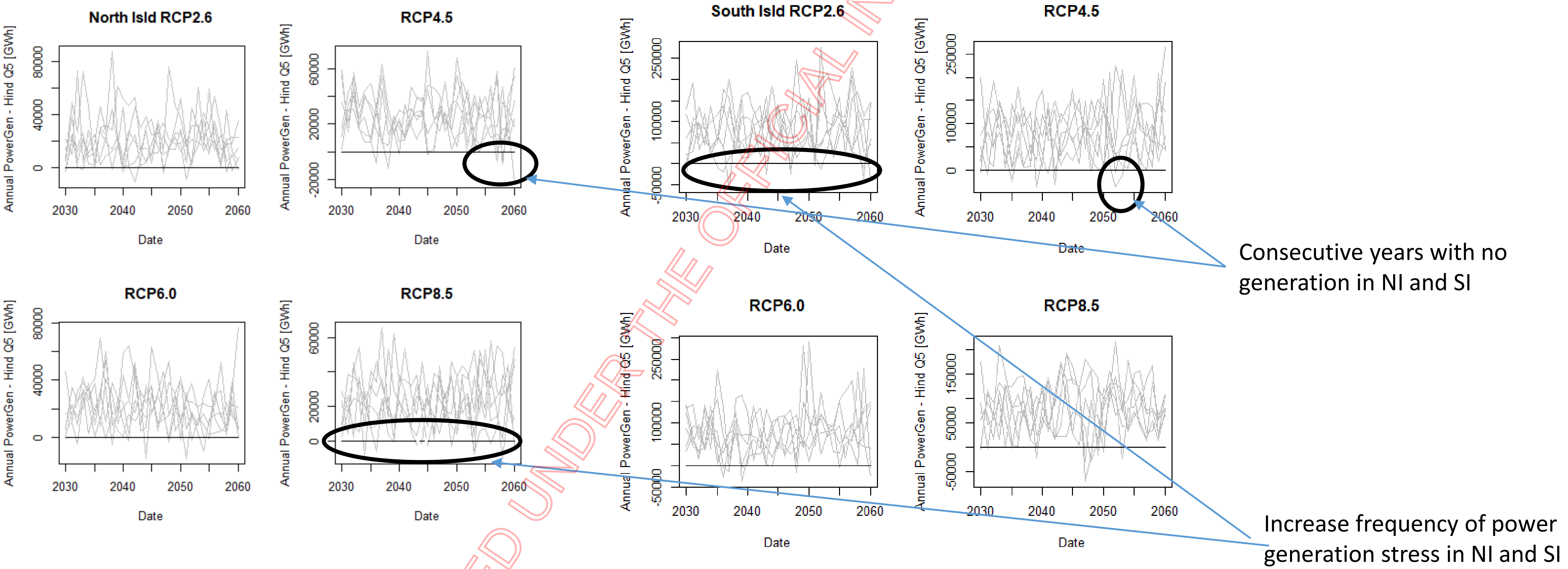
Increase frequency of power generation stress in NI

Grey lines represent the trace for each GCM- Black line represent no power generation capacity



Hydro-power- CMIP5 driven

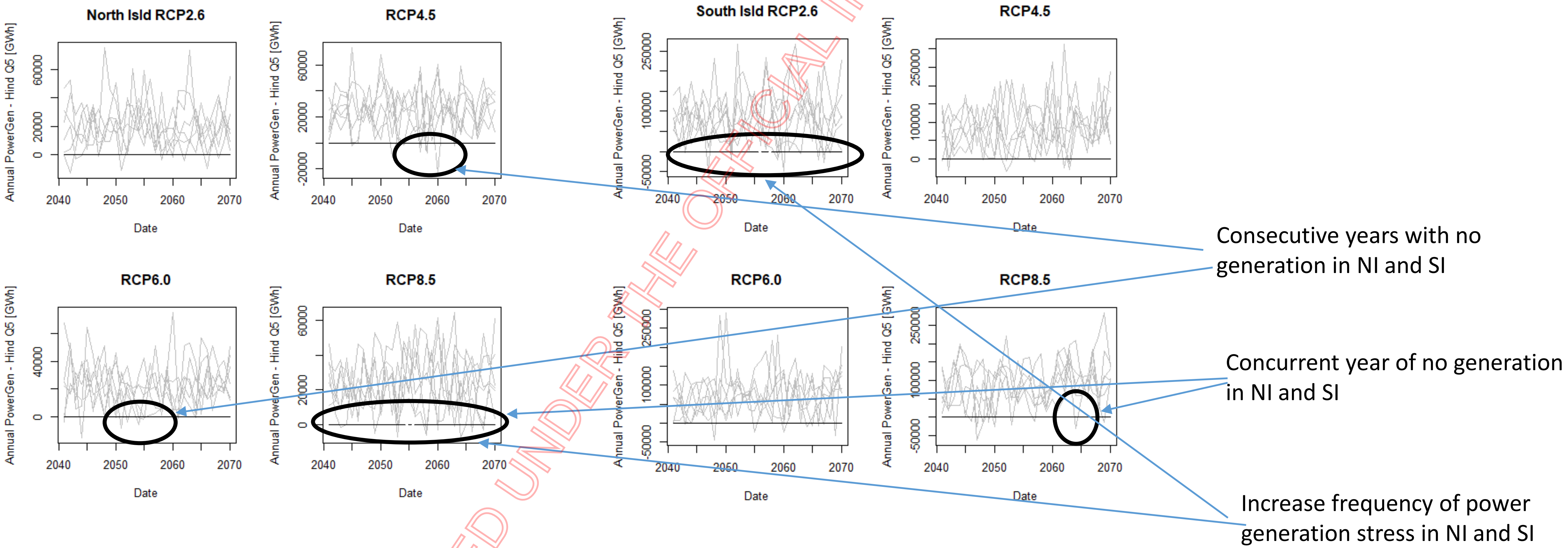
- **2030-2060- looking at existing system**
- **Power Generation Threshold at 5ercentile of hindcast (GCM specific) [Annual time scale]**



Grey lines represent the trace for each GCM- Black line represent no power generation capacity

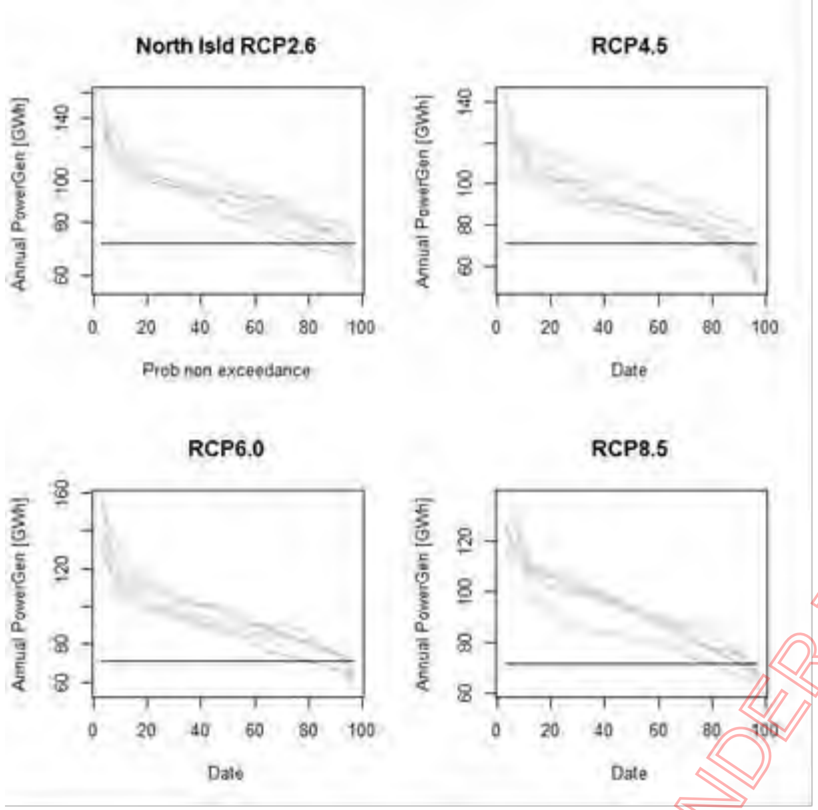
Hydro-power- CMIP5 driven

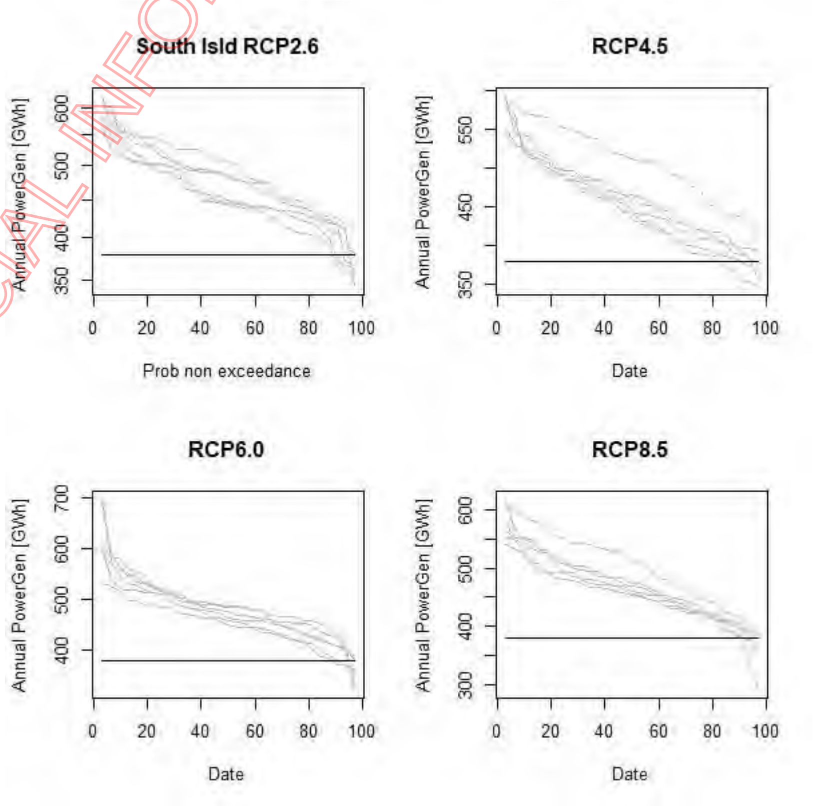
- **2040-2070- looking at existing system**
- **Power Generation Threshold at 5ercentile of hindcast (GCM specific) [Annual time scale]**



Grey lines represent the trace for each GCM- Black line represent no power generation capacity

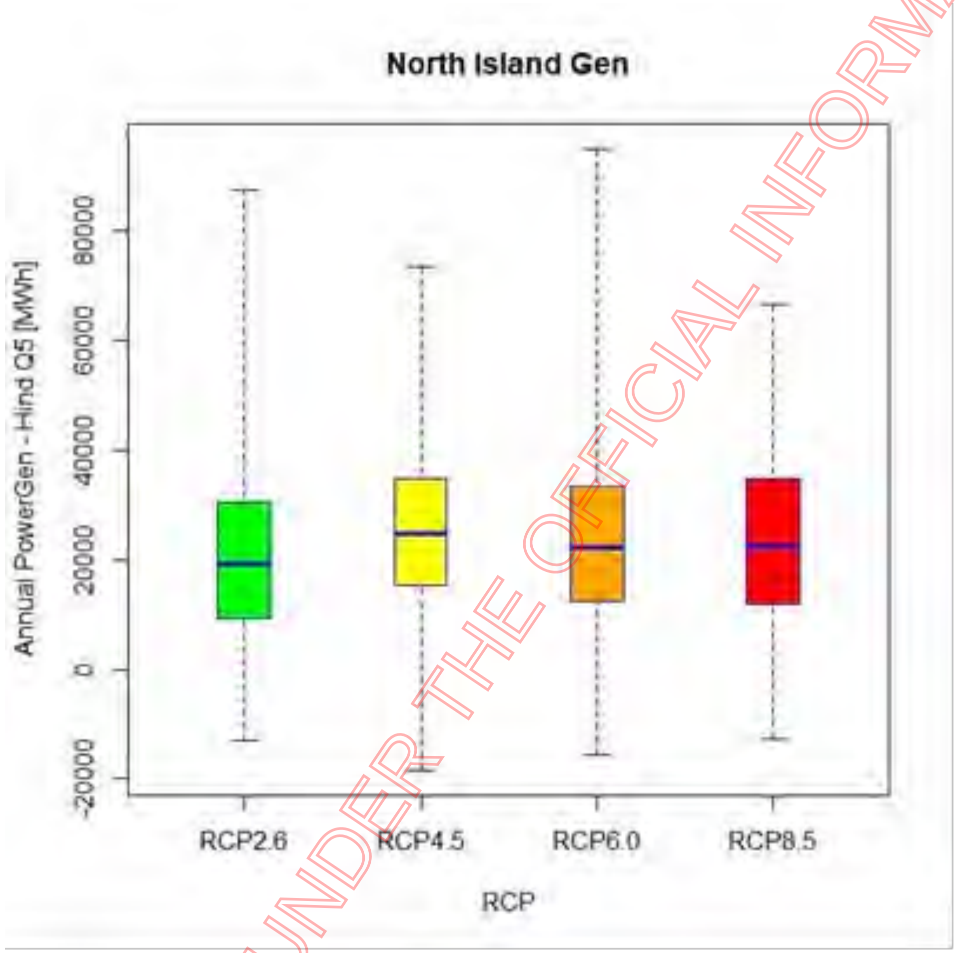
A representation of Intensity duration curve and a whisker box plot. All analysis done on the 2020-2050 time slice using annual time scale and the same threshold at 5 percentile power generation capacity.



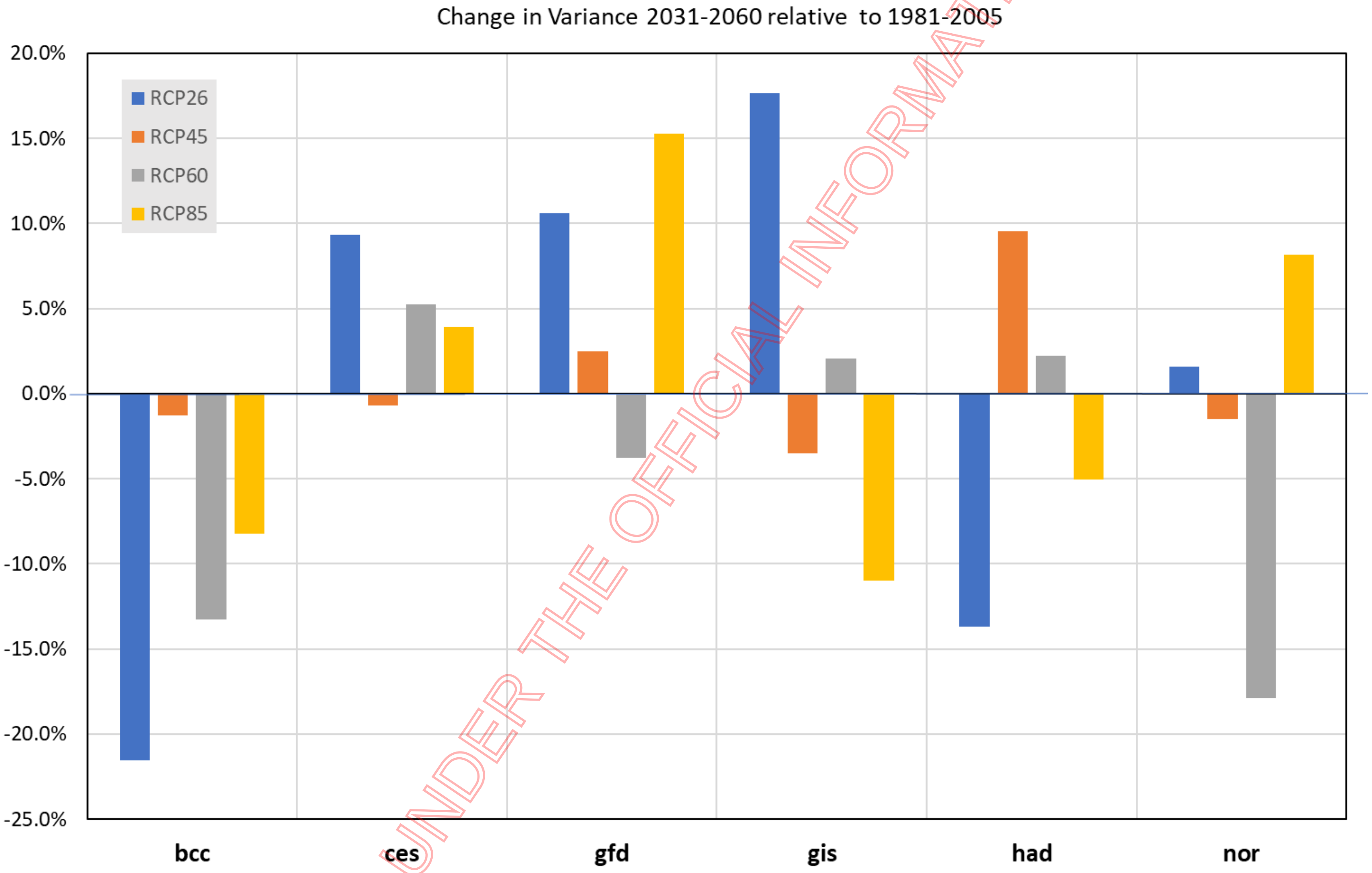


NI Generation

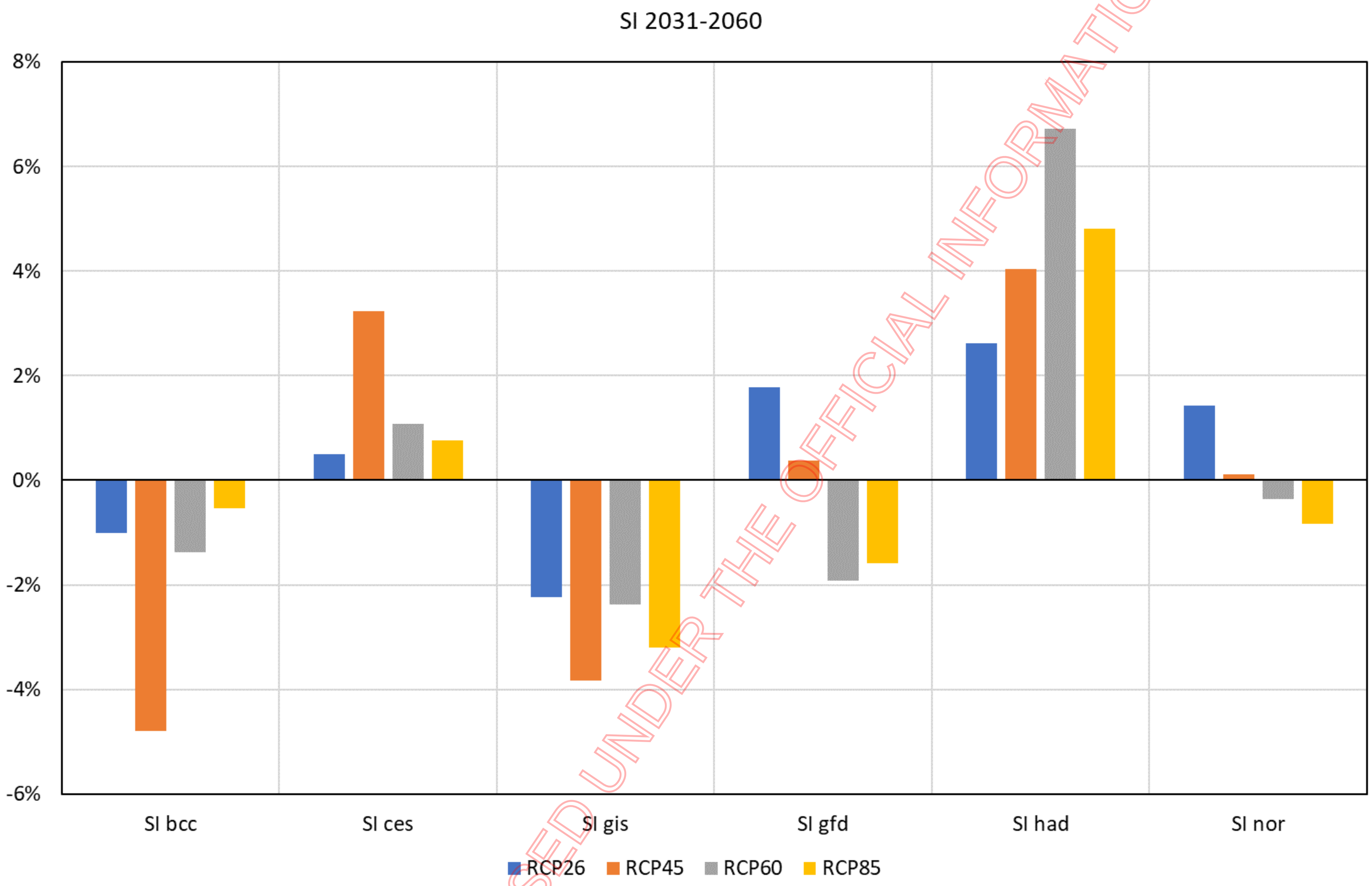
Hydro



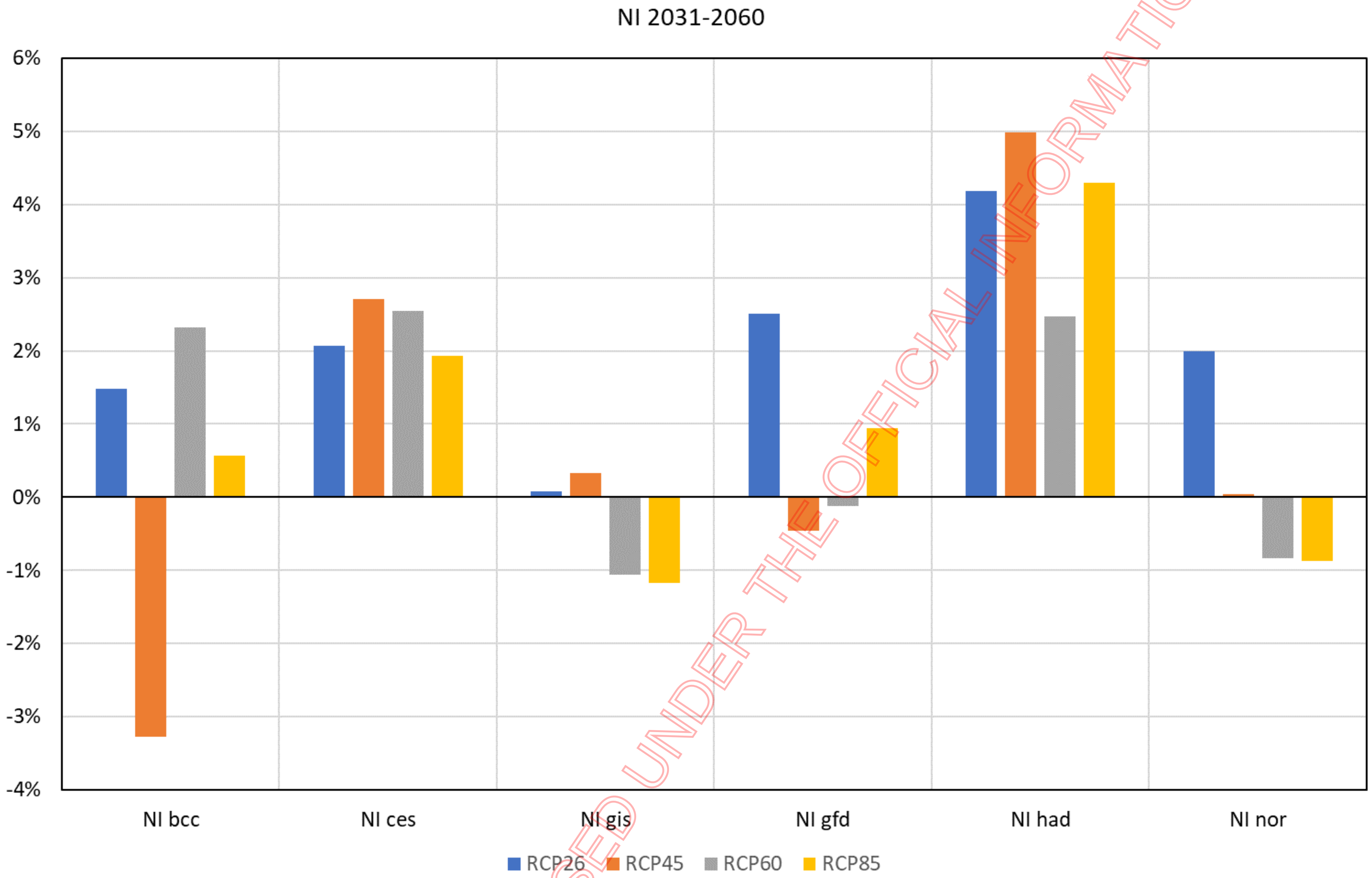
Wind Generation (NI – monthly variance)



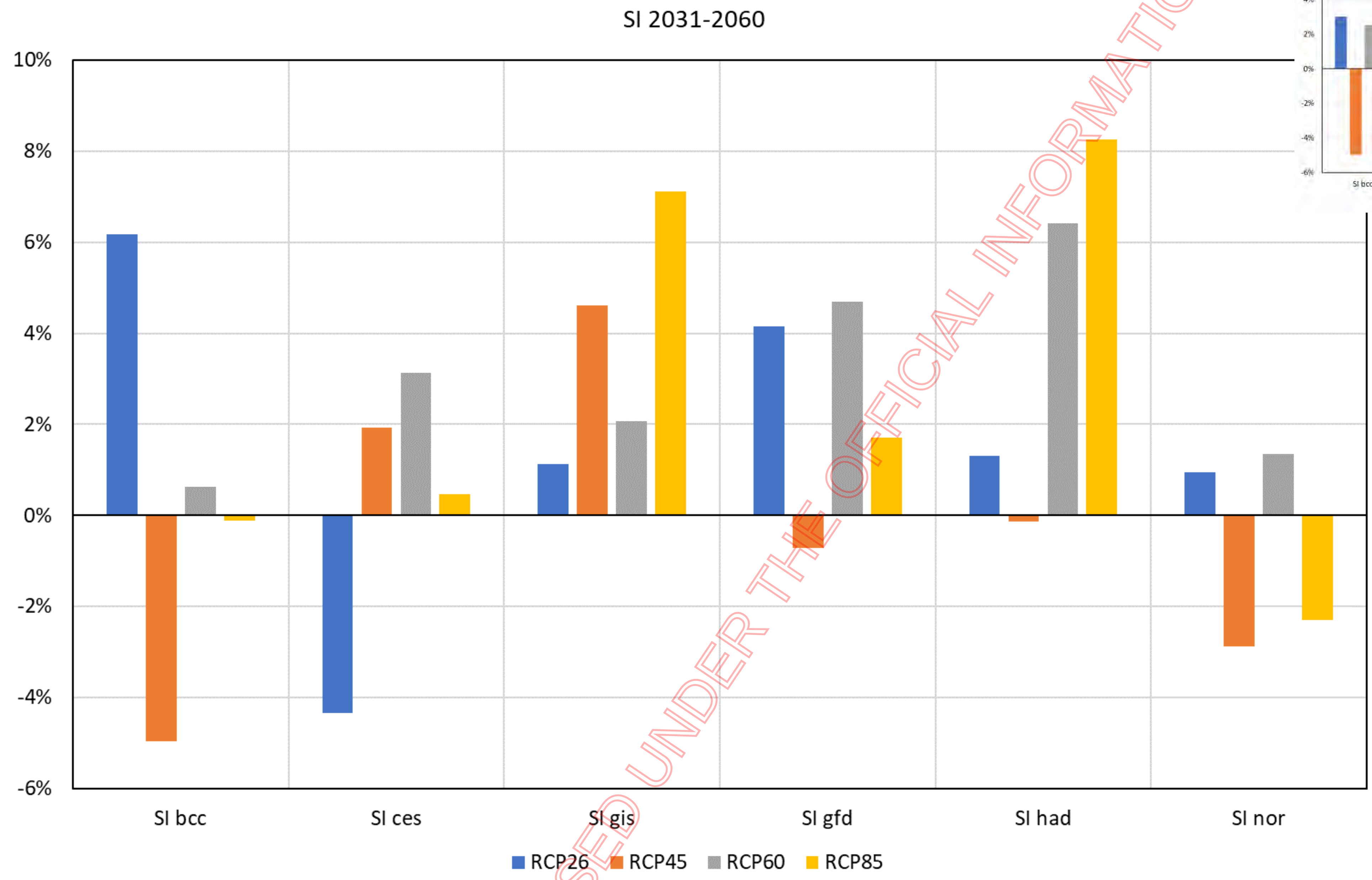
Relative Change in Median Wind Generation vs 1980-2005

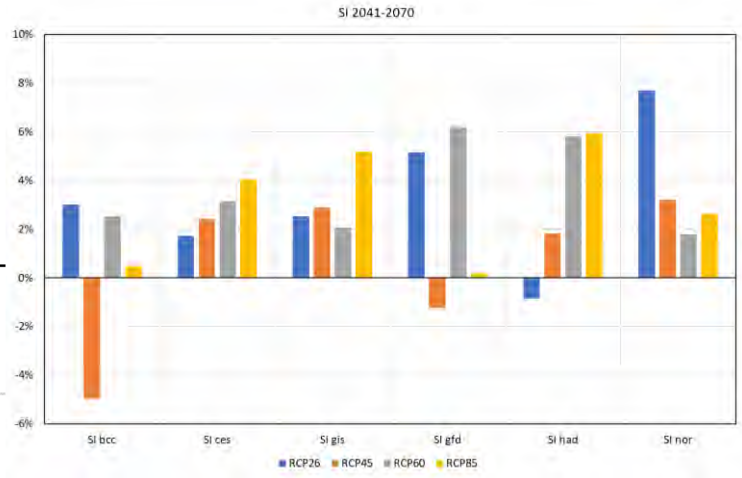


Relative Change in Median Wind Generation vs 1980-2005

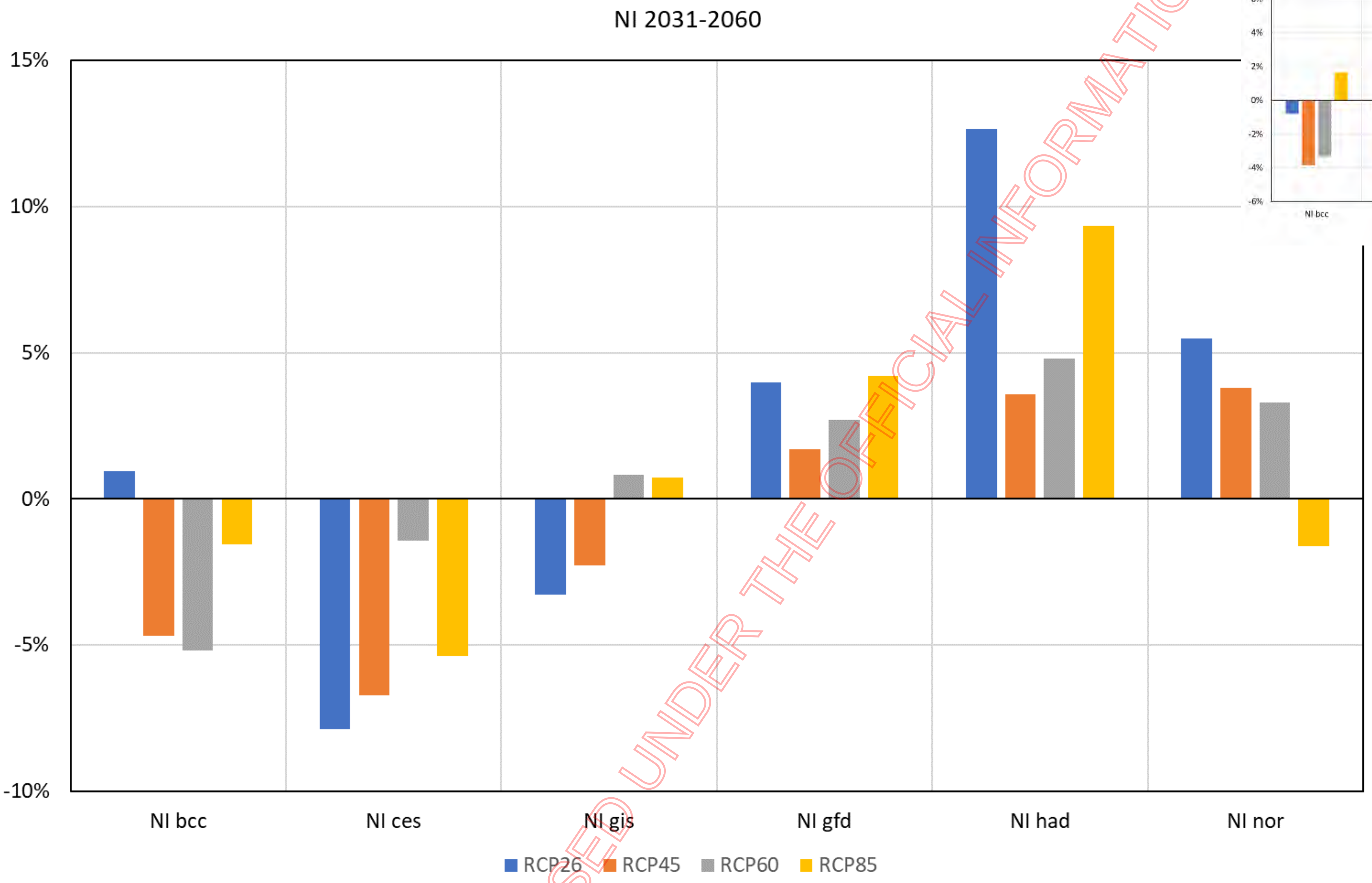


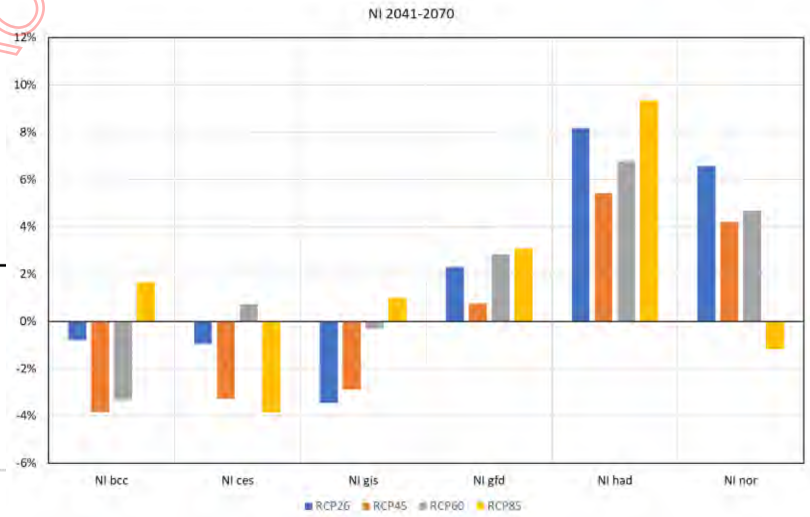
Relative Change in 5th Percentile Wind Generation vs 1980-2005



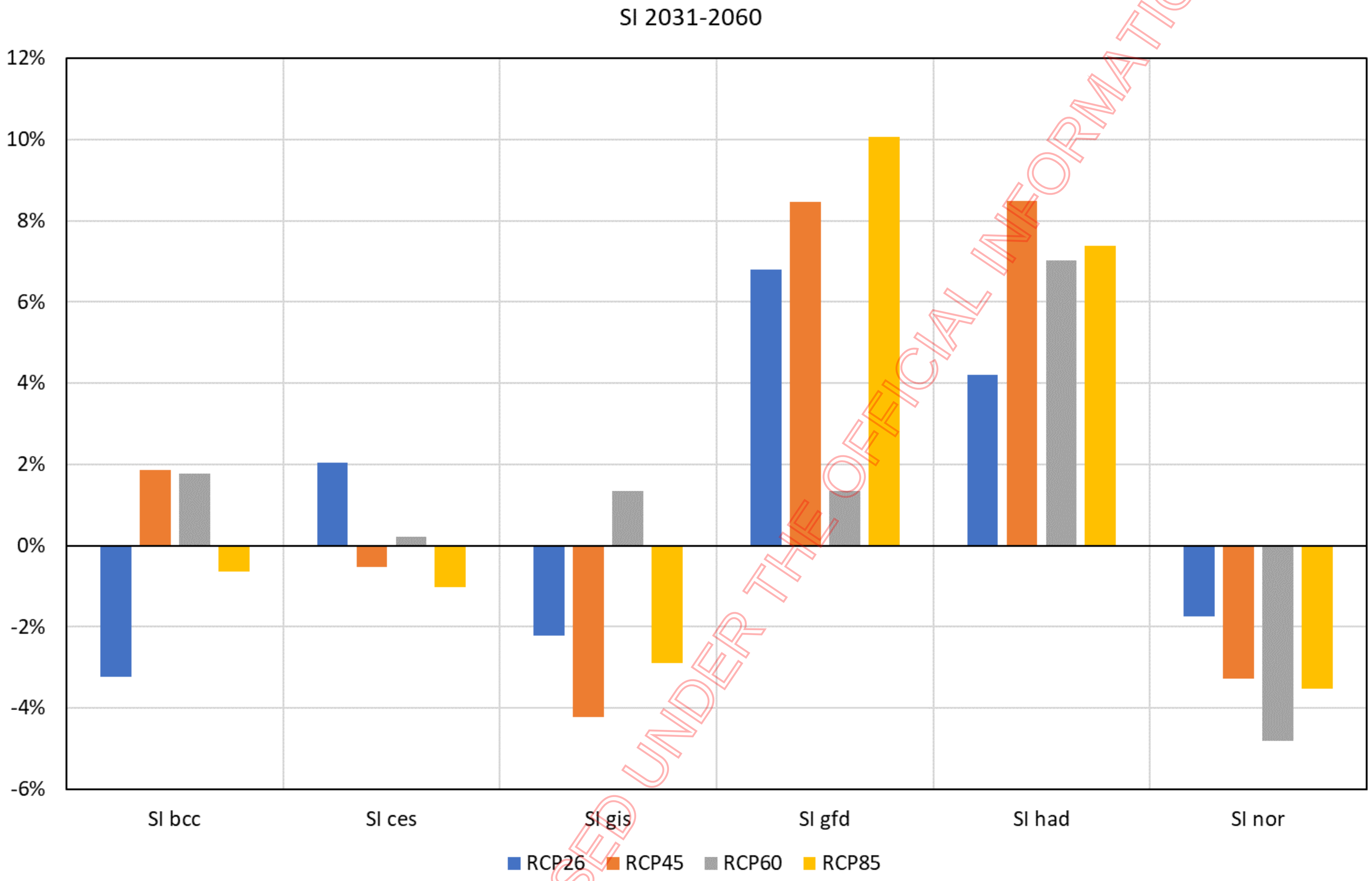


Relative Change in 5th Percentile Wind Generation vs 1980-2005

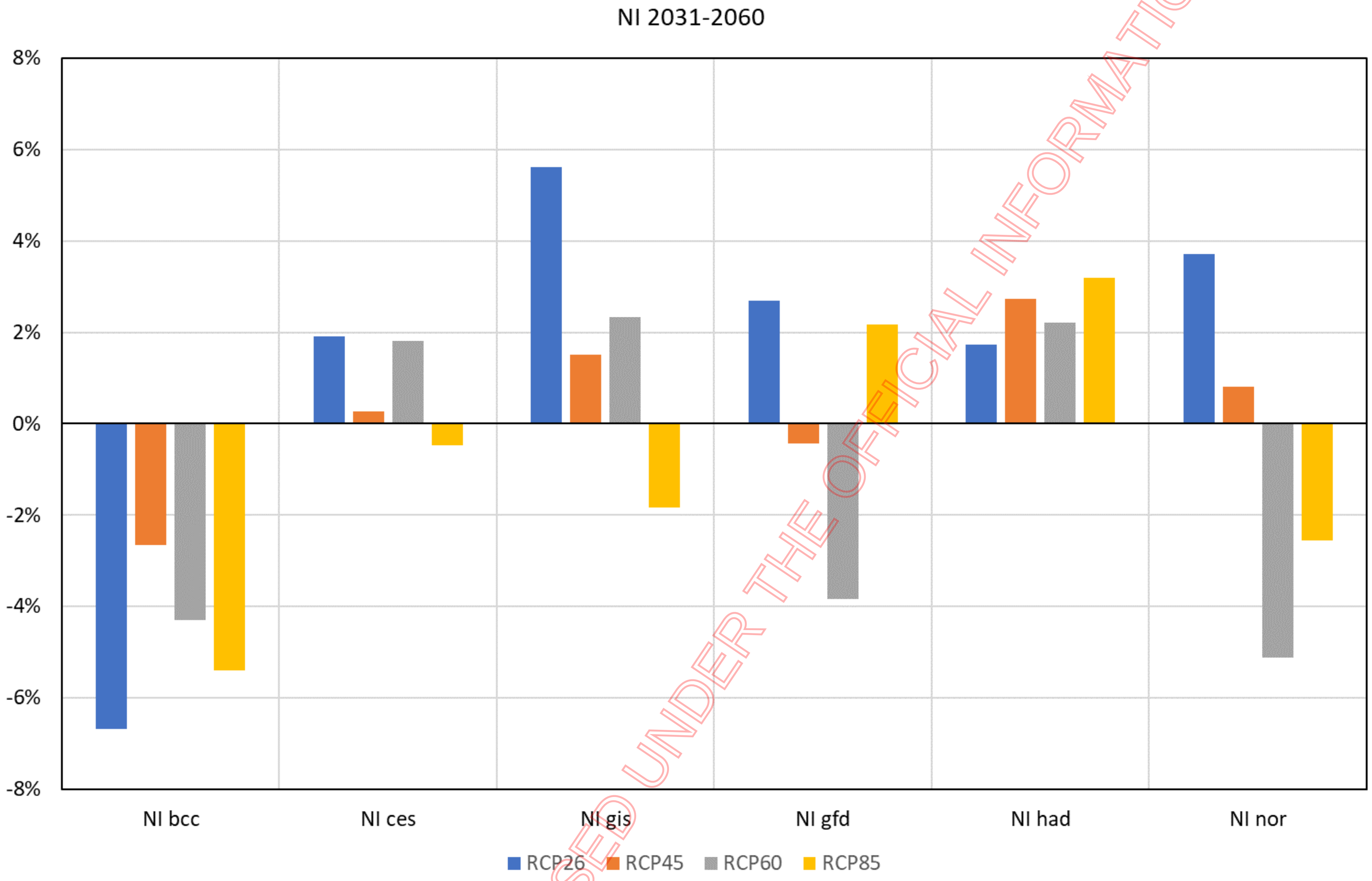




Relative Change in 95th Percentile Wind Generation vs 1980-2005



Relative Change in 95th Percentile Wind Generation vs 1980-2005



NIWA scientists - Freshwater update

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NZ Battery Project
Potential for pumped hydro-storage at Lake Onslow

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Lake Onslow project outline and timing

	Tasks	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22
1	**Baseline Study**											
	Climate											
	River Flow											
	Fishery / Freshwater fauna											
	Lake Onslow Bathymetry Survey											
	Met Station installation											
	Lake Buoy											
	Lake and river WQ sample analysis											
	Water Quality - NIWA Field Team (TN, TP [illegible])											
2	**Large Lake Impacts**											
	Methane study - GHG emissions modelling - future											
	Methane emission calculation - existing											
	Fine sediment											
	Hydrodynamic modelling - existing											
	Hydrodynamic modelling - future											
	Lake model reporting											
	Lit review - [illegible] and Mahinerangi Lakes											
	Large pumped hydro schemes abroad											
	Macrophytes and biosecurity review											
3	**International case studies**											
	Review of impacts and operations of comparable PHES schemes											
	Workshops											

field

workshop

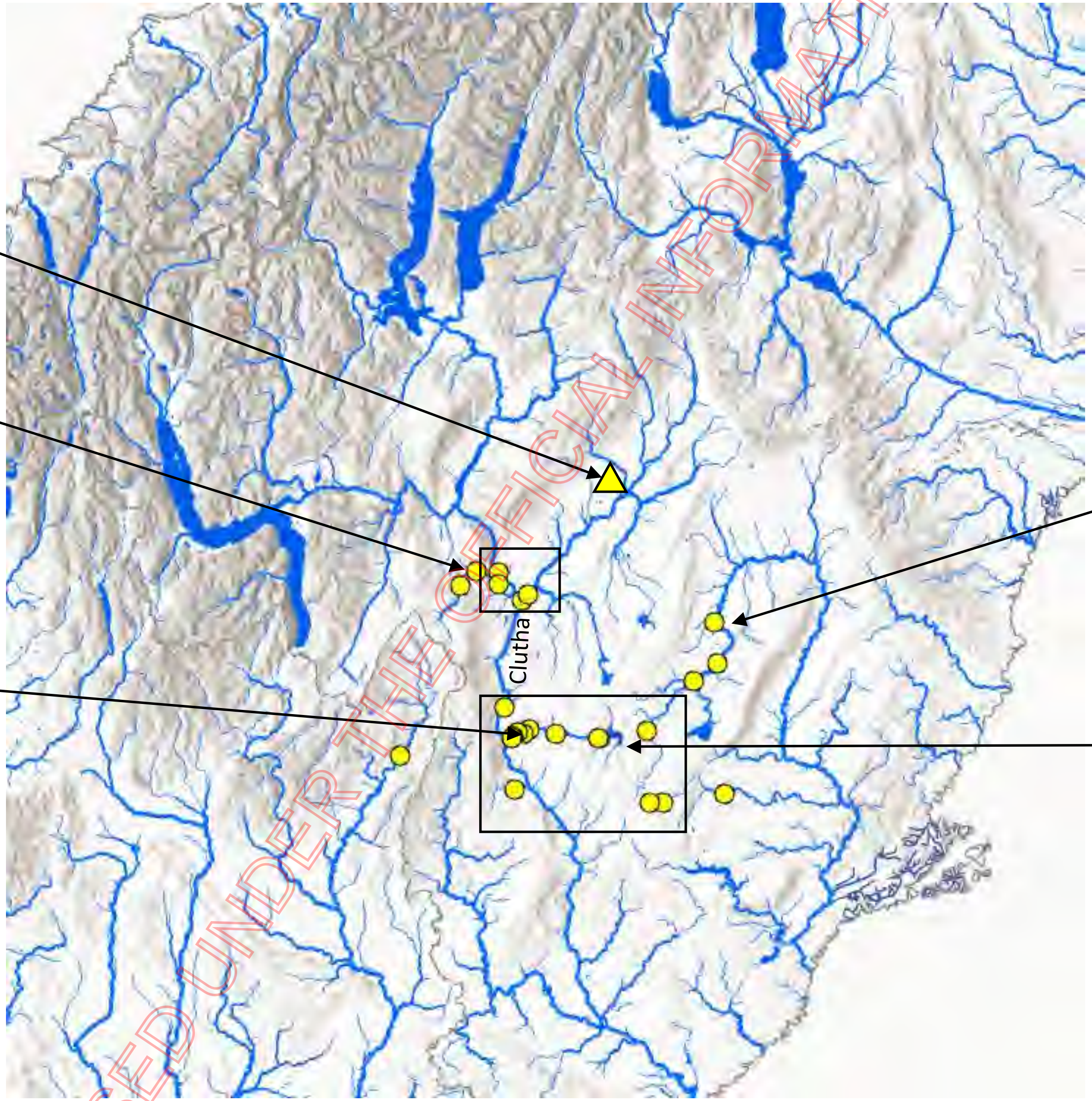
Hydrology: river flows

△ Met Station
○ Flow gauge

Lauder

Alexandra

Pioneer Energy sites on the Teviot River (14 km downstream of the Lake Onslow Dam).

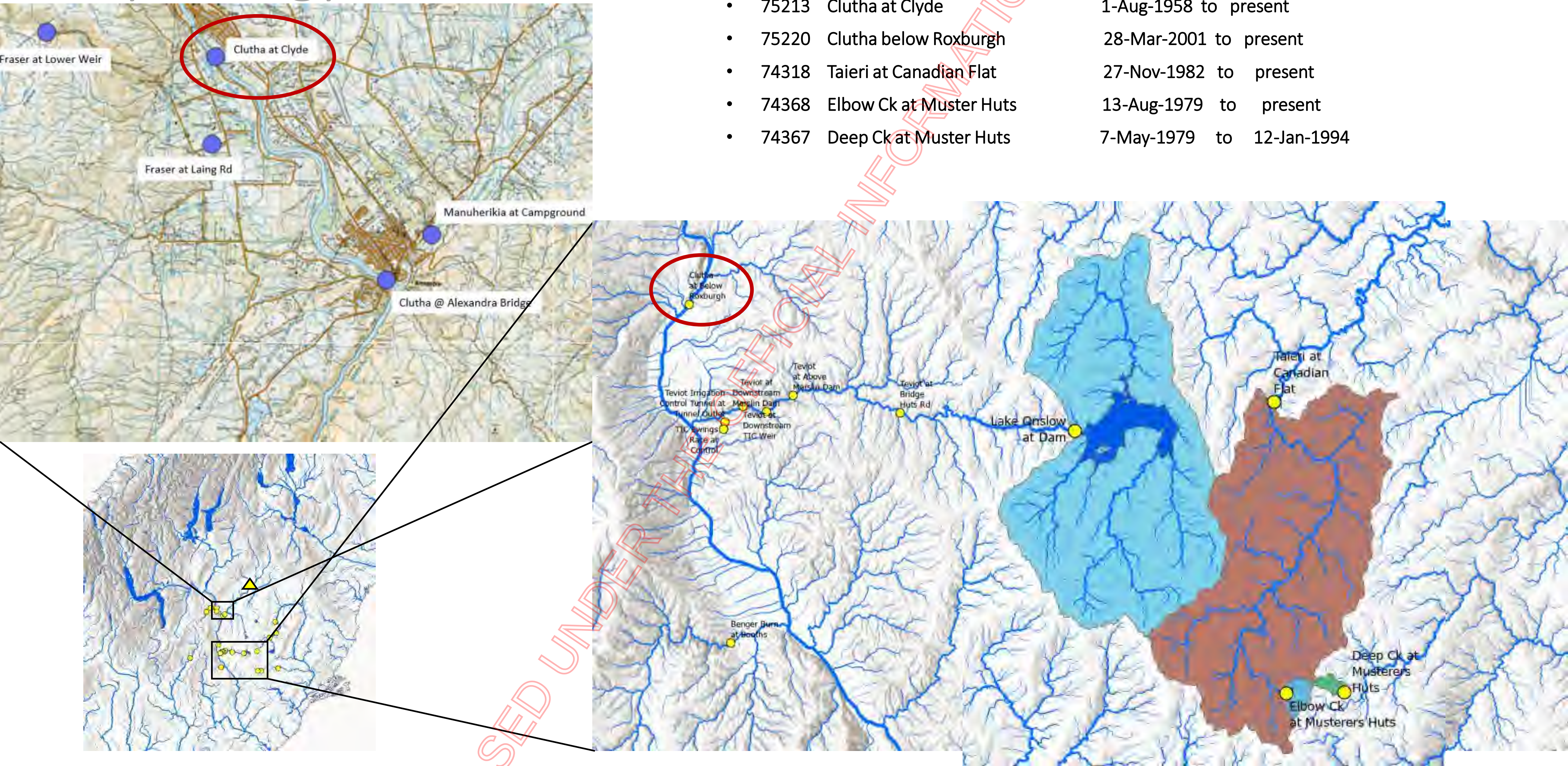


Taieri catchment

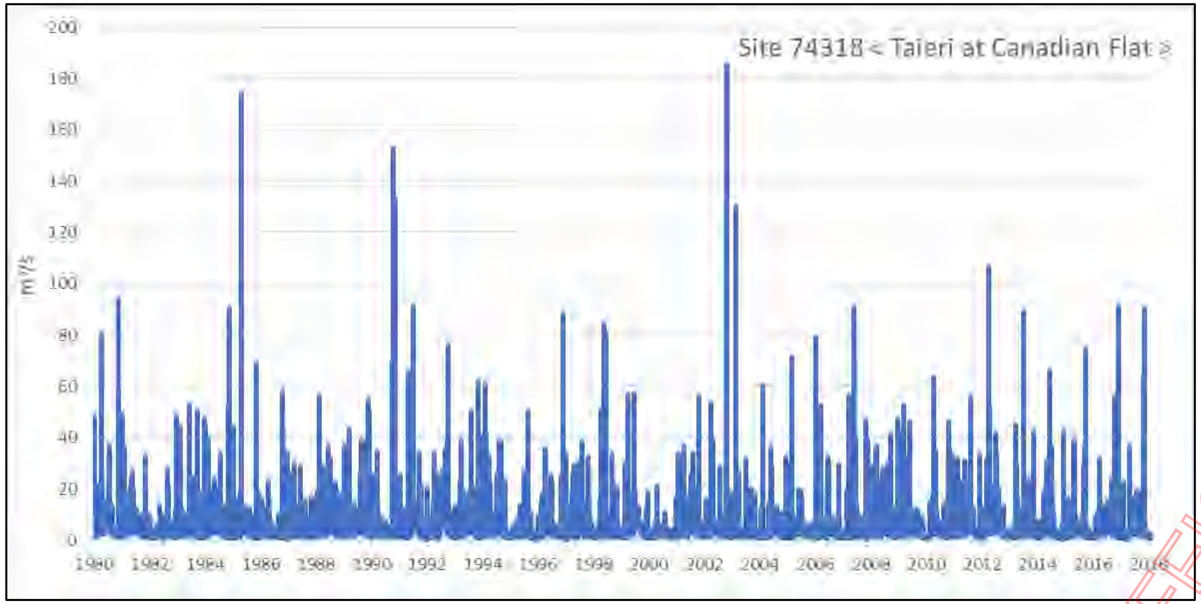
Lake Onslow

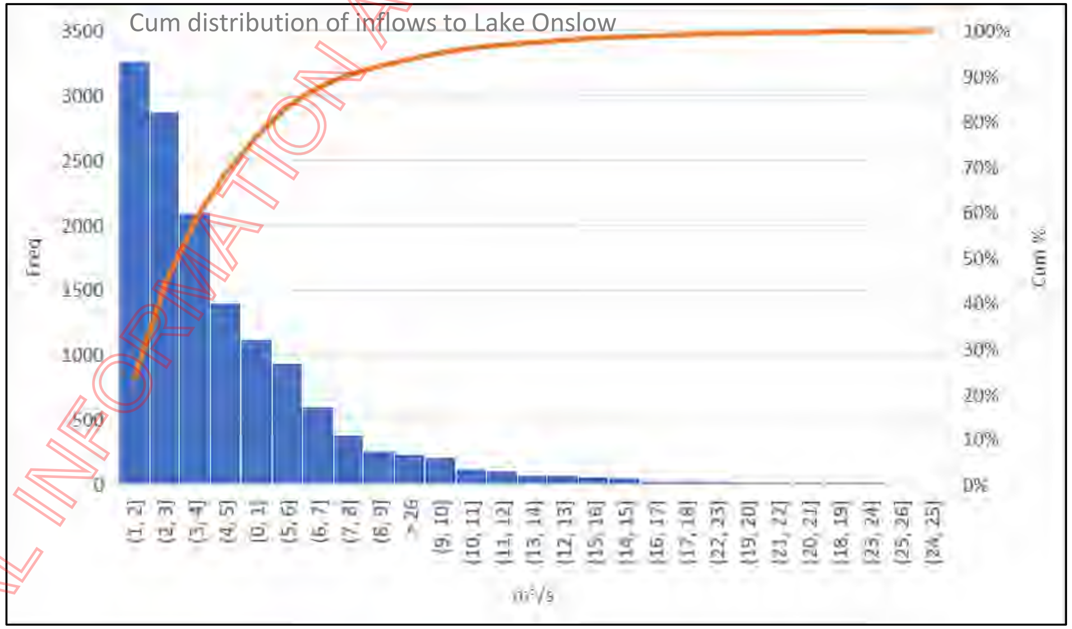
Hydrology : river flows

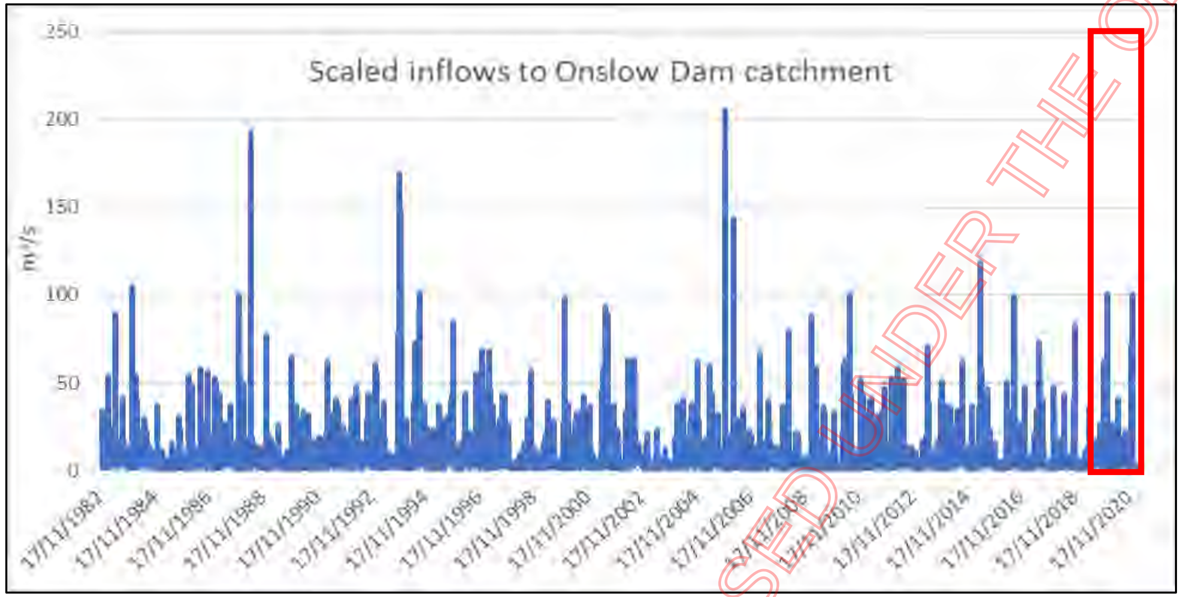
•	75213	Clutha at Clyde	1-Aug-1958	to	present
•	75220	Clutha below Roxburgh	28-Mar-2001	to	present
•	74318	Taieri at Canadian Flat	27-Nov-1982	to	present
•	74368	Elbow Ck at Muster Huts	13-Aug-1979	to	present
•	74367	Deep Ck at Muster Huts	7-May-1979	to	12-Jan-1994

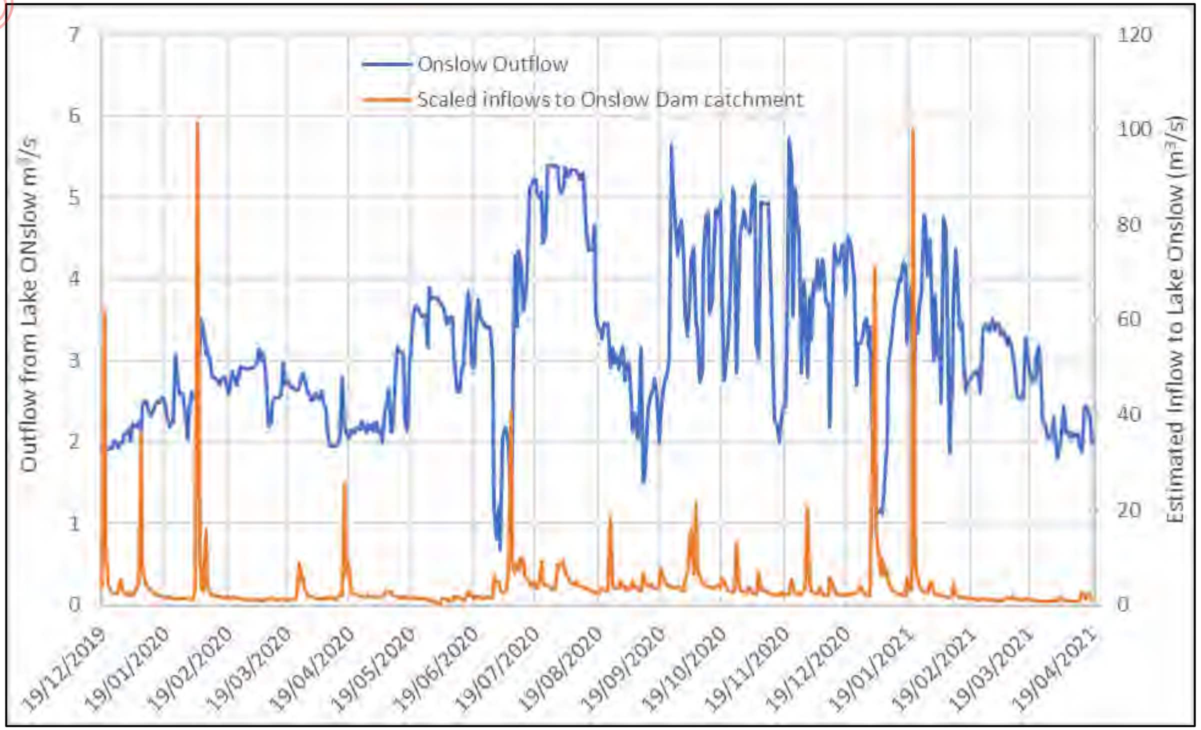


Hydrology: river flows









Hydrology

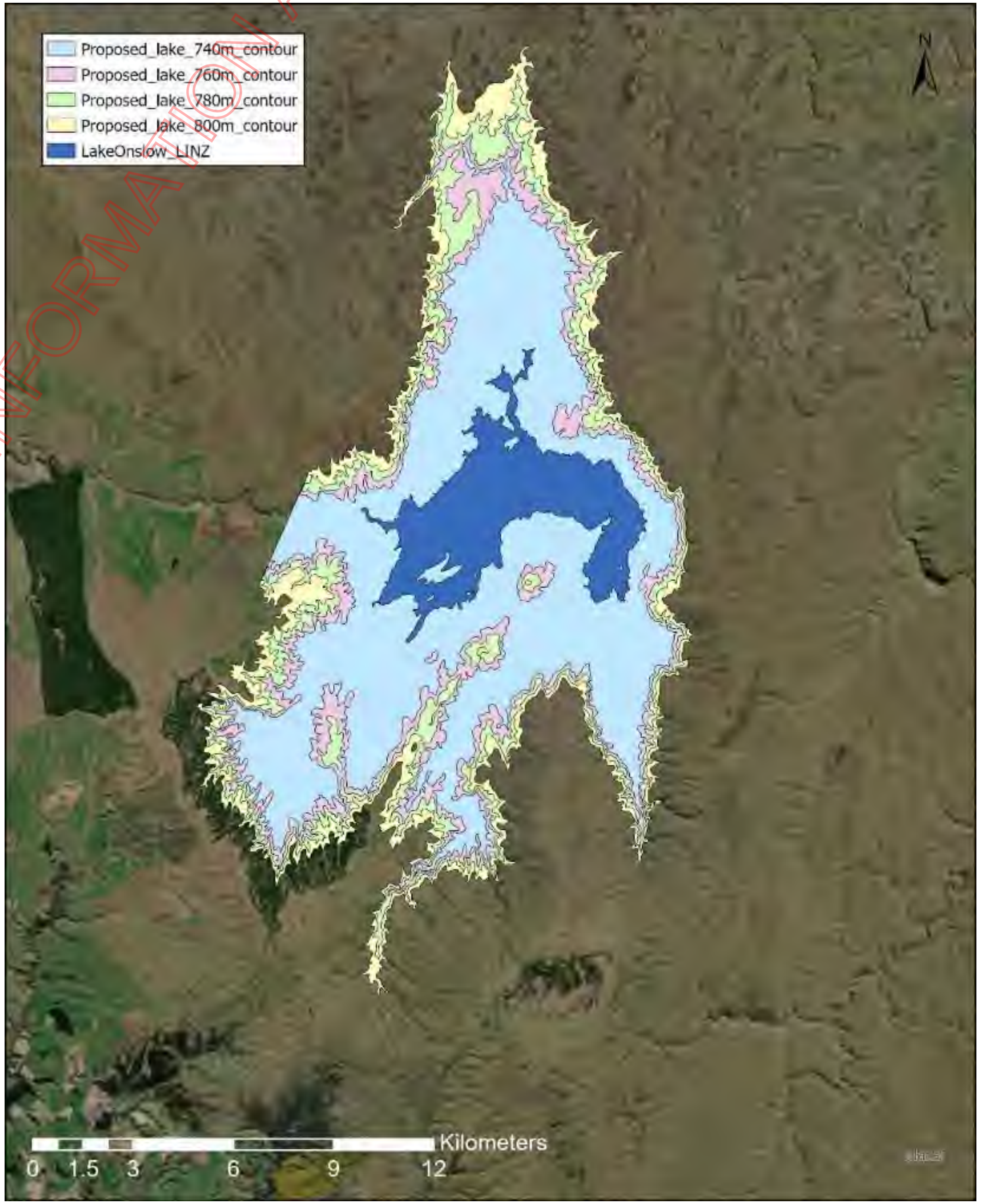
- **Flow statistics** (e.g.7-day mean annual low flow (MALF) for identified sites)
- Historic data from early 1980s to the present, to represent **climate variability**.
- Scaling and/or national models used to estimate **natural inflows** time series to Lake Onslow.
- **Post-development** flow regime likely to be dominated by the import and export of foreign water.
- **Awaiting guidance** on what this flow regime will look like.

Hydrodynamic and water quality modelling

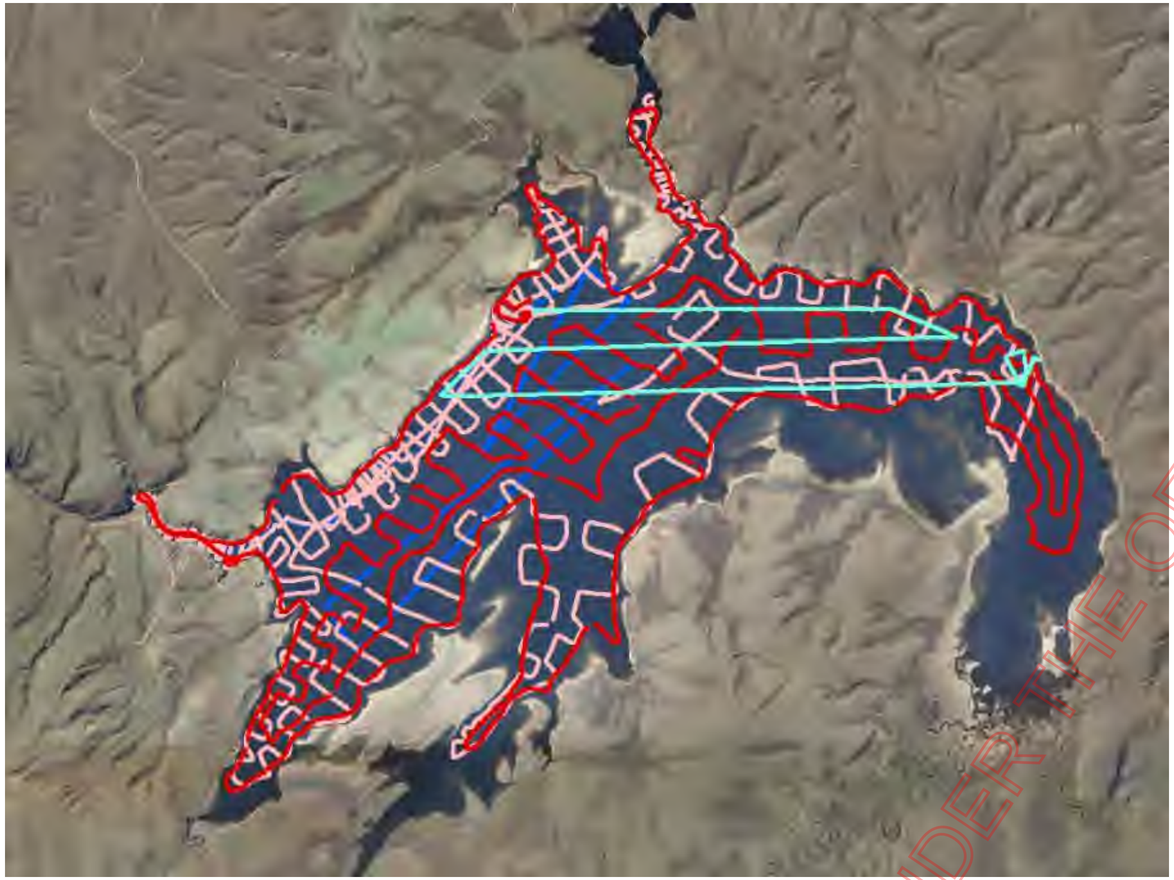
- Does (or when does) the current Lake Onslow stratify?
- Will (or when will) a future Lake Onslow stratify?
- How might nutrient, light, and primary production change?
- What will be the future trophic state of the lake?
- Will bottom waters remain oxygenated throughout summer? Or is there a danger of hypoxia/anoxia that could lead to the release of nutrients and greenhouse gases from the lake bottom?

Hydrodynamic modelling

- 5 lake scenarios
- Input data needs
  - Met data → currently using CliFlo Lauder data
  - Inflows and outflow time series (hydrology)
  - Inflow and outflow temperature not available
  - Morphometry (area vs depth) for each scenario
  - Elevation of inflows and outflow
    - Calibration data
  - Lake level
  - Lake temperature not available → buoy



Bathymetry: current lake morphometry



Hydrodynamic modelling: met inputs

- Compared data from 5 stations, chose CliFlo Lauder for similar elevation
  - Relative humidity: similar across stations except Middlemarch (higher over summer)
  - Precipitation: more at Middlemarch (479 mm/y) and Lauder (452 mm/y) than at Alexandra CWS (395 mm/y), Clyde 2 (381 mm/y) and Alexandra Aws (415 mm/y)
  - Wind speed: Lauder > Alexandra Aws > Middlemarch > Clyde 2 > Alexandra Cws
- Temp. adjusted for elevation difference

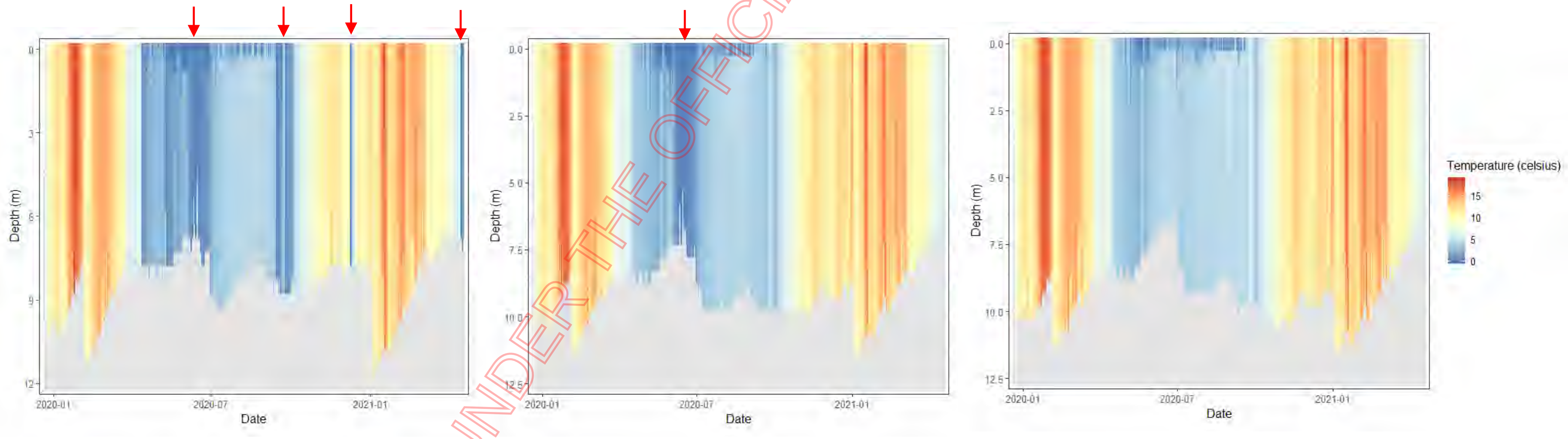
  Temp. lapse rate is 6.5 °C/km. Lauder is at 375 m while Onslow is at 680 m, so might expect temperatures to be 0.0065*(680-375) = 1.98 °C lower than at Lauder.
- Rel. humidity adjusted using Vaisala Humidity Conversion Formulas
- Longwave radiation data

Site number	Name	Lat	Lon	Distance	Elevation	Observing authority
5535	Lauder Ews	-45.0401	169.68419	55.6	375	NIWA
18437	Middlemarch Ews	-45.51814	170.13561	39.4	213	NIWA
36592	Alexandra Cws	-45.25366	169.39205	36.8	170	NIWA
39564	Clyde 2 Ews	-45.20342	169.3182	44.5	140	NIWA
41163	Alexandra Aws	-45.21452	169.37549	41.2	231	MetService

Hydrodynamic (GLM) modelling: preliminary results

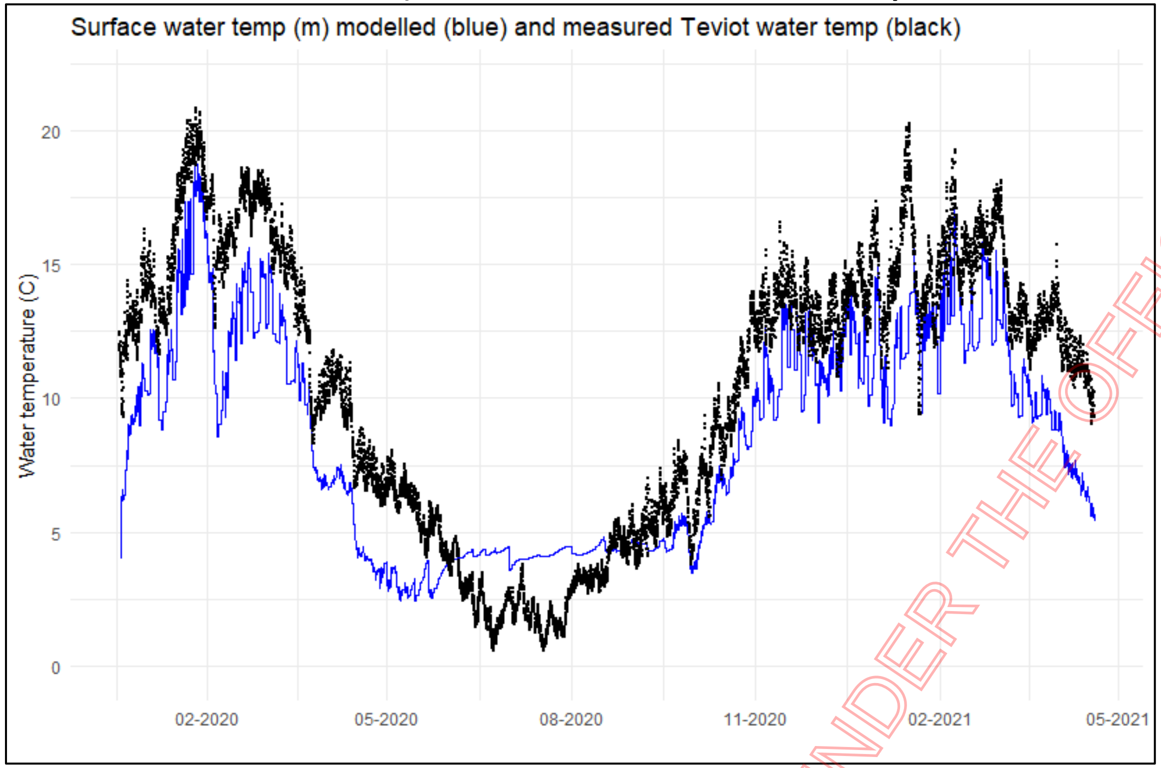
- Current lake morphometry and available input data, otherwise making assumptions (e.g., met data)
- Sensitivity to outflow elevation: the higher the outflow elevation, the fewer cold spells in the lake
- Sensitivity to inflow temperature: need to test this

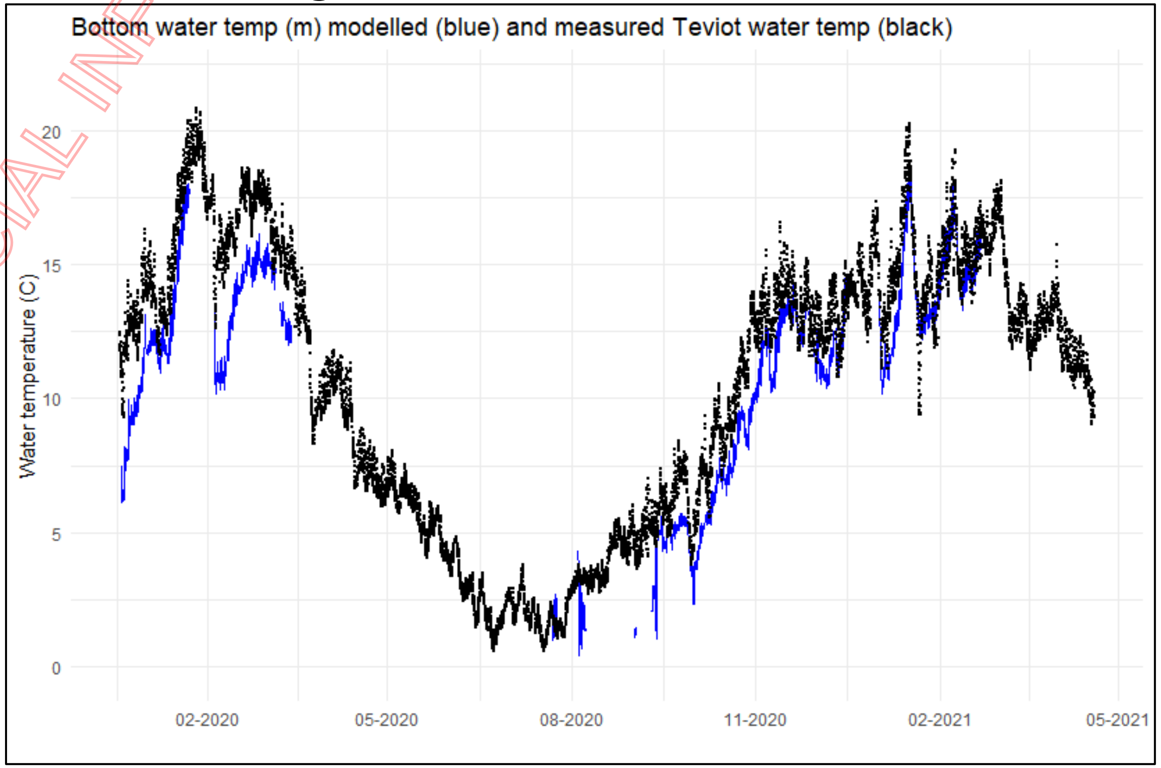
Outflow elevation = 680 m | Outflow elevation = 682 m | Outflow elevation = 683 m

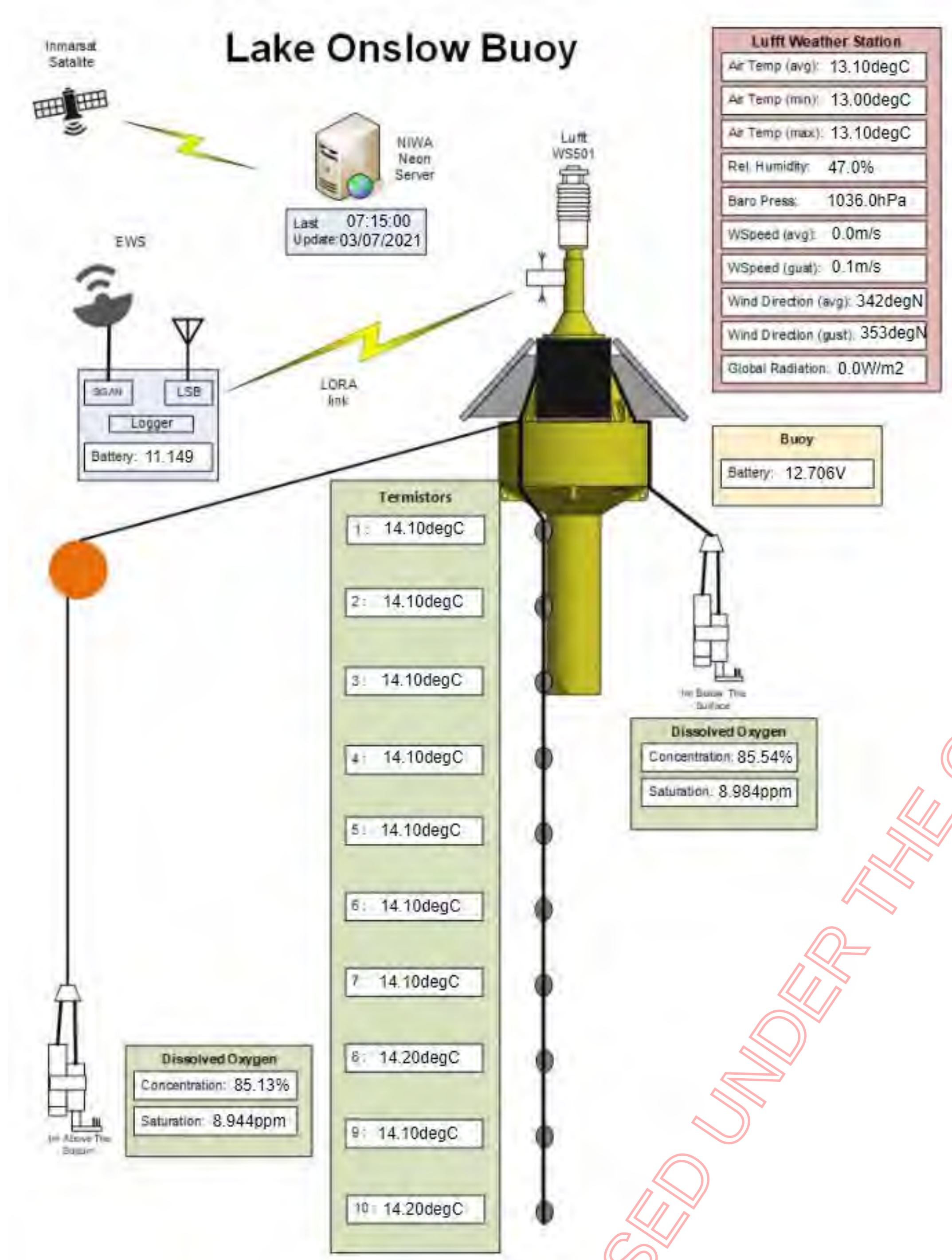


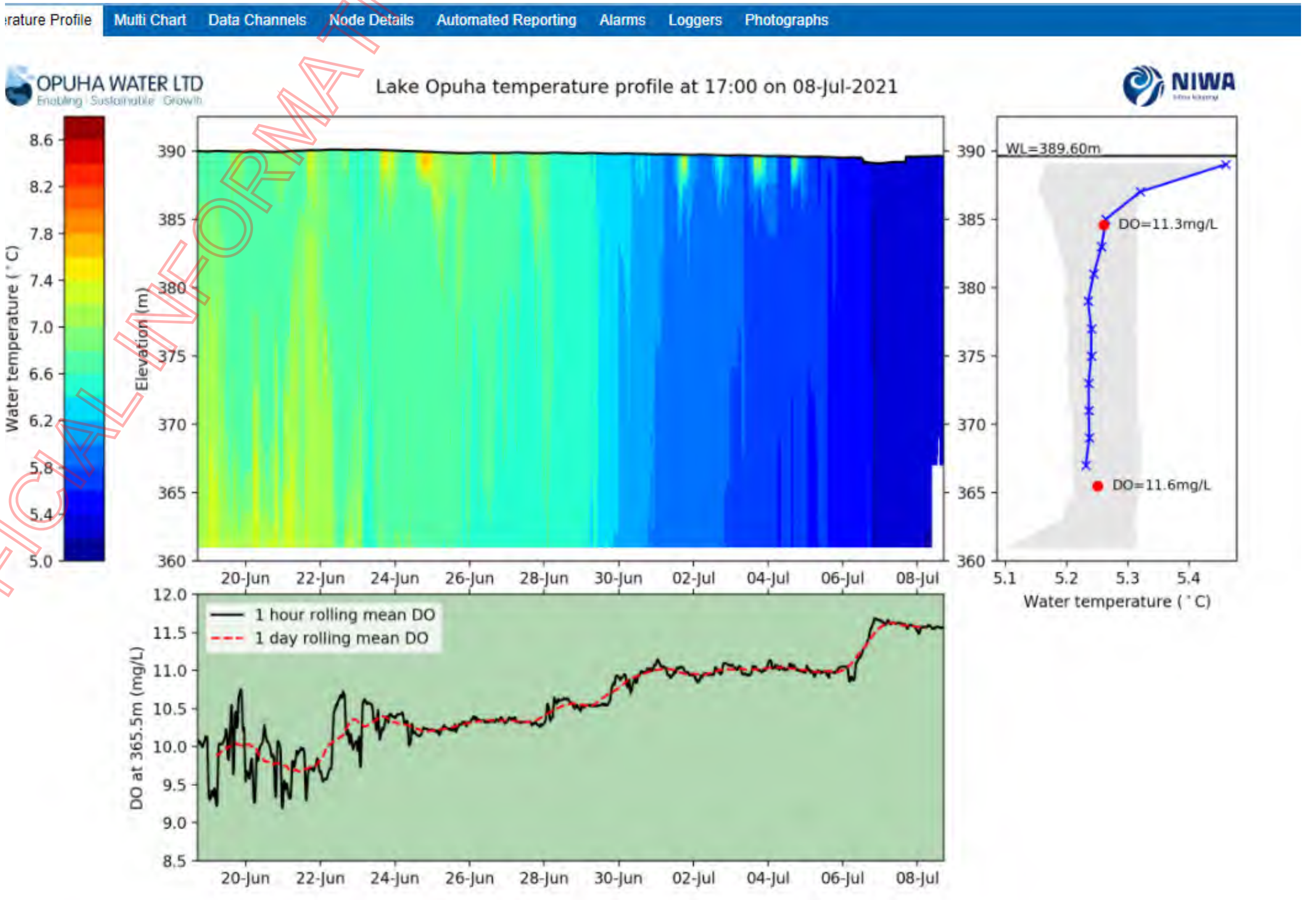
Hydrodynamic (GLM) modelling: preliminary results

- Current lake morphometry and available input data, otherwise making assumptions (e.g., met data)
- Comparison of simulated lake temperature (surface and bottom, with outflow elev. set to 683 m) with Teviot River temperature shows reasonable agreement






Lake Onslow Buoy
Inmarsat Satalite
NIWA Neon Server
Last Update 07:15:00 03/07/2021
EWS
Logger
LSB
Battery: 11.149
LORA link
Lufft WS501
Lufft Weather Station
Air Temp (avg): 13.10degC
Air Temp (min): 13.00degC
Air Temp (max): 13.10degC
Rel. Humidity: 47.0%
Baro Press: 1036.0hPa
WSpeed (avg): 0.0m/s
WSpeed (gust): 0.1m/s
Wind Direction (avg): 342degN
Wind Direction (gust): 353degN
Global Radiation: 0.0W/m2
Buoy
Battery: 12.706V
Termistors
1: 14.10degC
2: 14.10degC
3: 14.10degC
4: 14.10degC
5: 14.10degC
6: 14.10degC
7: 14.10degC
8: 14.20degC
9: 14.10degC
10: 14.20degC
Dissolved Oxygen
Concentration: 85.54%
Saturation: 8.984ppm
Dissolved Oxygen
Concentration: 85.13%
Saturation: 8.944ppm


Multi Chart
Data Channels
Node Details
Automated Reporting
Alarms
Loggers
Photographs
OPUHA WATER LTD
NIWA
Lake Opuha temperature profile at 17:00 on 08-Jul-2021
Water temperature (°C)
Elevation (m)
WL=389.60m
DO=11.3mg/L
DO=11.6mg/L
Water temperature (°C)
1 hour rolling mean DO
1 day rolling mean DO
DO at 365.5m (mg/L)
20-Jun 22-Jun 24-Jun 26-Jun 28-Jun 30-Jun 02-Jul 04-Jul 06-Jul 08-Jul

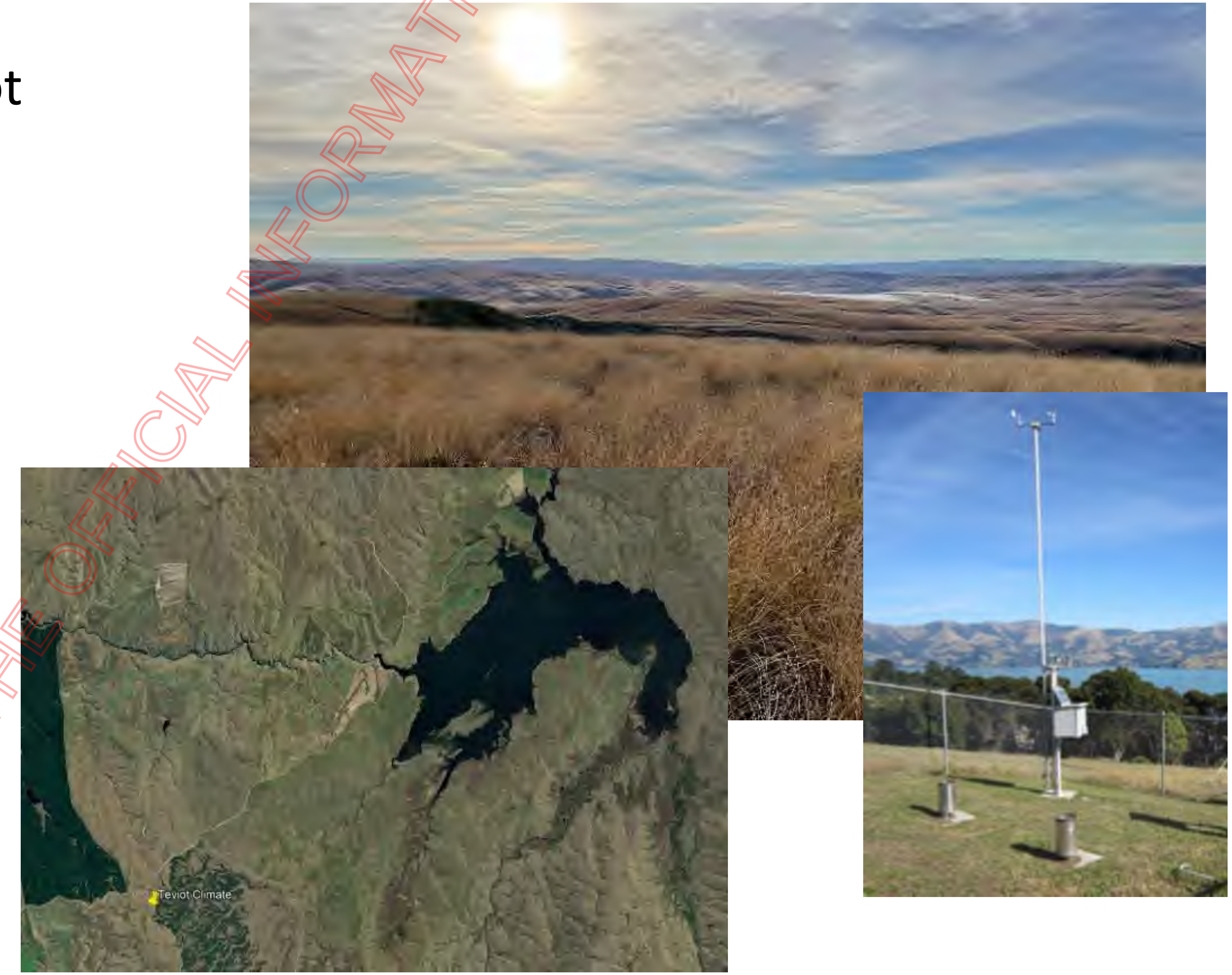
Buoy location

Depth ~ 6.5 m

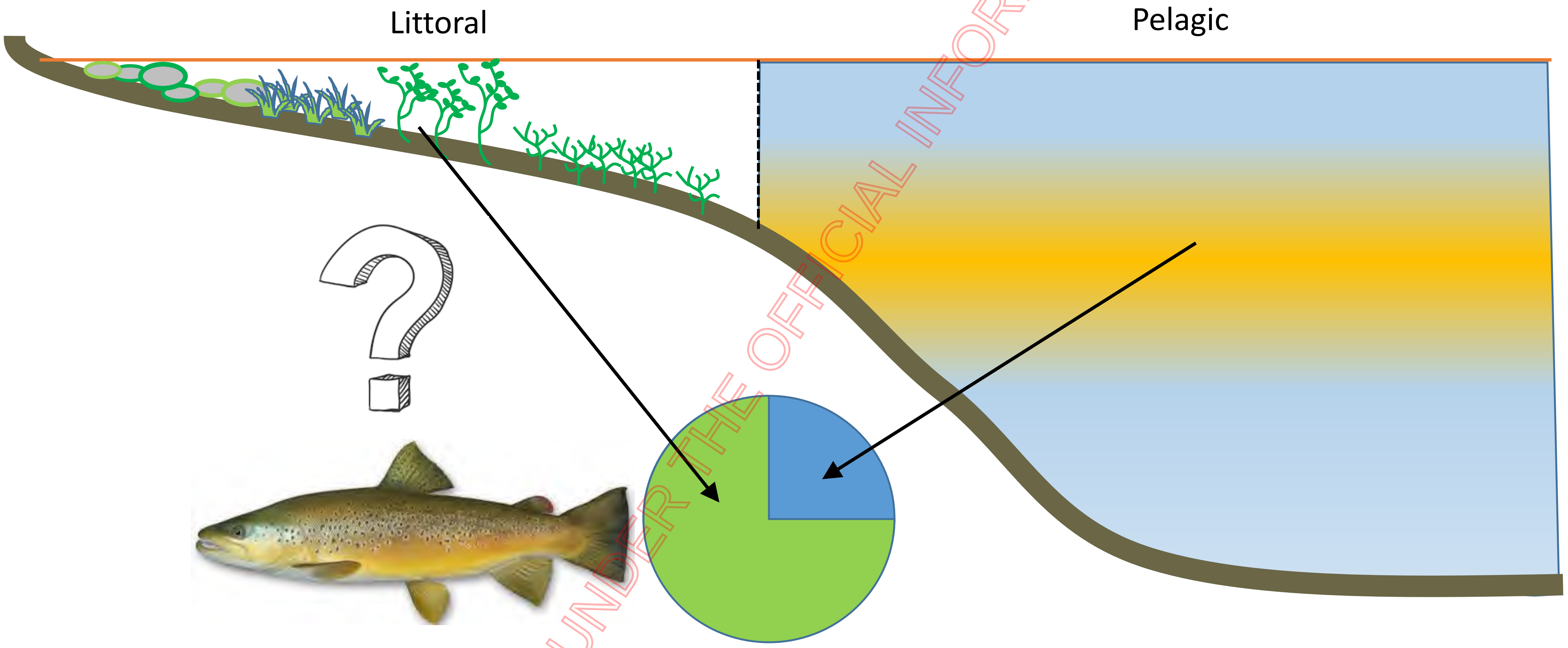
Monitoring weather and climate effects on Lake Onslow

Meteorological station near Mt Teviot

- Temperature
- Relative humidity
- Wind speed and direction
- Rainfall
- Barometric pressure
- Snow
- Solar radiation
  - Shortwave
  - Longwave

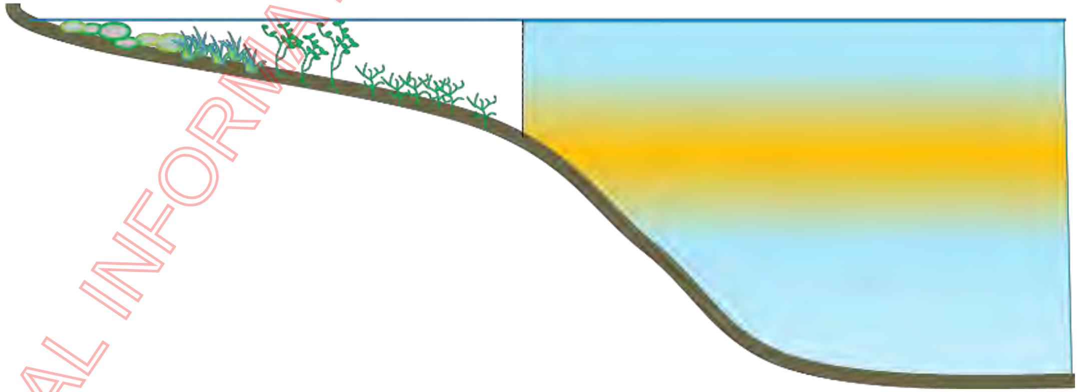


Why is lake level fluctuation a risk to trout productivity?



What is the relative contribution of littoral and pelagic habitats to trout production in Lake Onslow?

- Stable isotope analysis
- Time-integrated chemical tracer of broad carbon/energy dependencies of consumers
- Three channels of energy targeted in Onslow:
- (1) Detritus (littoral mostly = *Chironomus*)
- (2) Periphyton (littoral = snails)
- (3) Plankton (pelagic = zooplankton)



Littoral

Pelagic

What is the relative contribution of littoral and pelagic habitats to trout production in Lake Onslow?

- 3 – 5 sites, depending on resources
- Span heterogeneity of shoreline
- Replicate samples along replicate transects spanning depth-structured habitats

Summary

• Met station installation	This week
• Buoy deployment	This week
• Hydrodynamic modelling	In progress
• Greenhouse gas emissions estimates	In progress
• Literature reviews	**In progress**
• Biosecurity: macrophytes, lamprey	
• Overseas pumped hydro-storage	
• Fish food web study	Fieldwork planned for December

Thank you

s 9(2)(a)

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Climate, Freshwater & Ocean Science

NIWA
Taihoro Nukurangi

Today's programme

No	Time	Item	Lead
1.	9.30am – 9.35am	Welcome / Karakia	Adrian Macey and Hoani Langsbury
2.	9.35am – 10.15am	Project news update • Project status update past and future milestones	Andrew Millar and Carl Walrond
3.	10.15am – 11.30am	**Workstream 1** – Lake Onslow update • Progress update on the Environmental and Geotechnical engineering investigation tender and next steps. **Workstream 3** – Non hydro options – next steps	Sam Treceno, Carl Walrond and Bridget Moon
4.	11.30am – 11.45am	**Coffee / Tea break (15 mins)**	
5.	11.45am – 12.45am	Stakeholder update • Environmental and cultural fieldwork –landowner access • Stakeholder timeline for the LO engineering investigation work – approach, timings, process • Industry meeting discussions	Maria Hernandez –Curry and Carl Walrond
6.	12.45am – 1.15pm	**Lunch (30 mins)**	
7.	1.15pm – 1.45pm	NIWA work on correlations between wind and rain and impact of climate change	Carl Walrond, Malcom Schenkel and s 9(2)(a)
8.	1.45pm – 2.30pm	NIWA scientists - Freshwater update	s 9(2)(a)
9.	2.30pm – 3.00pm	Q&A Summary	Adrian Macey

NZ Battery Project Technical Reference Group Meeting

9 November 2021 – Online

Today’s programme

No	Time	Item	Lead
1.	9.30am – 9.35am	Welcome / Karakia	Adrian Macey and Hoani Langsbury
2.	9.35am – 10.15am	**Project news update** Project status update past and future milestones, Stakeholder update	Andrew Millar and Adrian Tweeddale
3.	10.15am – 11.00am	Workstream 1 – Lake Onslow pumped hydro and geotechnical programme update	Adrian Tweeddale
4.	11.00am – 11.20am	**Coffee / Tea break (20 mins)**	
5.	11.20am – 12.30pm	Dry year problem – brainstorming session on what is a dry year?	Malcolm Schenkel
6.	12.30pm – 1.00pm	**Lunch (30 mins)**	
7.	1.00pm – 1.30pm	Dry year discussion – continued	Malcolm Schenkel
8.	1.30pm – 2.15pm	Workstream 4 – Progress update	Conrad Edwards
9.	2.15pm – 2.30pm	Q&A Summary	Adrian Macey

NZ Battery Project update

For this session:

Purpose of this session

- Give you an overall project status update, cover off the current work underway and a general stakeholder overview
- Milestones we completed over the past 6 weeks
- What is coming up over the next 6 weeks

What we want from you

- This is for your information but please provide feedback or observations

Last 6 weeks' milestones

Lake Onslow pumped hydro

- ✓ We have negotiated and signed a contract and kicked off Te Rōpū Matatau (Mott MacDonald in consortium with GHD and Boffa Miskell) for the Lake Onslow engineering, geotechnical and environmental investigation. This investigation will be a key input into the feasibility of Lake Onslow.
- ✓ We have been working closely with landowners around Lake Onslow to secure access for further upcoming environmental and cultural fieldwork. We are close to getting land access agreements formalised and signed.

Other pumped hydro

- ✓ Identified potential alternative pumped hydro locations based on a GIS scan by NIWA and a direct industry engagement. Procurement process being finalised.

Non hydro options

- ✓ Developed a project scope of works for comparator technologies. On 1 October, we sent an Advance Notice of procurement for a feasibility study into comparator technologies to nine pre-selected suppliers on the All of Government Consultancy Services Panel. RFP issued 15 October.

Market integration

- ✓ We have commissioned further gross benefit economic analysis of Lake Onslow, as well as other potential pumped hydro sites

Next 6 weeks' milestones

A workshop with Treasury to discuss the alignment between the feasibility study and business case process was held on 27 October. Conversations are ongoing to finalise a approach before the end of the year.

Lake Onslow pumped hydro

- We are progressing through a series of kick-off workshops with Te Rōpū Matatau to finalise the arrangements for planned geotechnical investigations.
- Finalising access agreements with Lake Onslow landowners to support environmental and cultural fieldwork. Minister travelled down to Otago and met with the Teviot Valley community and affected landowners on 2 November.

Other pumped hydro

- We are proposing to procure desktop engineering and environmental support to further scope the preliminary findings from NIWA to determine whether these sites are genuinely prospective, and rule in or out any options, before generating significant uncertainty in these communities.

Non hydro options

- Complete RFP process and evaluate tenders for feasibility study into comparator technologies. Tender will close in the first week of November.

Market integration

- We are preparing more detailed independent SDDP modelling of NZ Battery options (including transmission costs), and Lake Onslow in particular. We will also work with Transpower to support this work.

Stakeholder update

Environmental and Cultural Fieldwork – next steps with Landowners

- Minister travelled down to Lake Onslow and surrounds on 2 November to meet with local landowners and community representatives. The trip proved successful and was a good insight into the challenges the Project faces.
- Land access approval is still a challenge for us but we are have sought external advice from WSP on the land access process and industry best practice.
- We have also talked to Waka Kotahi, Transpower and LINZ. Our preference in the first instance is a negotiated agreement. Without extensive fieldwork coverage there is the risk of large data gaps, which could undermine any recommendation on feasibility .
- Due date for access agreements to be signed is currently 19 November so we can get subcontractors booked in but we may need to give more time to landowners.

ENGOs (non-governmental organisations)

- DOC are running a workshop with local Otago based ENGOs in early December with support from MBIE. DOC will explain their work programme in much the same way they presented to the TRG.
- MBIE is considerable future national level ENGO engagement once we have meaningful findings to share.

Conversations are ongoing with other key stakeholders (e.g. electricity, technology groups)

Lake Onslow Feasibility Study Progress

Purpose

Purpose of this session

- To update you on the next steps for the Lake Onslow environmental, geotechnical and environmental investigation work that is underway withTe Rōpū Matatau (TRM).

What we want from you

- This is for your information, but please provide feedback or observations.

Next steps from here

- The Project team are working with TRM to explore different pumped hydro design options for Lake Onslow and review the current detailed geological fieldwork plan with the intention of beginning a procurement process in late November.
- Once agreed the geotechnical work will need resource consent application with ORC and CODC.

Why are we doing these investigations?

Lake Onslow pumped hydro

Is a pumped hydro scheme at Lake Onslow technically, economically, commercially, and environmentally feasible?

Can any adverse impacts or risks be effectively managed or mitigated?

- Cabinet agreed to fund the NZ Battery Project to **identify the best option** or options for managing dry year risk in a highly renewable electricity system.
- Engineering, geotechnical and environmental **investigations** of a pumped hydro scheme at Lake Onslow **will assess its feasibility**
- This investigation is **a key input for Phase 1** of the NZ Battery Project, as it will provide us with design elements and options that will allow us to assess the technical, commercial and environmental feasibility of a Lake Onslow pumped hydro scheme. This **information** will also help form a credible **cost estimate and construction schedules**, on which to make a decision to progress into Phase 2.

What is the scope of this work?

- The scope covers the majority of the technical areas and it is divided in two parts:

Phase 1A: A predominantly desktop-based technical study that will identify the options for the key parameters for the design and configuration of the pumped hydro scheme, and will select the optimal design configuration for more detailed engineering design and geotechnical de-risking.

Phase 1B: A focused technical study, including drilling boreholes, which will provide further engineering detail on the optimal design configuration.

- The remaining areas, such as the assessment of the environmental values, historic heritage values, Ngāi Tahu values, and the archaeological values of the Lake Onslow area, have work already underway.

Workstream 1 - Lake Onslow (Pumped Hydro)

- Minister Woods received the briefing on the procurement process and next steps for the Lake Onslow environmental, geotechnical and environmental investigation. The Minister has agreed with our revised approach.

- We have commenced a series of kick-off workshops with Te Rōpū Matatau (TRM). TRM are making good progress and coming rapidly up to speed with the Project status.

- The Project team are working with TRM to explore different pumped hydro design options for Lake Onslow and review the current detailed geological fieldwork plan with the intention of beginning a procurement process in November.

Workstream 1 - Lake Onslow (Pumped Hydro) … continued

- Conversations continue with landowners regarding access to upcoming environmental, cultural values and non-invasive geotechnical fieldwork. We are aiming to sign the majority of land access agreements with landowners this this month.

- Our preferred approach is to secure land access agreements for the fieldwork under commercial agreements.

- Landowners met with environmental fieldwork subcontractors, environmental planning advisers and property access specialists to ask and receive answers to their questions, independent of MBIE.

- On 2 November, Minister Woods and members of the NZ Battery Project team visited Lake Onslow and surrounds to meet with landowners.


What is a dry year?

This is pre-reading ahead of a group discussion:

Purpose of this material

- Last time members ask for more information about what a dry year is, and hence what problem we're trying to solve
- We have given some thought to the question, but we want to test our thinking by workshopping the issues with you as part of the TRG meeting
- This pre-reading material is intended to get you thinking about some of these issues ahead of the meeting. We will not go through all these slides in session.

What we want from you

- Read the material and think about what it means for the problem we're trying to solve
- Be prepared to share your views and insights at the meeting

Next steps from here

- During the meeting we'll facilitate a brainstorm / discussion about these issues and what it means for the project
- This will ultimately help us to build our problem definition and strategic case for investment

Background

Cabinet paper "December 2020 Update on the NZ Battery Project" gives some direction to frame what NZ battery Project needs to address

1. This paper provides a progress update on the project known as 'the New Zealand Battery', a project to investigate the feasibility of options to address New Zealand's dry year problem in a highly renewable electricity system. The paper also seeks a revision to reporting lines on the project.

3. The purpose of the NZ Battery project is to investigate options to resolve New Zealand's dry year risk problem in a highly renewable electricity system. Dry year risk refers to the shortfall in electricity generation than can occur in a year where inflows to hydro lakes are significantly below normal and the lakes are 'dry'.

5. Dry year risk is a contributing factor to high electricity prices because the electricity market factors the cost of scarcity into electricity forward prices. The NZ Battery project will investigate ways to reduce this effect, thereby allowing electricity price to better follow the downwards trend of new electricity generation investment costs.

9. The revised criteria are:

9.1 Objective – To manage or mitigate dry year risk in the electricity system

9.2 Criteria - Any proposal or group of proposals will be assessed against its ability to:

9.2.1 provide at least [5,000 GWh][1] of energy storage or equivalent energy supply flexibility

9.2.2 provide significant levels of employment for post COVID-19 recovery

9.2.3 reduce emissions either directly or indirectly through facilitating decarbonisation

9.2.4 maximise renewable electricity in order to provide a pathway to achieve the goal of 100 per cent renewable electricity

9.2.5 lower wholesale electricity prices, and

9.2.6 be practical and feasible.

9.3 Any proposals that meet the above criteria will be assessed against the detailed work that will be undertaken on pumped hydro, which will be the primary focus for the project.

[1] The potential magnitude of the dry year problem in 2030 given expected changes in electricity supply and demand, will be investigated as part of the project.

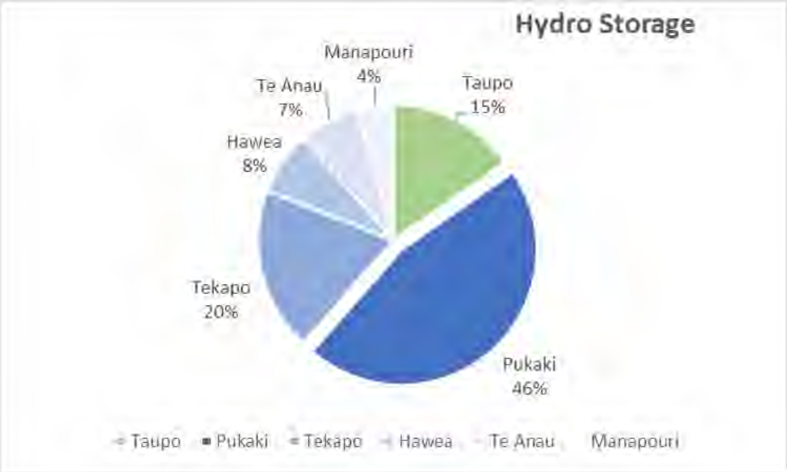
Summarising

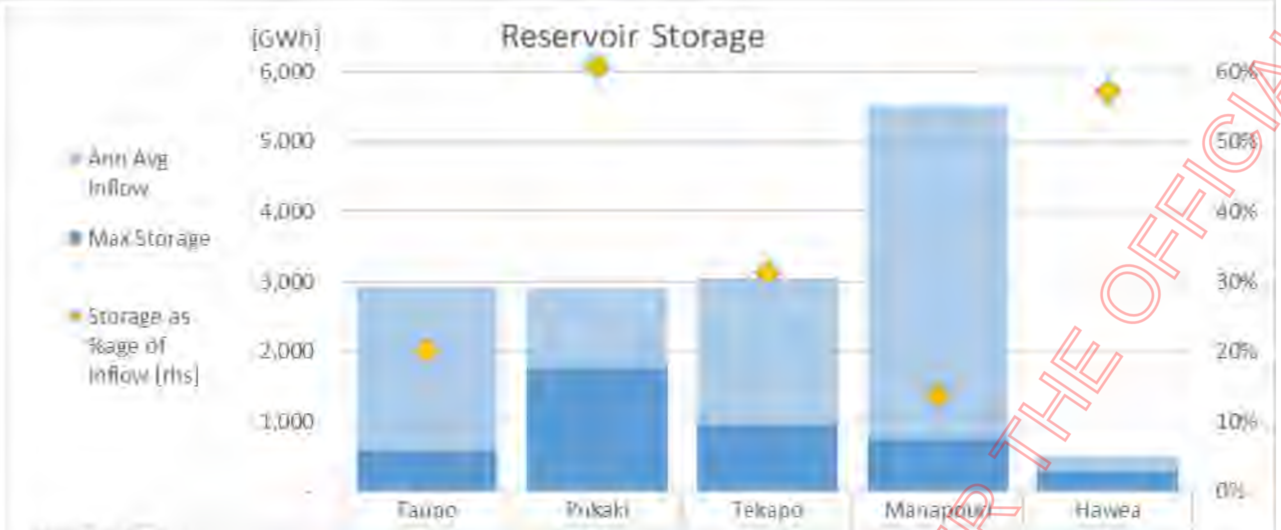
- We need to find a 100% renewable solution to NZs 'dry year' problem
- 'Dry year' has something to do with hydro flows being less than normal, by around 5,000GWh or some other magnitude to be determined
- Lake levels in a 'dry year' are low
- Electricity market spot prices are high in a 'dry year'

Before we look into what may define a 'dry year' we will have a look at current hydro storage is capable of; how big, where located and how long to empty, because low lake levels are an indicator of system stress.

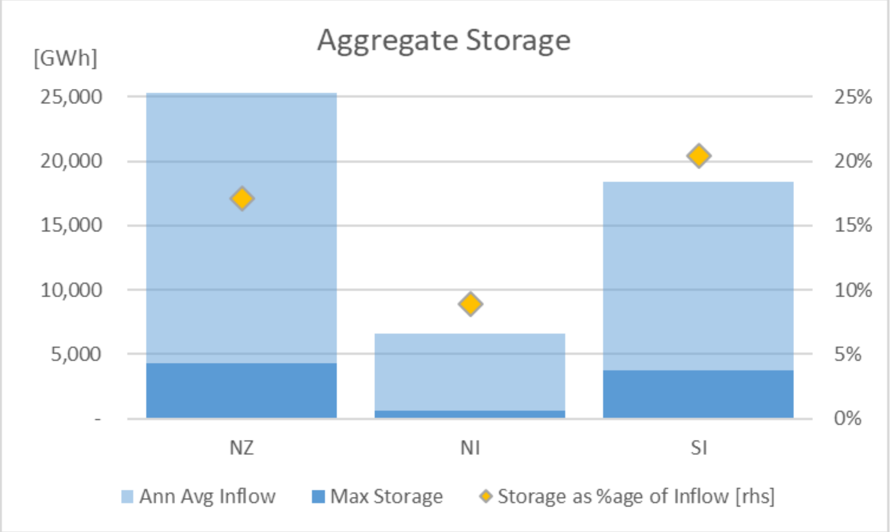
Hydro Storage

- Hydro storage
  - Dominated by South Island reservoirs, 85% of NZ storage in South Island.
  - Lake Pukaki is largest, 46% of national storage.
  - National storage less than 20% of annual total NZ flows
  - And, individual reservoirs can be emptied in a matter of weeks to months





	Taupo	Pukaki	Tekapo	Manapouri	Hawea
Ann Avg Inflow	2,933	2,910	3,035	5,507	510
Max Storage	587	1,768	947	750	292
Weeks to empty	4.4	7.2	10.5	3.1	9.4
Storage as %age of Inflow [rhs]	20.0%	60.8%	31.2%	13.6%	57.2%



What is a dry year?

- We need to solve the 'dry year' problem… but…
    - What is that problem?
    - How big is it?
    - When does it occur and how long does it last?
    - Where is the impact?

What do past dry years tell us about the dry year problem?

- We have inflow data since 1932
- But no other relevant information for most of those years….
- Let's dig into the dry years that we do have some information on…

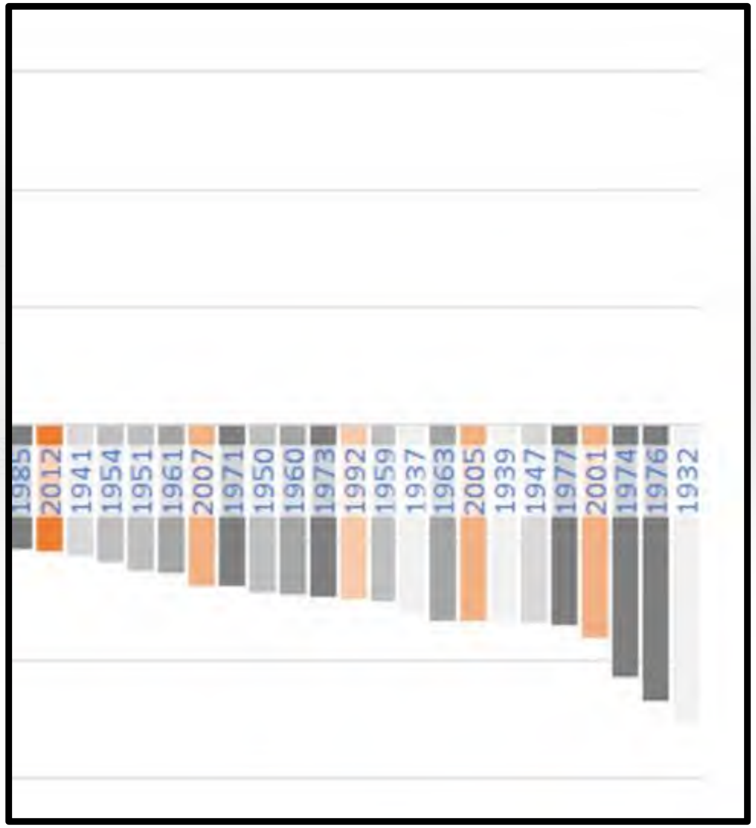
Digging

- Let's look at the 5 driest years for which we have reasonable data

  In order of severity;

  - 2001
  - 2005
  - 1992
  - 2007
  - 2012

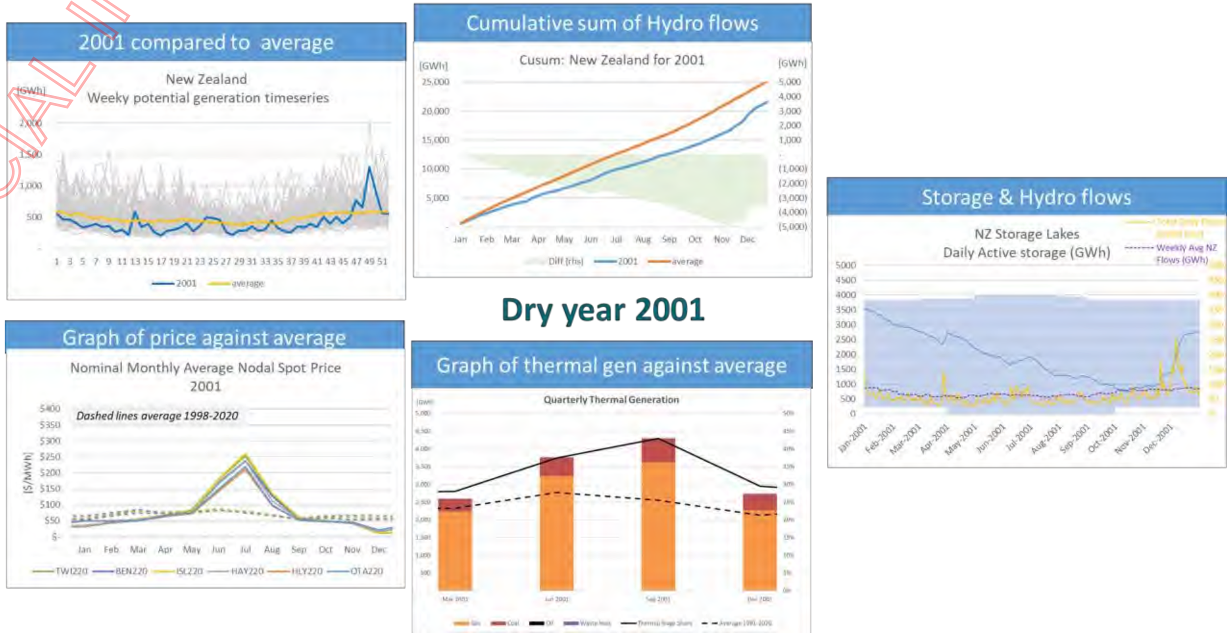
- What did we experience in these years?



The charts

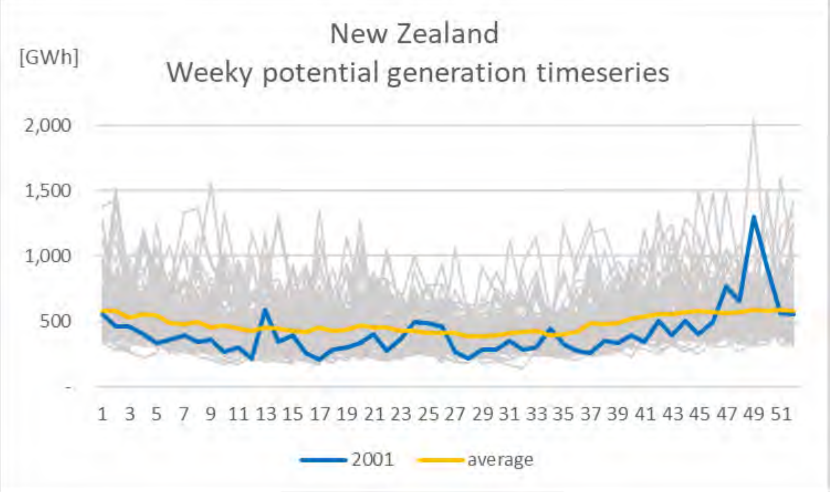
"Dry years" characterised by low hydro flows, falling storage, high prices and above average use of thermal generation.

- Flow year compared to average
  - Variability of weekly flows
- Cumulative sum of hydro flows
  - Cumulative sum of weekly flows, sustained deviation from average
- Graph of price against average
  - Monthly average nodal price for given nodes & year
- Graph of thermal gen against average
  - Thermal generation by fuel (bars), percentage of generation total supplied by thermal generation (lines)
- Storage and hydro flows
  - Use of storage for the particular year



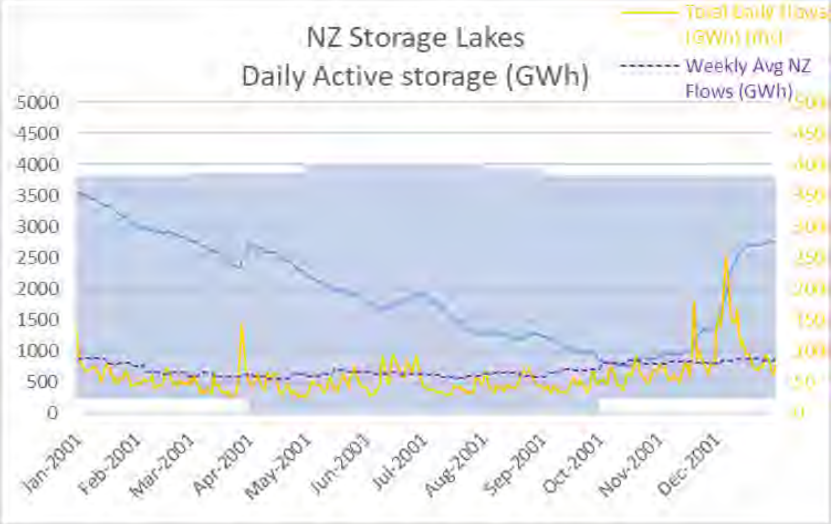
Dry year 2001

2001 compared to average

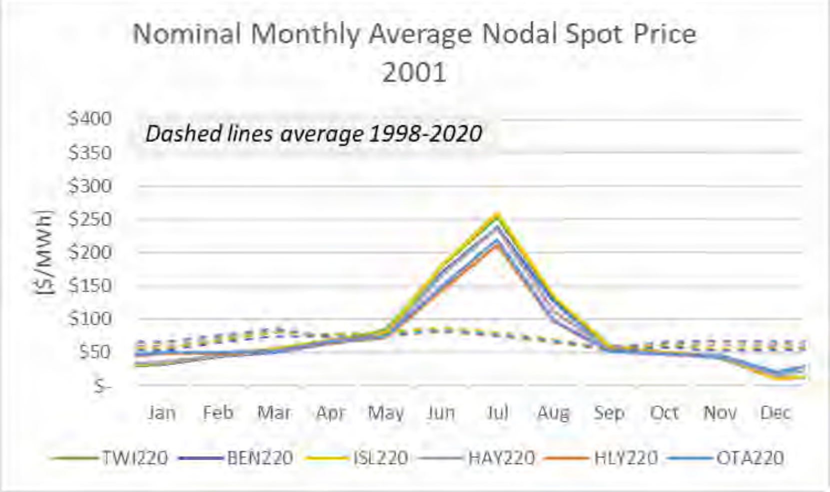


Cumulative sum of Hydro flows

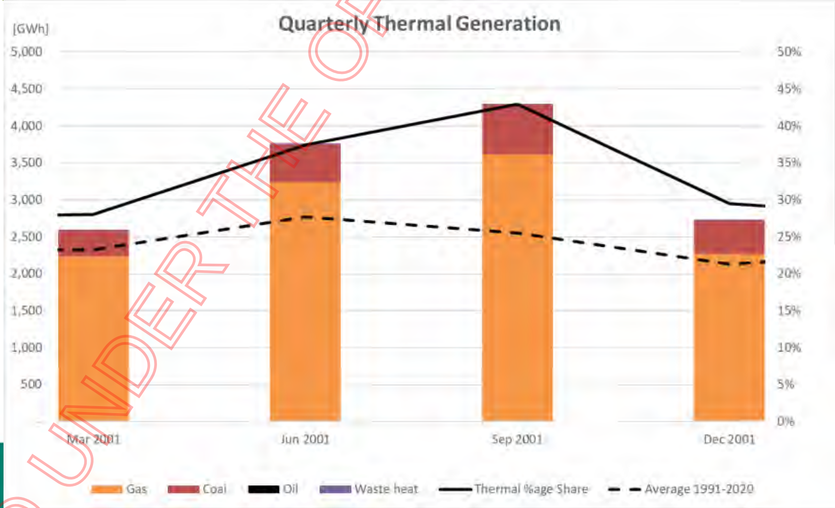
Storage & Hydro flows



Graph of price against average

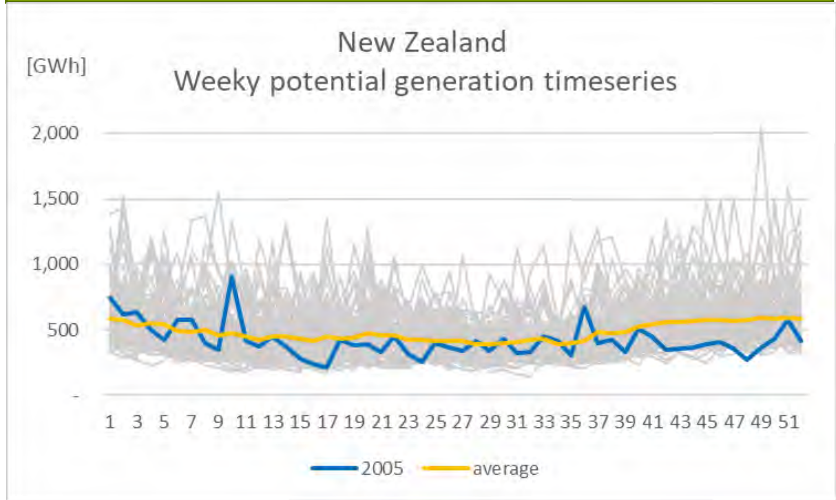


Graph of thermal gen against average

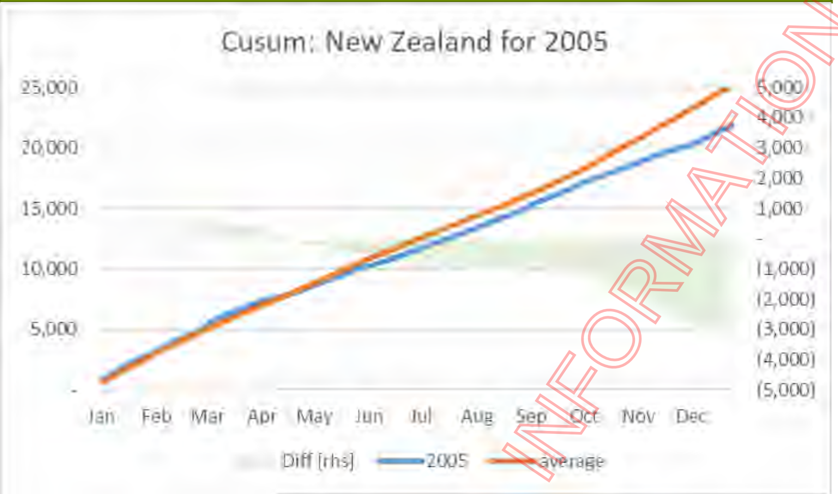


- **Cumulative inflows** below average throughout the year – culminating at ~ 5,000 GWh below average by November
- **Lake storage** drawn down steadily with national storage under 1,000 GWh by November
- **Prices** spike Jun/Jul/Aug
- **Thermal generation** elevated well above average in September quarter

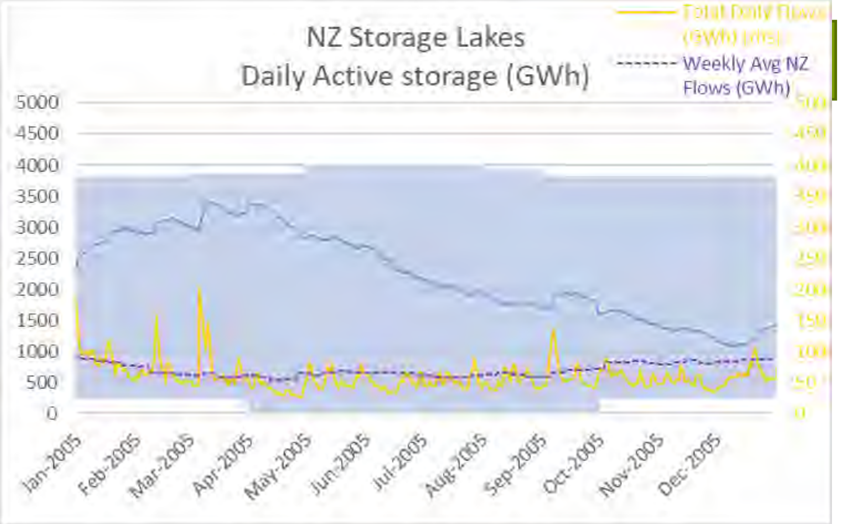
2005 compared to average



Cumulative sum of Hydro flows

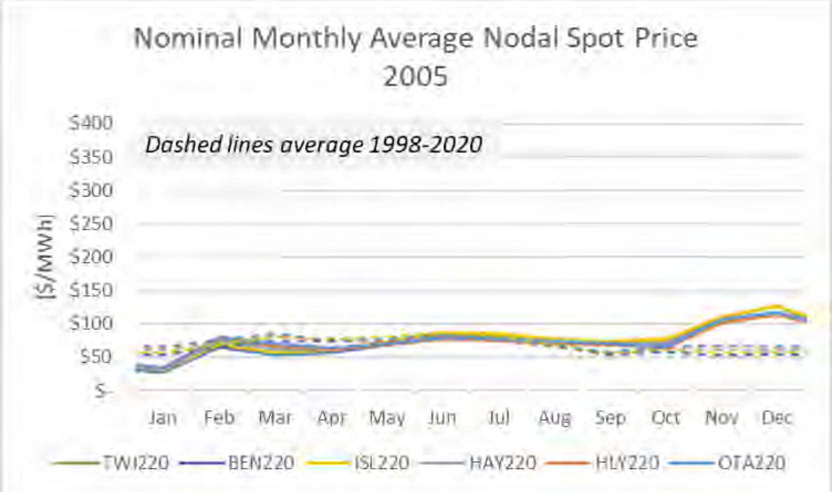


Storage & Hydro flows

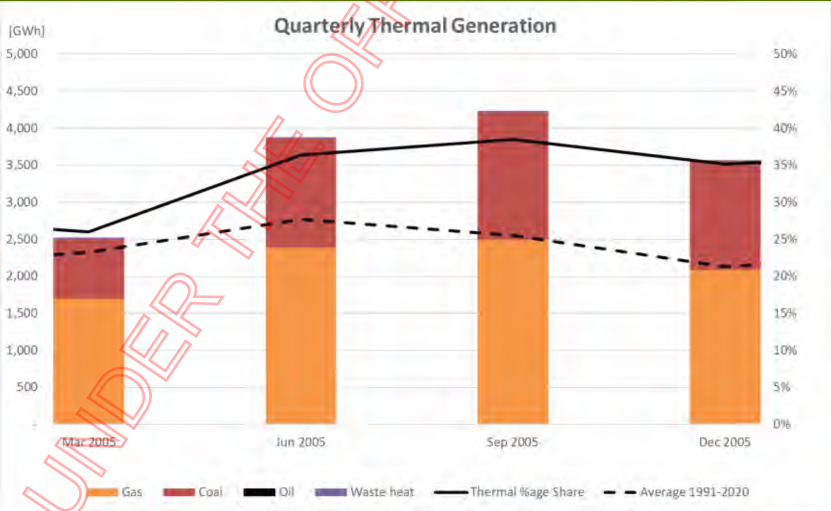


Dry year 2005

Graph of price against average

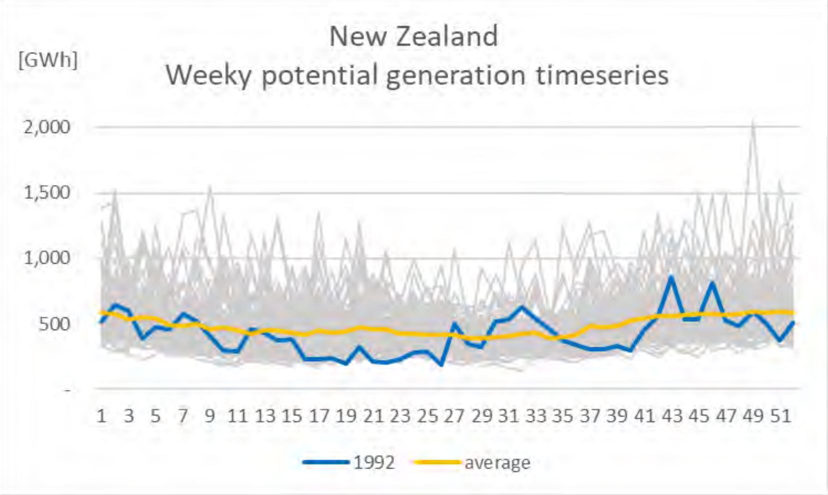


Graph of thermal gen against average

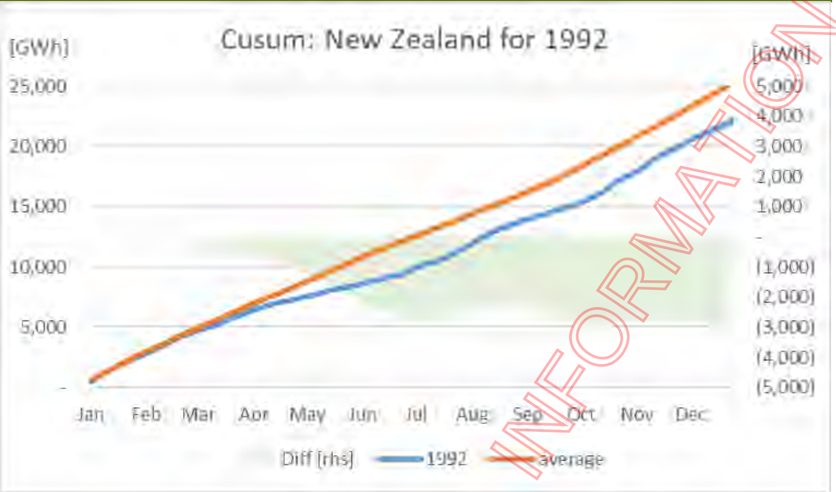


- **Cumulative inflows** below average throughout the year – eventually at ~ 3,000 GWh below average for the year
- **Lake storage** built up during Summer/Autumn before steady decline through Winter
- **Prices** near average through Winter
- **Thermal generation** elevated above average from Winter onwards

1992 flows compared to average

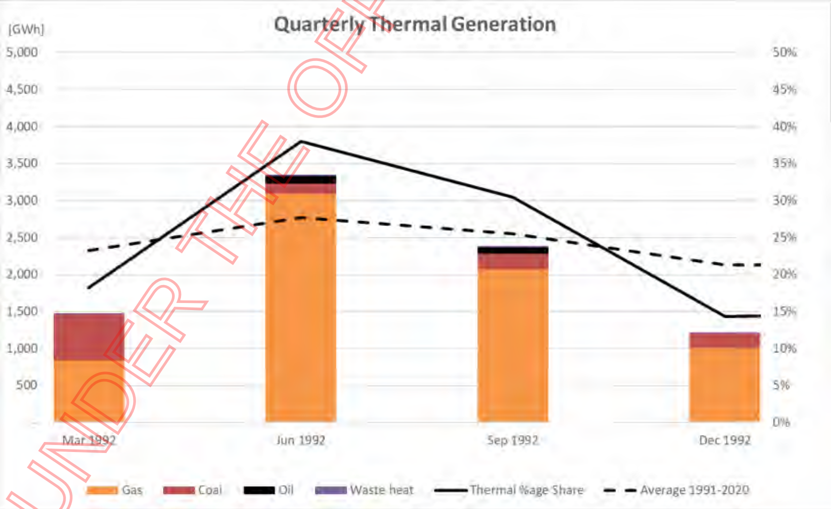


Cumulative sum of Hydro flows

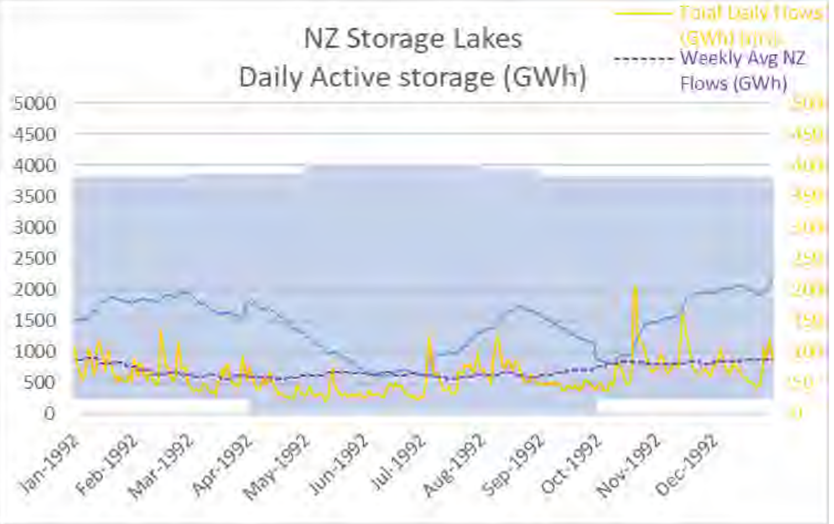


Dry year 1992

Graph of thermal gen against average

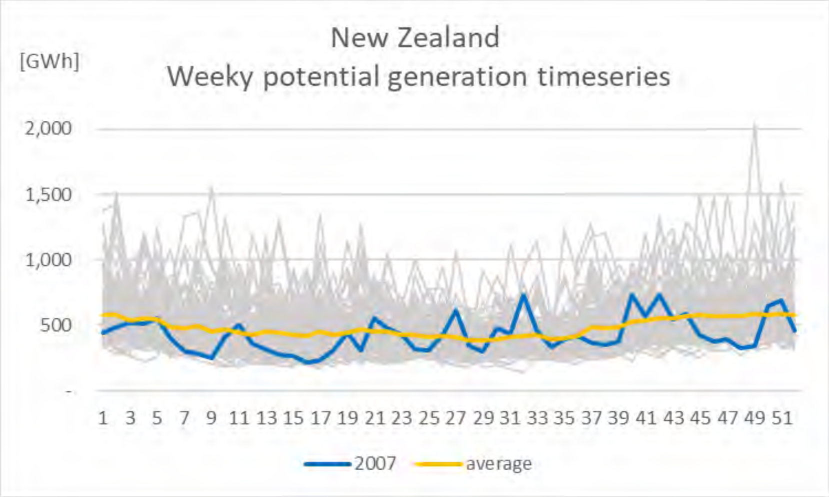


Storage & Hydro flows



- **Cumulative inflows** average through Summer then decline sharply to remain ~ 3,000 GWh below average for the rest of the year
- **Lake storage** started year low, held steady 'til Winter, declined sharply to very low levels mid Winter before recharging
- **Prices** no market – no nodal prices in 1992
- **Thermal generation** elevated above average for June quarter, especially

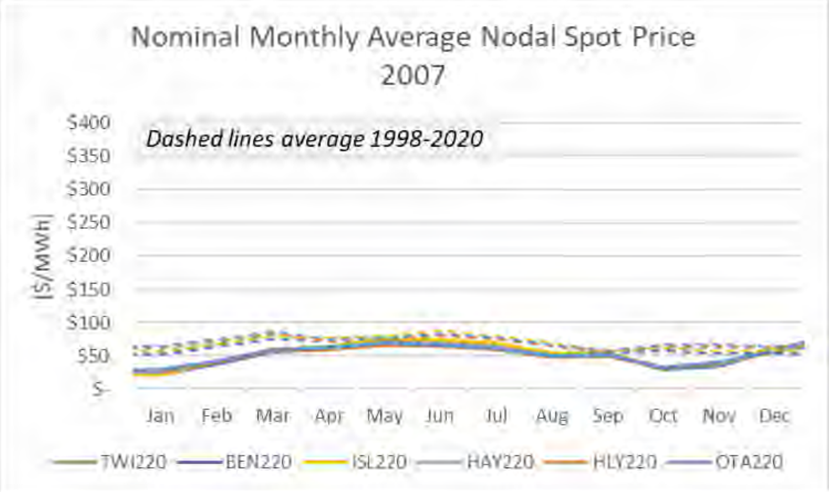
2007 flows compared to average



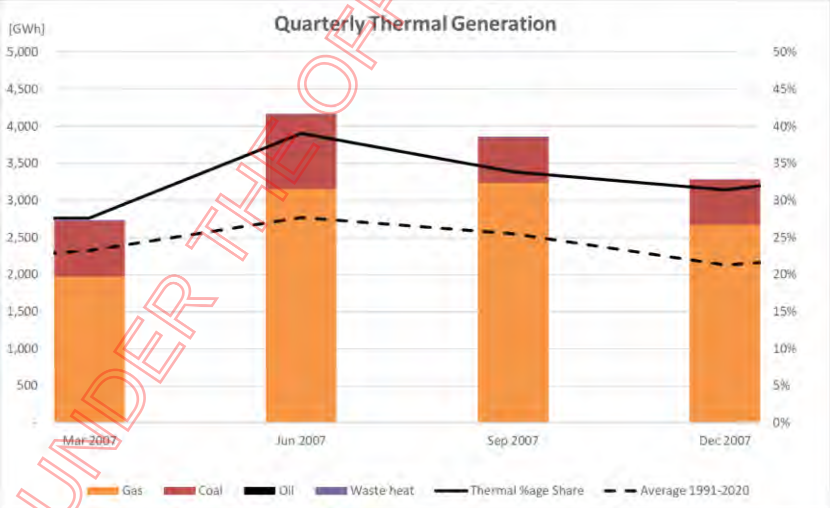
Cumulative sum of hydro flows

Dry year 2007

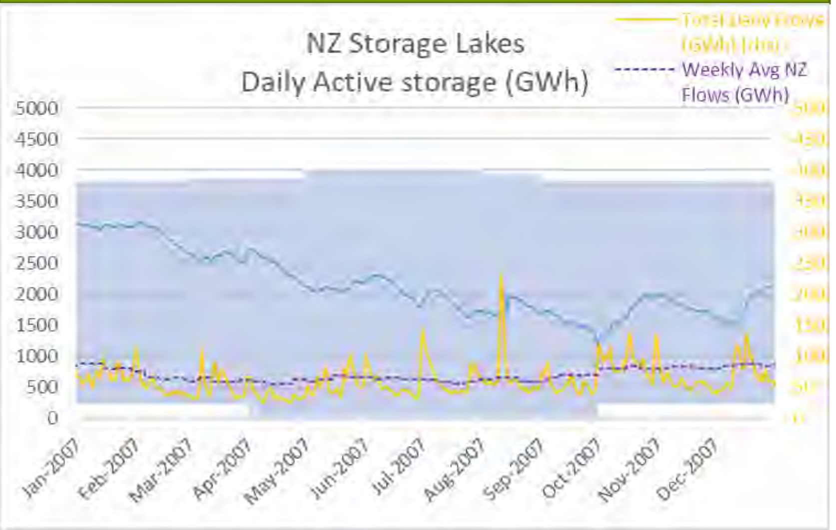
Graph of price against average



Graph of thermal gen against average

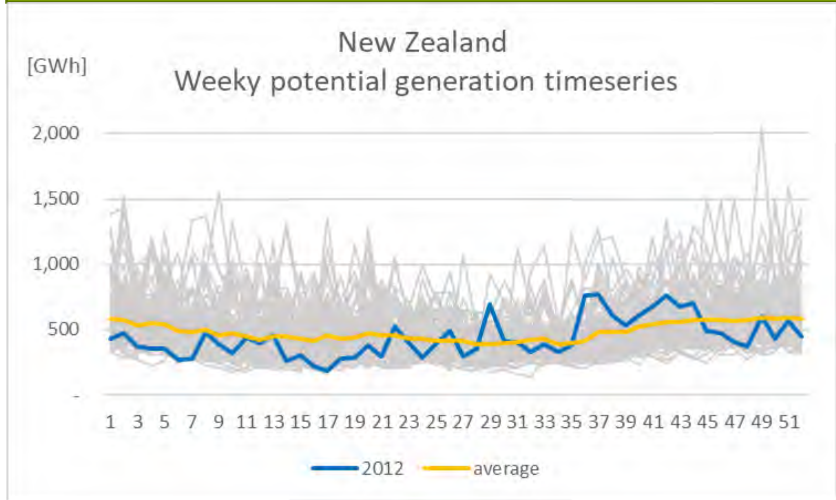


Storage & Hydro flows



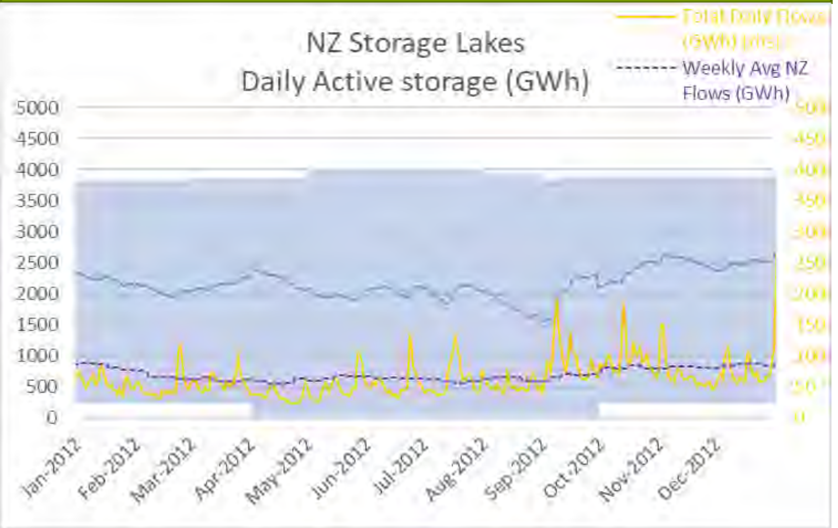
- **Cumulative inflows** below average throughout the year – between ~ 2,000 to 3,000 GWh below average for much of the year
- **Lake storage** slowly declined through Winter
- **Prices** near average throughout
- **Thermal generation** elevated above average throughout the year

2012 flows compared to average



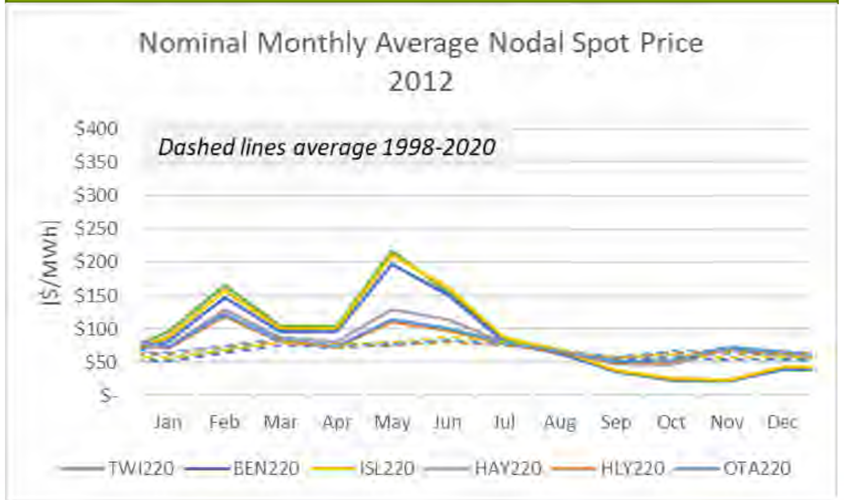
Cumulative sum of hydro flows

Storage & hydro flows

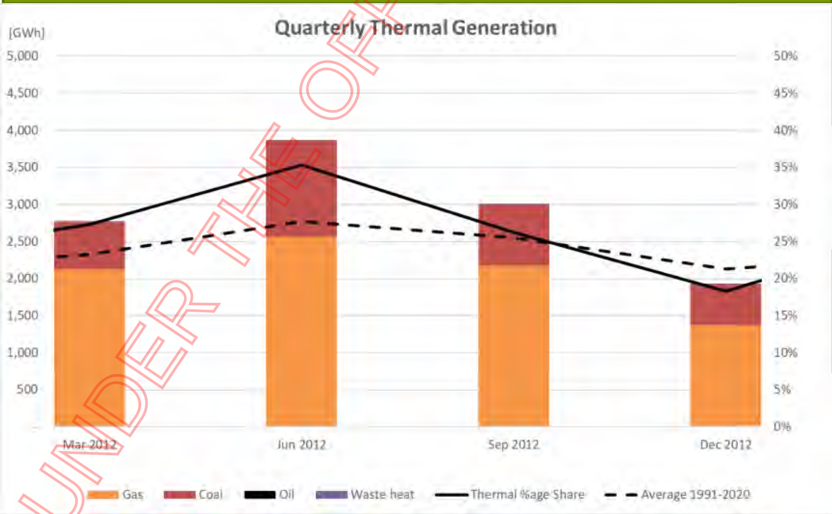


Dry year 2012

Graph of price against average



Graph of thermal gen against average



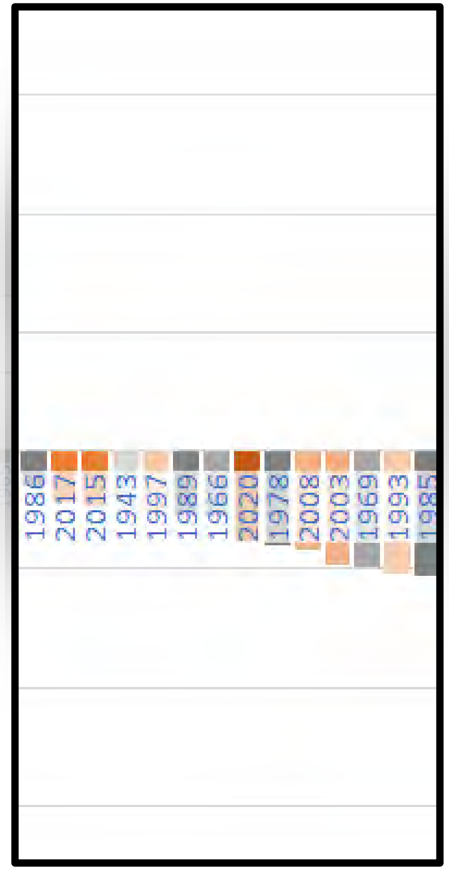
- **Cumulative inflows** below average throughout the year – down to ~ 3,000 GWh below average for Winter before moving towards average
- **Lake storage** fairly steady throughout the year hovering between 2,500 & 1,500 GWh
- **Prices** spike in late Summer & the again late Autumn
- **Thermal generation** elevated above average for first three quarters

There are some notable absences in that list of 5

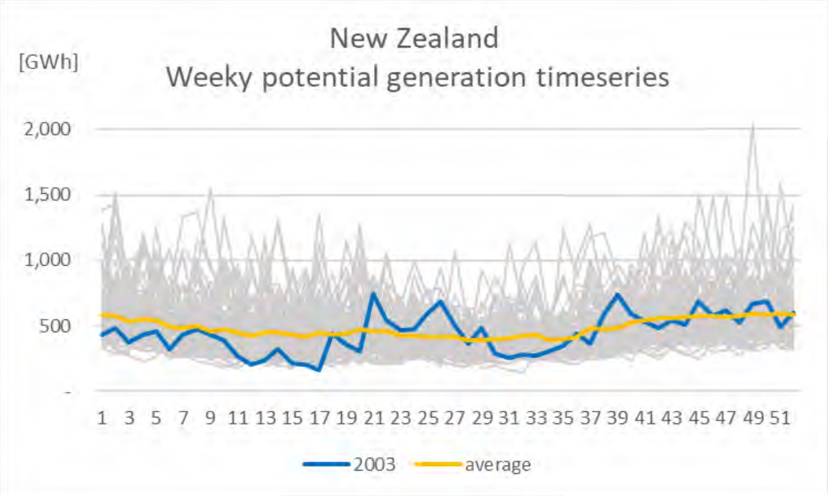
- Let’s look at some other years we (or at least, I) might remember as ‘dry years’

  - 2003
  - 2008
  - 2020
  - 2017

- What made them ‘dry’?

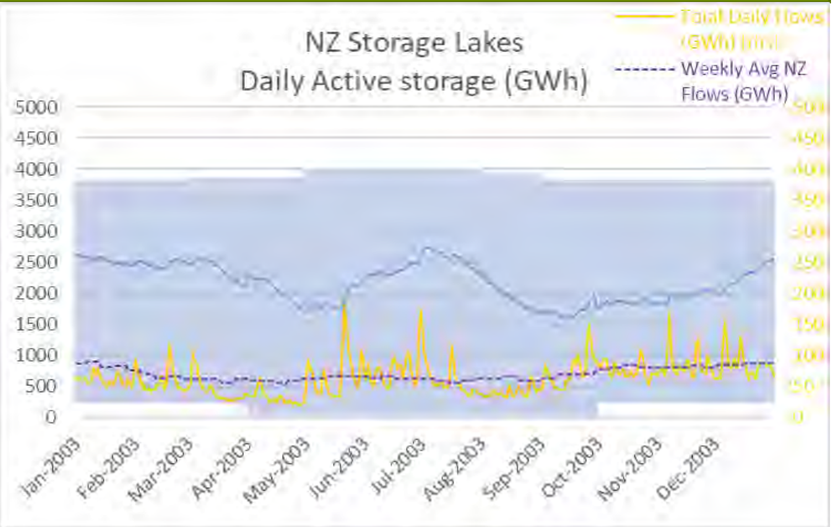


2003 flows compared to average



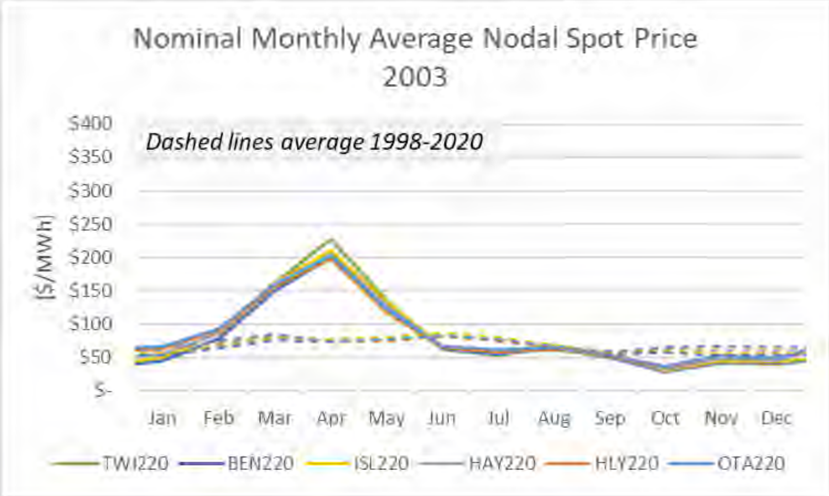
Cumulative sum of flows for 2003

Storage & hydro flows

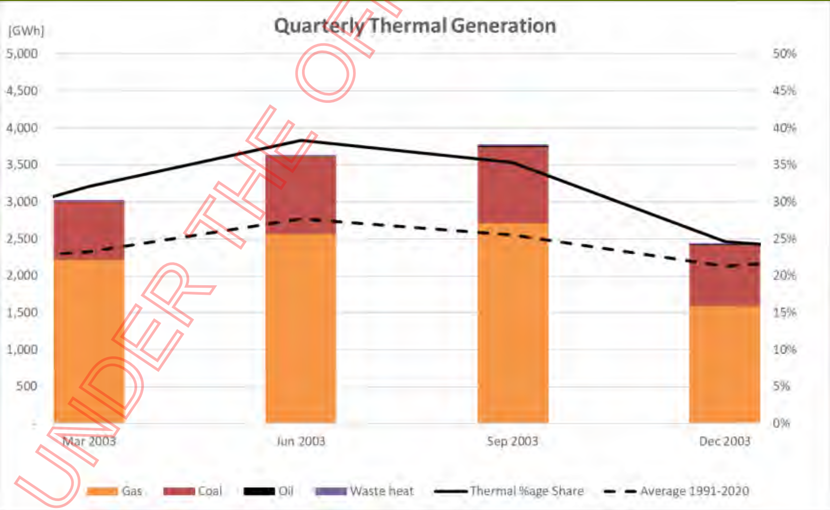


Dry year 2003

Graph of price against average

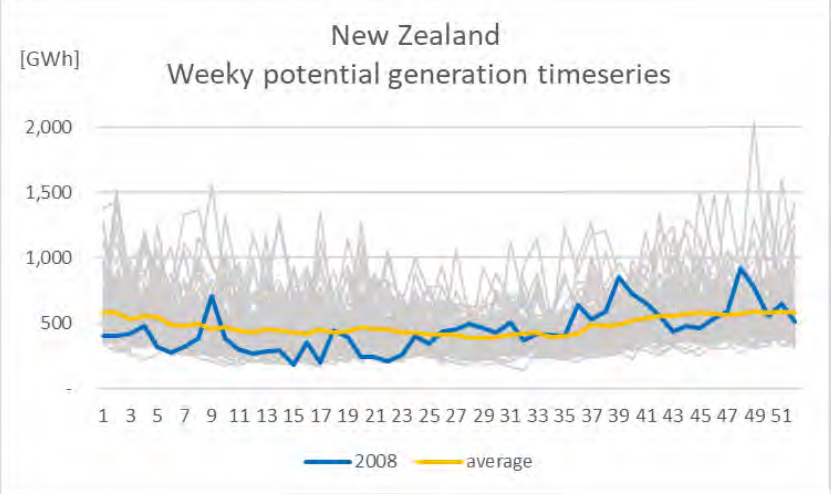


Graph of thermal gen against average

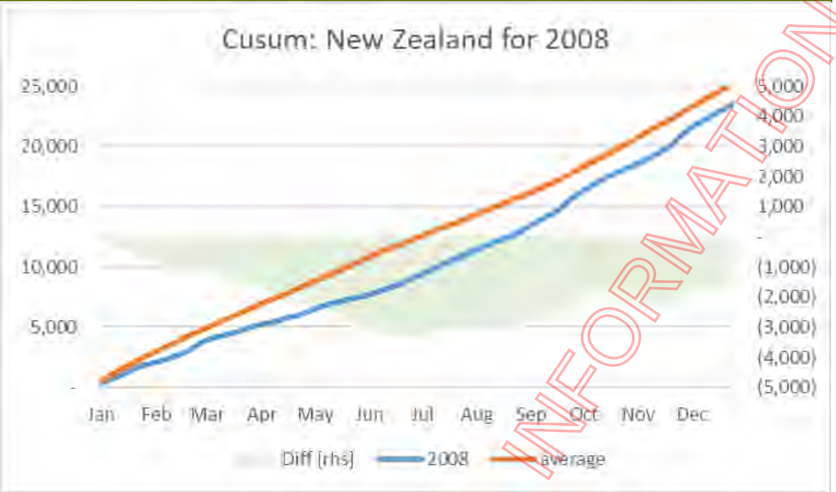


- **Cumulative inflows** below average throughout the year – down to ~ 2,000 GWh below average from early Winter onwards
- **Lake storage** fairly steady through Summer, declining with the onset of Winter before recovering with a number of mid-Winter inflow events
- **Prices** spike in Autumn then settle down to average
- **Thermal generation** elevated above average for whole year

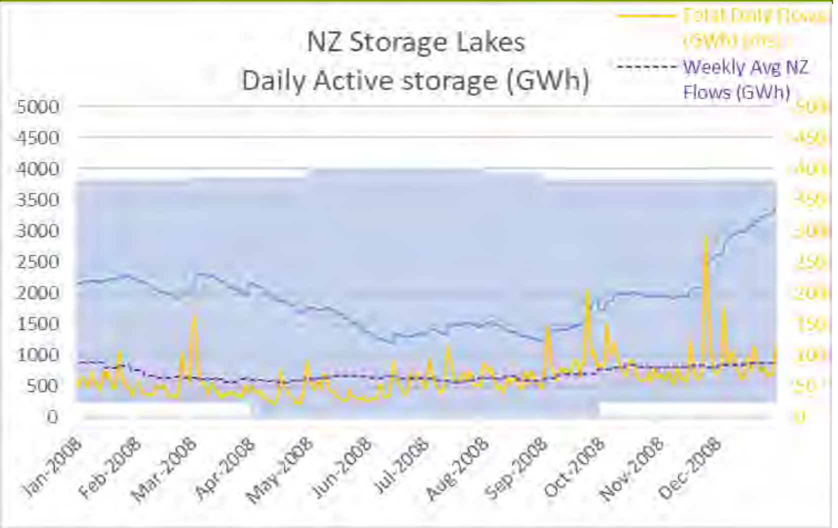
2008 flows compared to average



Cumulative flows for 2008

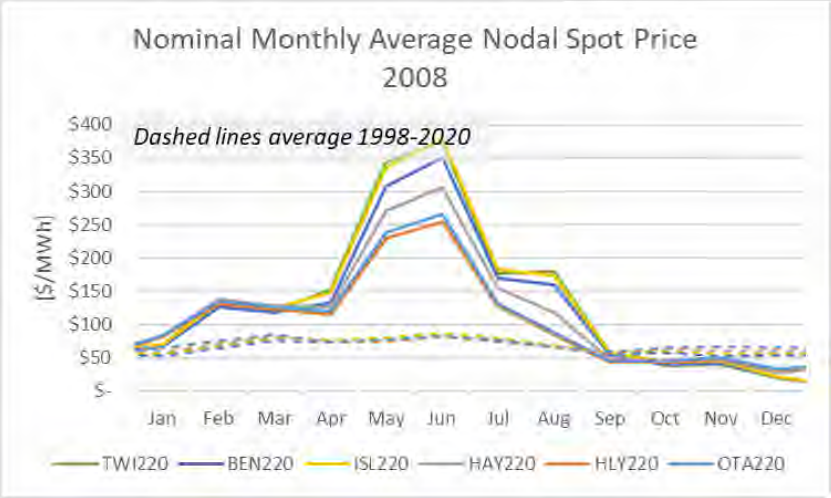


Storage & hydro flows

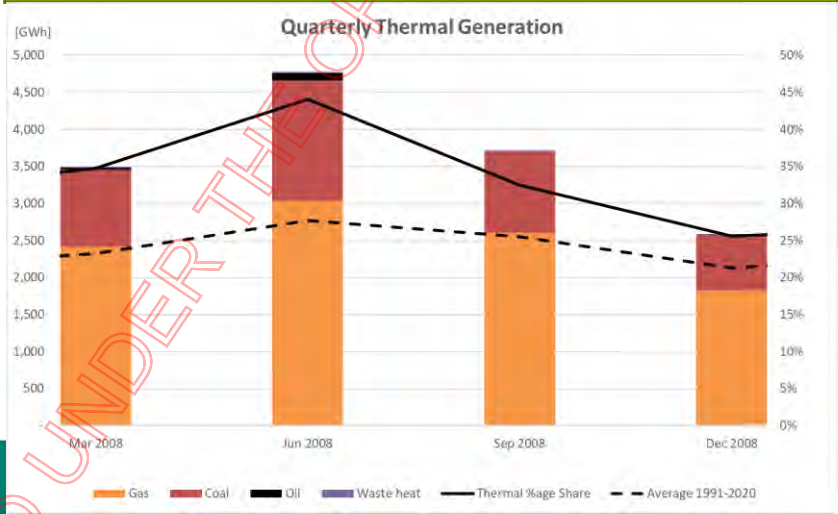


Dry year 2008

Graph of price against average

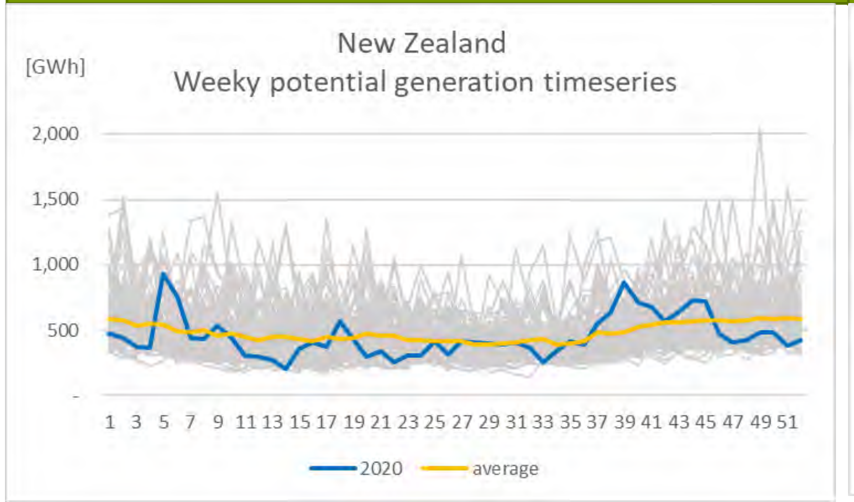


Graph of thermal gen against average



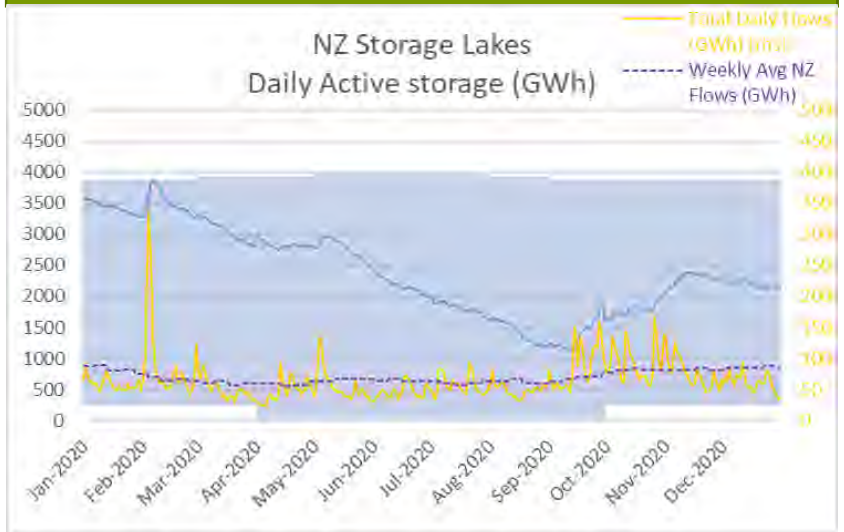
- **Cumulative inflows** below average throughout the year – down to ~ 3,000 GWh below average for Winter
- **Lake storage** fairly steady through Summer, declining with the onset of Winter before plateauing ahead of Spring inflows
- **Prices** extreme from Autumn into early Spring
- **Thermal generation** elevated above average for whole year, especially for Jun quarter

2020 flows compared to average



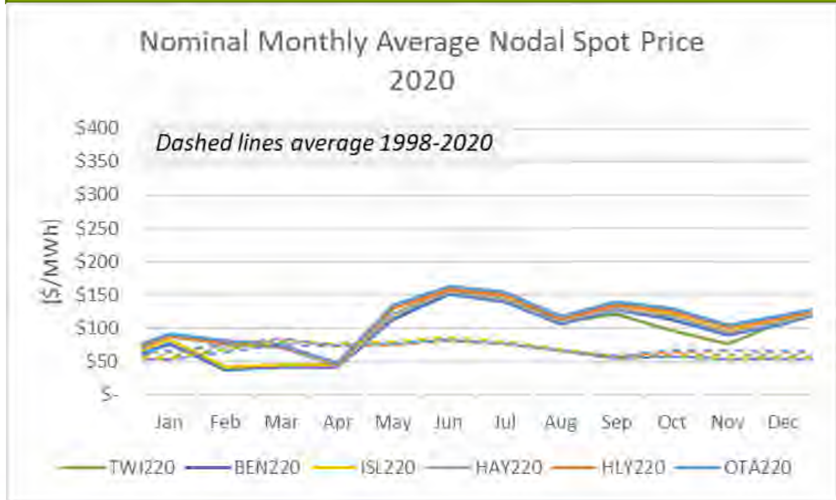
Cumulative sum of flows for 2020

Storage & hydro flows

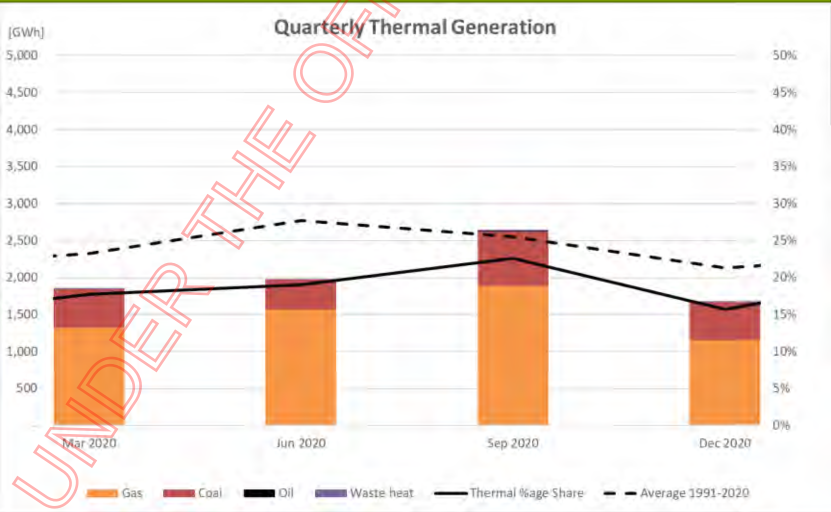


Dry year 2020

Graph of price against average



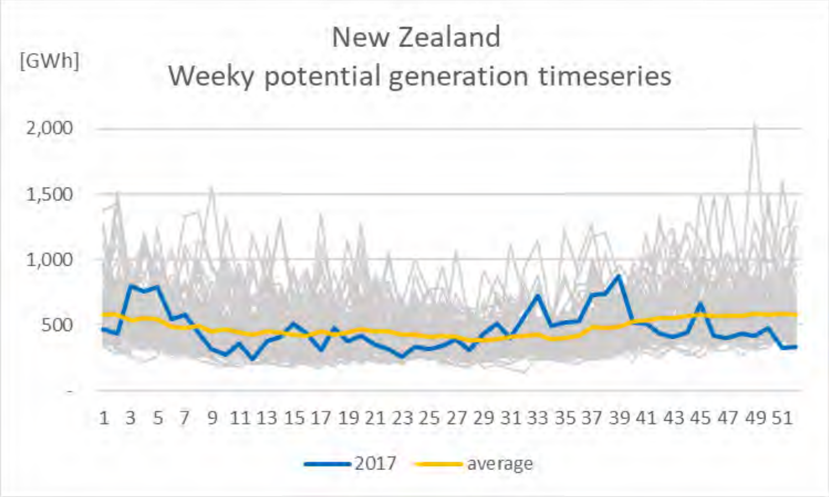
Graph of thermal gen against average



- **Cumulative inflows** below average from Autumn onwards – down to ~ 1,500 GWh below average
- **Lake storage** started year near full and then drawn down through to Spring
- **Prices** above average from early Winter into early Spring
- **Thermal generation** elevated above average for whole year, more-so for Sep quarter

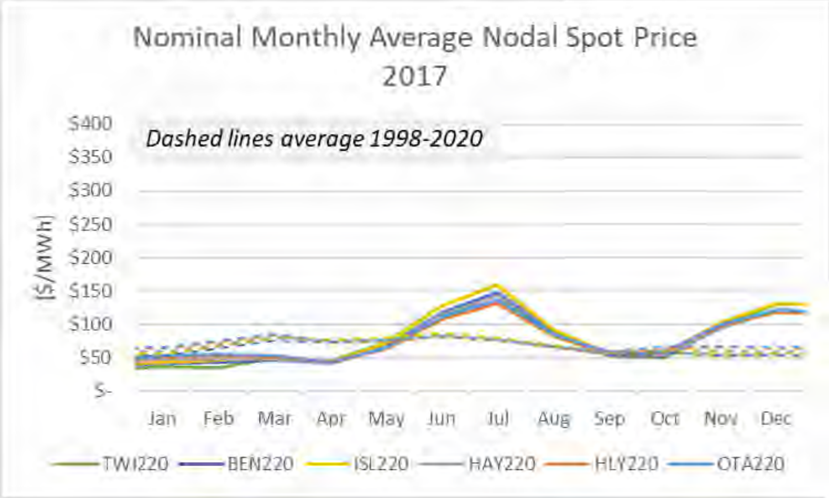
Dry year 2017

2017 flows compared to average

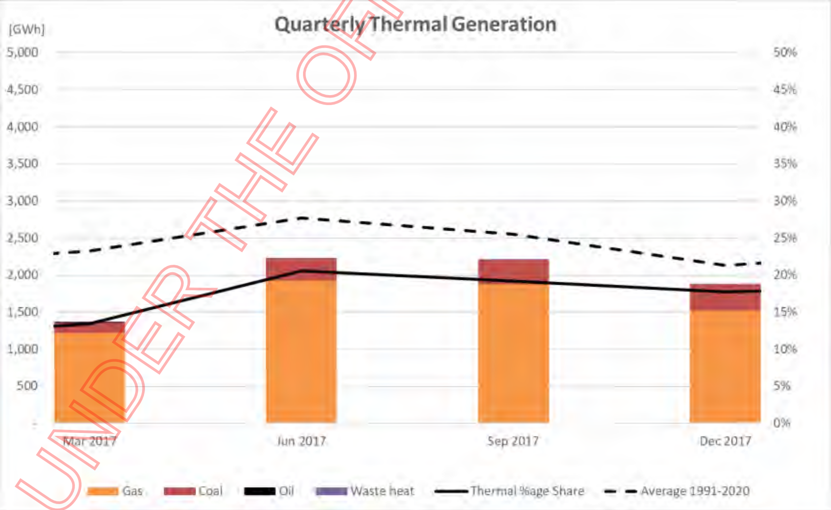


Cumulative sum of flows for 2017

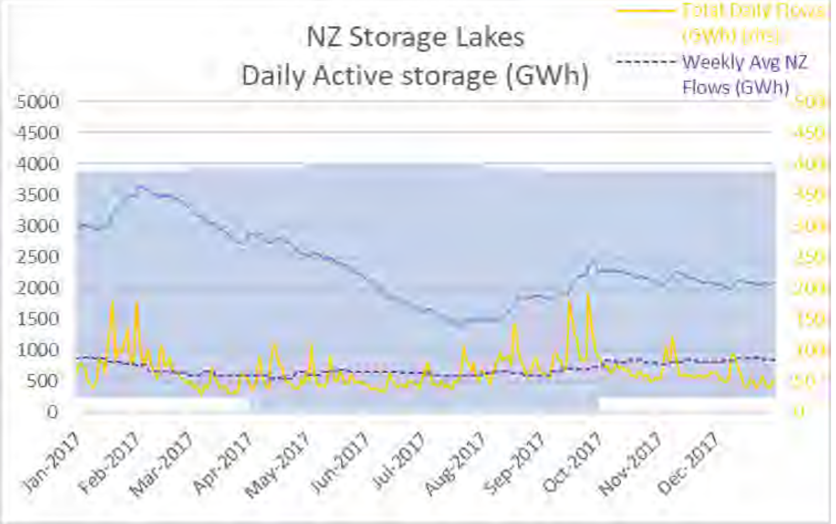
Graph of price against average



Graph of thermal gen against average



Storage & hydro flows



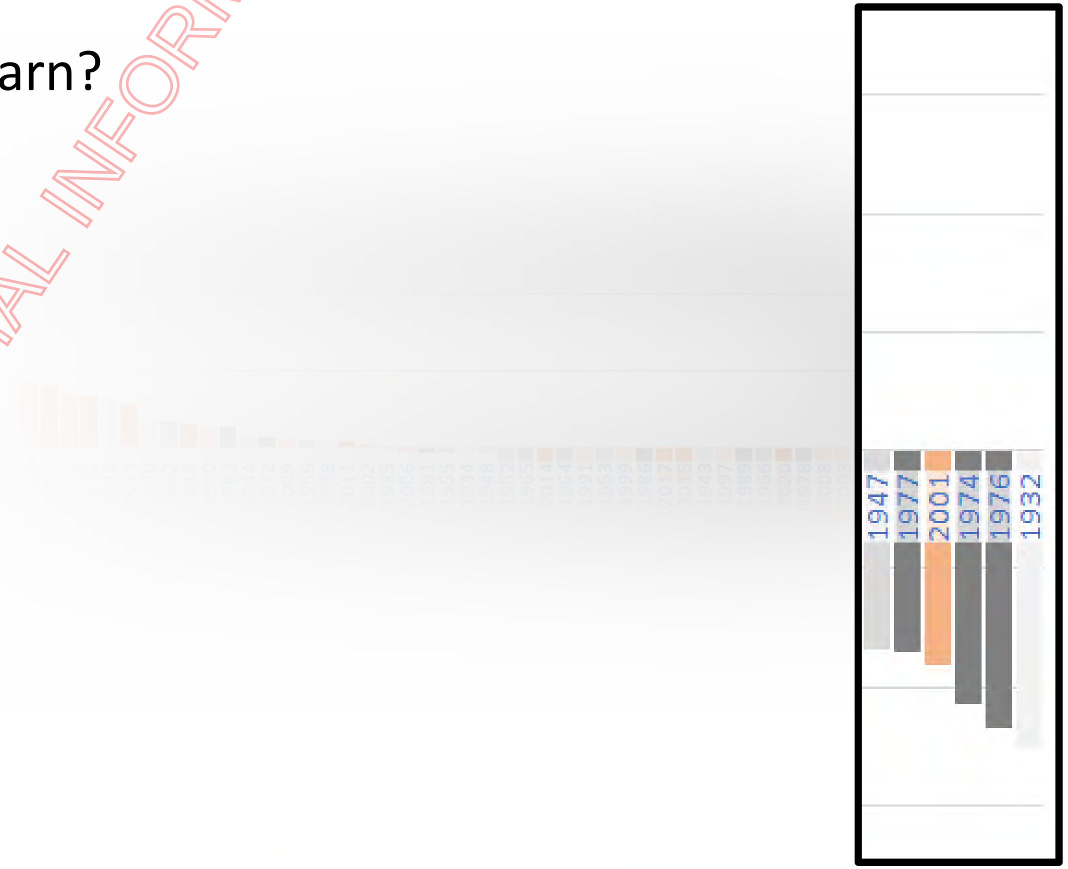
- **Cumulative inflows** oscillate around average +/- 1,000 GWh above/below average
- **Lake storage** started Winter near full and then drawn down through to Spring
- **Prices** above average from in Winter and again in late Spring/early Summer
- **Thermal generation** elevated above average for whole year.

What might we have experienced in the other years that were physically dry?

- It was a different time… but what could we learn?

  - 1932
  - 1976
  - 1974
  - 1977
  - 1947

3 in quick succession!



Summarising

- A number of years from the recent past have been investigated to see what the data can tell us
- Varying levels inflow deficit lead to various levels of storage, price & thermal fuel usage
- Do any of these indicate a reliable characterisation of a ‘dry year’?
- Perhaps years where Public/Official Conservation Campaigns were called for can shed some light (we have already seen the inflows/storage/price & thermal usage for these)

Recent “Dry Years” – how long did they last, when did they happen?

- **May-July 1992: Electricity shortage**

In early May ECNZ advised of the effect of drought on South Island hydro storage lake levels and outlined actions being taken to conserve storage. With the level of inflows to the lakes dropping further the situation deteriorated to such an extent that by early June a call had been made for voluntary savings of 10% of demand.

A combination of electricity savings by the public and generation initiatives by ECNZ continued into July when inflows to the South Island lakes began to increase. In early August the power savings were called off.

- **July-September 2001: Supply shortage**

Low lake levels, coupled with unusually high demand for electricity, resulted in a shortage of electricity in the winter of 2001. Wholesale electricity spot market prices rose sharply as a result.

As uncertainty in electricity supply and wholesale prices increased, the Minister of Energy initiated industry meetings from late July to early September. During this period the Government implemented a 10-week conservation campaign of a 10 percent saving in electricity use by the public and a 15 percent saving by the government sector. This initiative, along with temporary relaxation of transmission security and greater use of thermal generation, ensured supply was maintained without interruption.

- **March-June 2003: Winter supply shortage**

The Government identified the prospect of a dry year for New Zealand's hydroelectric system, and an electricity savings campaign was planned and implemented progressively with the assistance from the electricity industry's Grid Security Committee and Winter Power Group.

The Government subsequently set a 15 percent electricity savings target for the government sector in order to provide leadership in electricity savings to help reduce the risk of winter power shortages. The public was asked to endeavour to achieve savings of 10%.

- **May-July 2008: Winter supply shortage**

During 2008 the driest March - June period since 1947 was recorded. By June hydro storage had approached the Emergency Zone, indicating a roughly 10 percent chance of electricity cuts being required. Constant monitoring and evaluation of conservation options by the Electricity Commission, with assistance from the electricity industry, included a public awareness campaign led by the industry encouraging all consumers to use power prudently and make savings whenever possible. The campaign was discontinued in mid-July.

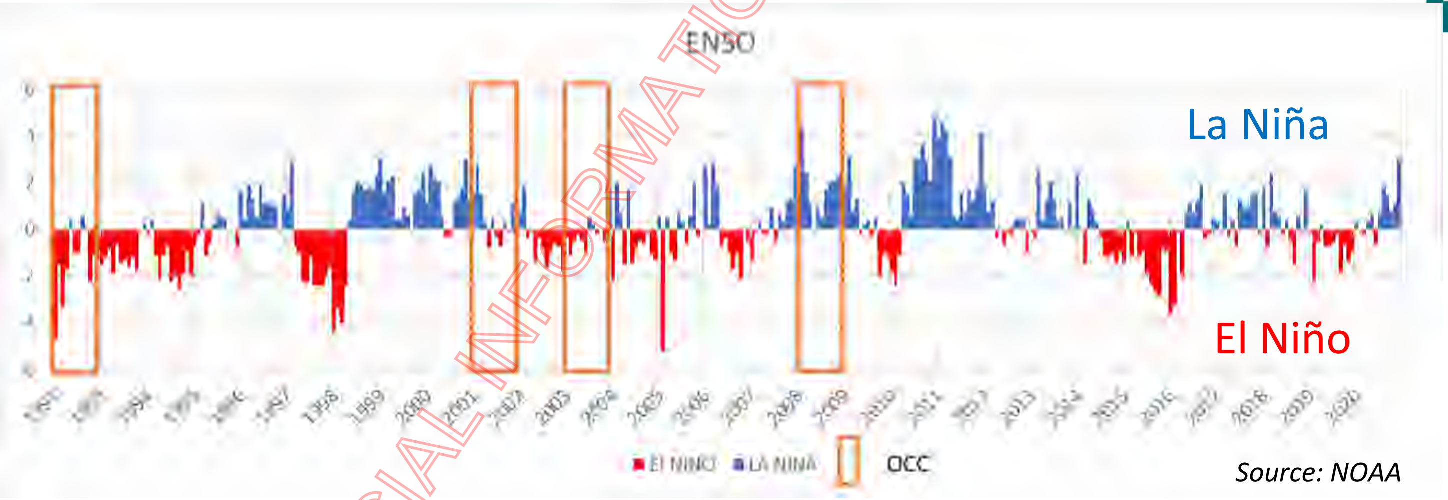
Take outs from these 4 years

- Each of these events lasted for around three months
- All occurred with at least some part having Winter in the event – no Summer occurrence
- All saw increased use of thermal generation – above average for extended period of time
- Start/end times for these events varied from as early as March (running through to June) to as late as July (and running through to September)

El Niño Southern Oscillation (ENSO) Index

What can we learn from climate cycles?

- ENSO El Nino Southern Oscillation (ENSO) Index measures observed sea level pressure differences between Darwin & Tahiti (Index accessed from NOAA website)
- And what does it mean for New Zealand inflows? Explanation from NIWA for El Niño (negative index) & La Niña (positive index).



Source: NOAA

From NIWA

El Niño's average influence on New Zealand

It's important to bear in mind that while we know the average outcome of El Niño because of historical data, no El Niño is average—each comes with a unique set of climate characteristics and therefore can be expected to influence the weather differently.

During El Niño, New Zealand tends to experience stronger or more frequent winds from the west in summer, which can encourage dryness in eastern areas and more rain in the west. In winter, the winds tend to blow more from the south, causing colder temperatures across the country. In spring and autumn, south-westerly winds are more common.

From NIWA

La Niña's average influence on New Zealand

Northeasterly winds tend to become more common during La Niña events, bringing moist, rainy conditions to northeastern areas of the North Island and reduced rainfall to the lower and western South Island. Warmer than average air and sea temperatures can occur around New Zealand during La Niña.

Years when Official Conservation Campaigns called appear in times where either La Niña or El Niño conditions dominate, or a mix of the two.

What can we learn from efforts of others?

Simulation efforts of others looking at the performance of the electricity system under a full range of inflows have been carried out by others

ICCC, Gentailers, Consultants to NZ Battery, System Operator.

The Interim Climate Change Commission looked at this as well

5.1 Can the dry year problem be solved?

A 'dry year' occurs when hydro inflows are lower than usual, meaning that less energy is stored in the form of water. This is a particular challenge for the New Zealand electricity system due to its reliance on hydropower, which supplies 60% of New Zealand's electricity on average.

Specifically, dry years are made up of weeks to months of constrained hydro availability that fall within any given period of time, and are most challenging when combined with winter peaks in demand. New Zealand has experienced some dry years recently – the public was asked to conserve electricity in 1992, 2001, 2003 and 2008 as part of official conservation campaigns.

At present, a combination of natural gas and coal provides the energy storage to meet dry year needs. New Zealand must move away from these fuels. But, when the system is so reliant on hydro, it is a challenge to build a cost-effective renewable electricity system that is able to deal with this loss. Solutions focus on either building capacity that is infrequently used, or storing energy that is infrequently accessed. Both of these solutions will come at a significant cost.

OPTIONS

The question the Committee posed was: what technically feasible options could displace fossil fuel use with emissions-free solutions and still meet security of supply during a dry year by 2035?

Estimated costs are based on evidence gathered from the work of relevant experts and updated as necessary. More information is available in the technical annex.

The chapter examines the following options:

- 'Overbuilding' renewables
- Long-term battery storage
- Biomass
- Hydrogen
- Pumped hydro storage
- Indicative large scale demand interruption.

All of the costs provided are for the marginal cost of emissions abatement (i.e. the cost over and above that of natural gas as a solution to the dry year).

All modelled futures anticipate that coal is no longer used for electricity generation by 2035. The remaining fossil fuel generation used to provide security of supply in a dry year is natural gas. The Committee examined options to replace this natural gas using the 99% renewable future[3] to 'size' the problem.

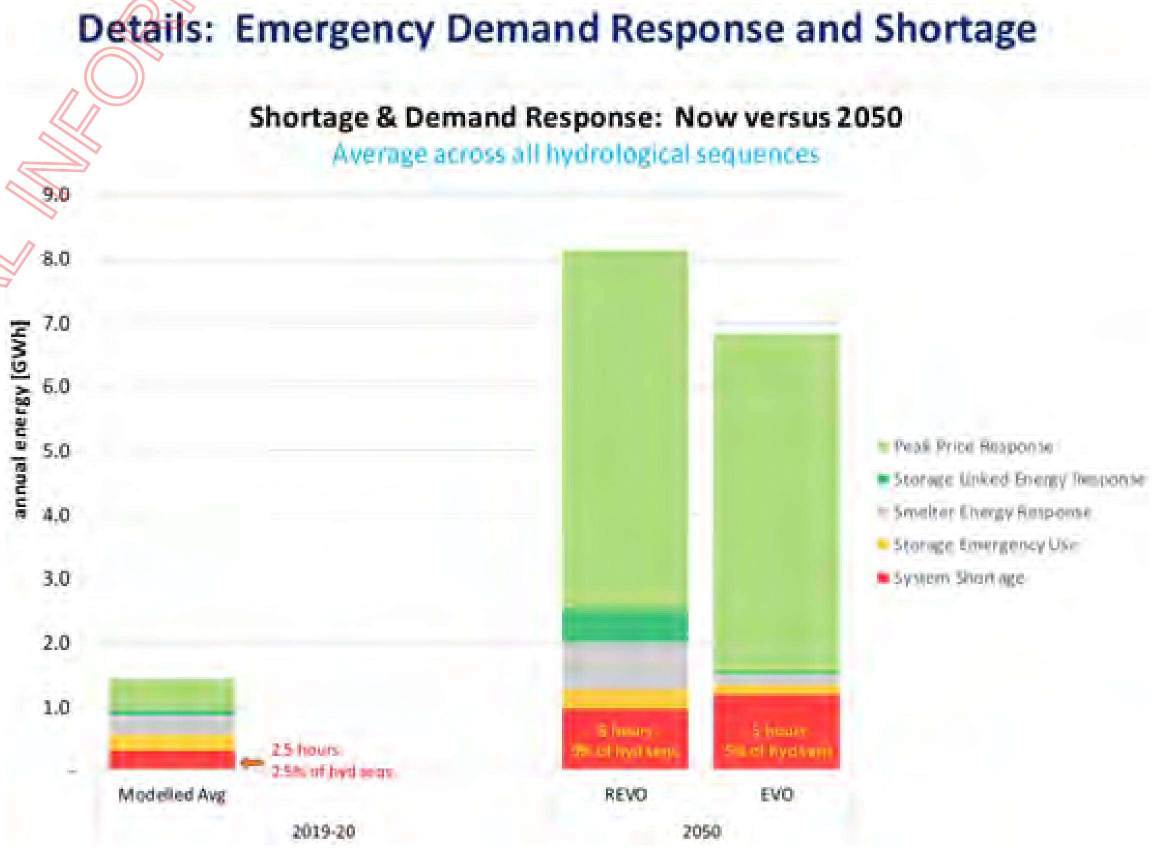
Figure 5.1 illustrates the volume of gas used each month in the driest/calmest year of the 87 weather years, as modelled in the 99% renewable electricity future. The total gas used over the year is about 25 PJ. This represents the maximum 'size' of the dry year problem that must be met.

The options outlined above were sized to meet the equivalent generation[4] – that is replacing 25 PJ of natural gas. Accounting for efficiency losses, this is about 3,400 GWh of electricity.

Figure 5.1: Gas use by month in 99% renewable electricity in the driest/calmest weather year

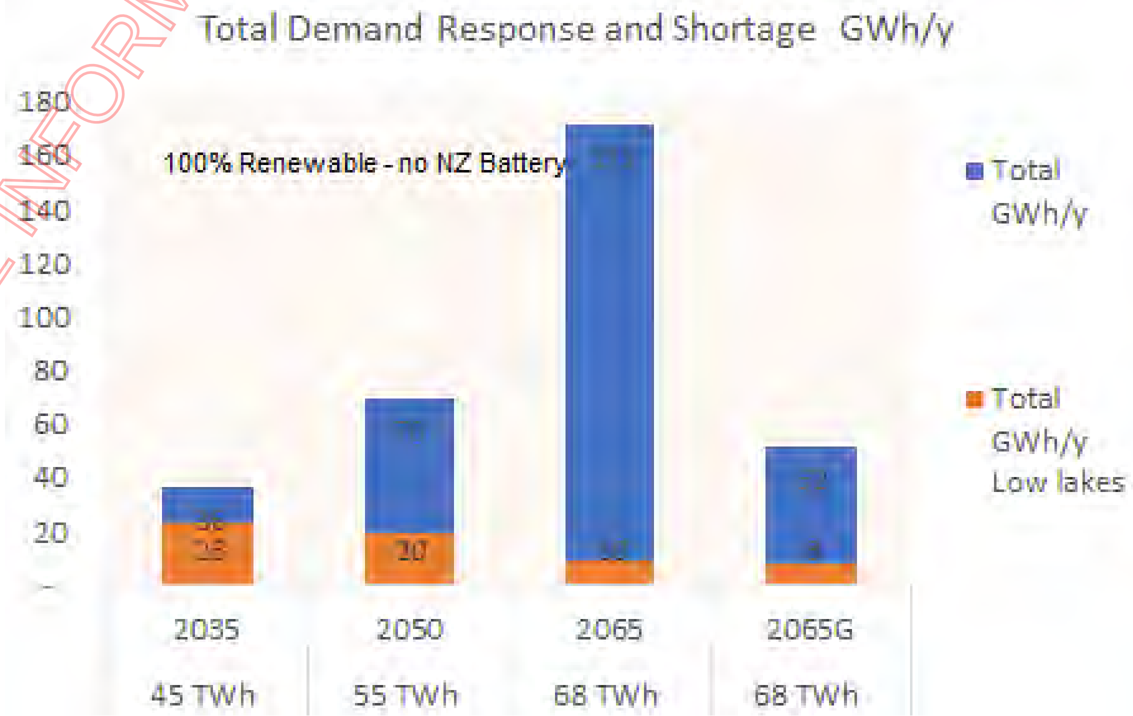
Ideally we could model the impact of those years in a modern system

- Meridian has done just that…
- But its modelling (like most other modelling) produces an average across all hydrological years ⇒ not a distribution, which would be more helpful
- It shows the current system would experience an average of ~1.5 GWh of shortage / demand reduction [what thermal assumptions?] (ref 40,000 GWh total demand)
- In a future system [supplied entirely by renewable overbuild], that increases to 8 GWh -> largely assumed to be planned / price responsive (ref [60,000 GWh total demand)



What can we learn from averages?

- Concept / John Culy also did that as part of its earlier work for us
- Again, it produces an average across all hydrological years
- In future system states supplied entirely by renewable overbuild, it determines there'd be an average of 36 GWh/yr in 2035 (.01%) of demand response or shortage, rising to 171 GWh/yr by 2065 (0.2%)



Security of Supply Assessment

- The Electricity Authority derived a set of margins for use in the security of supply assessment;
  - A Winter Energy Margin of 14-16 percent for New Zealand
  - A Winter Energy Margin of 25.5-30 percent for the South Island
  - A Winter Capacity Margin of 630-780 MW for the North Island
- The margins are to be interpreted as consistent with an economically efficient level of capacity (MW) and energy capability (GWh) – balancing the social costs of shortages with the investment cost of new generation.

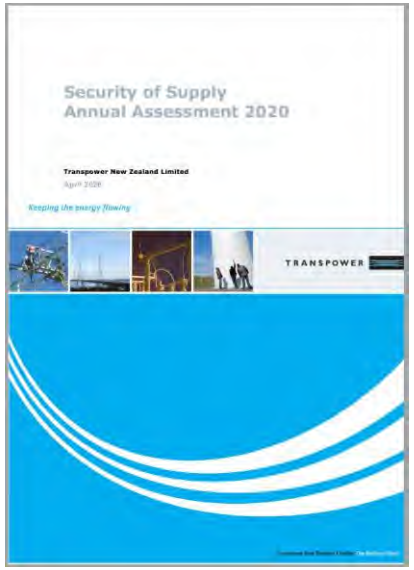


Table 5: Summarising the North Island WCM components

Component	Comprises	Description
North Island expected capacity (MW)	NI Thermal MW	Installed capacity of North Island thermal generation sources allowing for forced and scheduled outages, available fuel supply and operational and transmission constraints.
	NI Hydro MW	Installed capacity of North Island controllable hydro schemes allowing for forced and scheduled outages and de-rated to account for energy and other constraints which affect output during peak times.
	NI Other MW	Expected winter peak generation from geothermal, wind, cogeneration and uncontrolled hydro scheme generation.
North Island expected demand (MW)	NI Peak Demand MW	Expected average of the highest 100 hours of demand in winter inclusive of losses. This is referred to as H100 NI demand.
	NI Demand Response and Interruptible Load MW	Expected demand response and interruptible load over the highest 100 hours of demand during winter peak. This is subtracted from NI Peak Demand to calculate NI expected demand.
Expected HVDC transfer north	South Island MW	The net amount of MW the South Island can supply to the North Island during peak periods. This is a similar calculation to above (supply capacity minus H100 NI demand); however, also takes into account HVDC transfer capability.

Table 3: Summarising the New Zealand WEM components

Component	Comprises of	Description
New Zealand expected energy supply (GWh)	Thermal GWh	Maximum expected thermal generation available to meet winter (1 April to 30 September) energy demand allowing for forced and scheduled outages, available fuel supply and operational and transmission constraints.
	Mean Hydro GWh	Expected winter (1 April to 30 September) hydro generation based on mean inflows and expected 1 April start storage of 2,750 GWh.
	Other GWh	Expected winter (1 April to 30 September) energy available from cogeneration[21], geothermal and wind generation based on long-run average supply.
New Zealand expected energy demand (GWh)	NZ Energy Demand GWh	Expected winter demand, allowing for the normal demand response to periods of high spot prices (excluding any response due to savings campaigns or forced rationing).

Table 4: Summarising the South Island WEM components

Component	Comprises	Description
South Island expected energy supply (GWh)	Mean Hydro GWh	Expected winter (1 April to 30 September) hydro generation based on mean inflows and assumed 1 April start storage of 2,400 GWh
	Other GWh	Expected winter (1 April to 30 September) wind generation based on long-run average supply.
Expected HVDC transfers south (GWh)	HVDC GWh	Expected winter (1 April to 30 September) HVDC transfers received in the South Island
South Island expected energy demand (GWh)	SI Energy Demand GWh	Expected winter demand, allowing for the normal demand response to periods of high spot prices (excluding any response due to savings campaigns or forced rationing).

Security of Supply Assessment for 2020

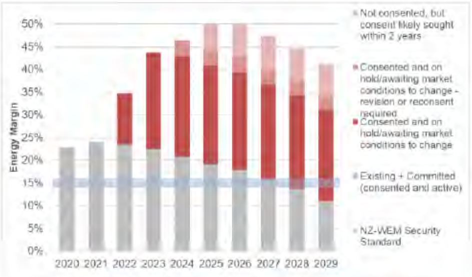


Figure 7: NZ WEM – Medium Demand

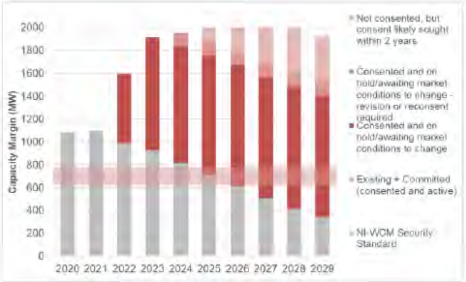


Figure 11: NI WCM – Medium Demand

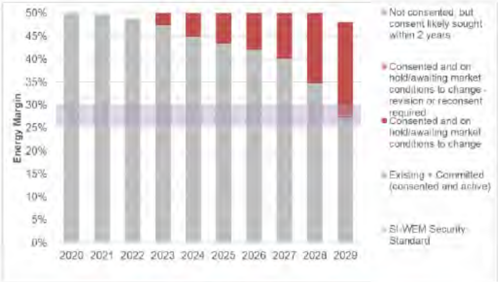


Figure 17: SI WEM – Medium Demand

- The assessment is made for three forecast demand scenarios and one thermal constrained scenario.
- For the middle demand scenario (charts at left) it looks like existing generation plant is sufficient to remain within the energy margin bands for at least the next five years.
- Extra capacity needed to meet North Capacity Margin can be found from already consented projects.
- South Island generation capability able to meet SI energy margin through to last year of horizon, where new generation will be needed.

Q. What is a dry year?

- We need to solve the 'dry year' problem… but…
  - What is that problem?
  - How big is it?
  - When does it occur and how long does it last?
  - Where is the impact?

Q. What is that problem?

- **Cabinet paper**

Dry year risk refers to the shortfall in electricity generation than can occur in a year where inflows to hydro lakes are significantly below normal and the lakes are ‘dry’.

- **ICCC**

Specifically, dry years are made up of weeks to months of constrained hydro availability that fall within any given period of time, and are most challenging when combined with winter peaks in demand.

Can we do better?

Q. How big is it?

- **Cabinet paper**

9.2 Criteria - Any proposal or group of proposals will be assessed against its ability to:

*9.2.1 provide at least [**5,000 GWh**][1] of energy storage or equivalent energy supply flexibility*

[1] The potential magnitude of the dry year problem in 2030 given expected changes in electricity supply and demand, will be investigated as part of the project.

- **ICCC**

the volume of gas used each month in the driest/calmest year of the 87 weather years, as modelled in the 99% renewable electricity future. The total gas used over the year is about 25 PJ. This represents the maximum 'size' of the dry year problem that must be met.
*The options outlined above were sized to meet the equivalent generation[82], that is replacing 25 PJ of natural gas. Accounting for efficiency losses, this is about **3,000 GWh** of electricity.*

Can we do better?

Q. When does it occur and how long does it last?

- **ICCC**

Specifically, dry years are made up of ***weeks to months*** *of constrained hydro availability* ***that fall within any given period of time****, and are* ***most challenging when combined with winter peaks in demand****.*

Can we do better?

Q. Where is the impact?

- **Cabinet paper**

5. Dry year risk is a contributing factor to high electricity prices because the electricity market factors the cost of scarcity into electricity forward prices. The NZ Battery project will investigate ways to reduce this effect, thereby allowing electricity price to better follow the downwards trend of new electricity generation investment costs.

- **ICCC**

New Zealand has experienced some dry years recently – the public was asked to conserve electricity in 1992, 2001, 2003 and 2008 as part of official conservation campaigns.
Thermal fuel use in a dry year leads to increased greenhouse gas emissions

Can we do better?

Q. Anything else we should consider?

- Are there any other indicators we could use to characterise a 'Dry Year'.
- Do we need a definition of a 'Dry Year'? Or can we frame the problem in terms of Security of Supply?
- If security of Supply is frame, do we need indicators such;
    - Energy Margins
    - Capacity Margins
    - Expected Unserved Energy

If so these will need to be determined by simulation of Battery Solution(s).

Should they be prescriptive or indicative of merits of particular solution? May need to weigh up alternatives with varying economics, unserved energy, & generation adequacy (margins).

What is a dry year?

- We need to solve the ‘dry year’ problem… but…
  - What is that problem?
  - How big is it?
  - When does it occur and how long does it last?
  - Where is the impact?

Conrad's contribution:

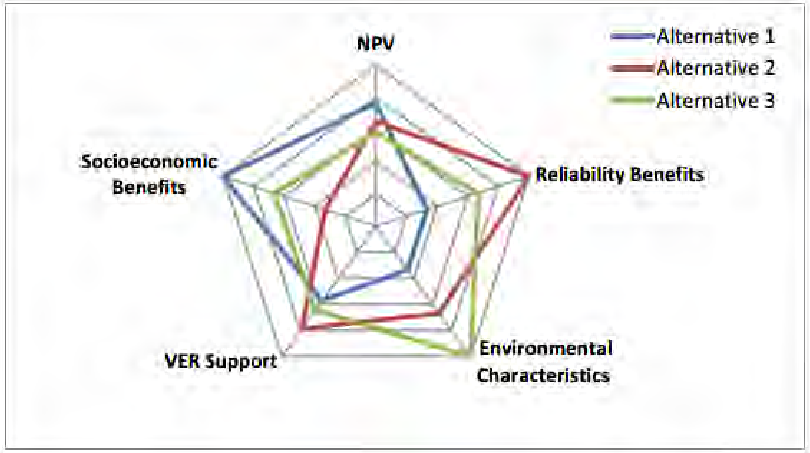
It's a complex issue, and as Einstein would say, we need to define it as simply as possible, but not simpler

Malcolms's contribution:

A dry year is like art – you know it when you see it – but you only see it after it has happened

Solving the 'dry year' problem

- What is that problem? The problem is one of security of supply/resource adequacy. Reliance on variable/intermittent renewable resources lead to periods of system stress.
- How big is it? 3,000 to 5,000 GWh appears to be the appropriate size of the problem. Of the recent years contemplated above, many have cusum deficit from average of 3,000 GWh & in 2001 this blows out to 5,000 GWh.
- When does it occur and how long does it last? 'Dry year' events appear to last around 3 months, terminating by a combination of decreasing demand and increasing inflows – both arriving in Spring.
- Where is the impact? Declining storage and rising spot prices increase the threat of conservation campaigns (and today, increasing thermal fuel burn and carbon emissions).



Solving the 'dry year' problem is a matter of balancing cost supply against cost of non-supply – use of a range of metrics allows an assessment of alternative solutions

Market integration workstream 4 update

Purpose

Purpose of this session

- To update you on progress and work plan for the Market integration workstream
- Mostly about work recently or soon-to-be commissioned that will be delivering results by Q1 2022

What we want from you

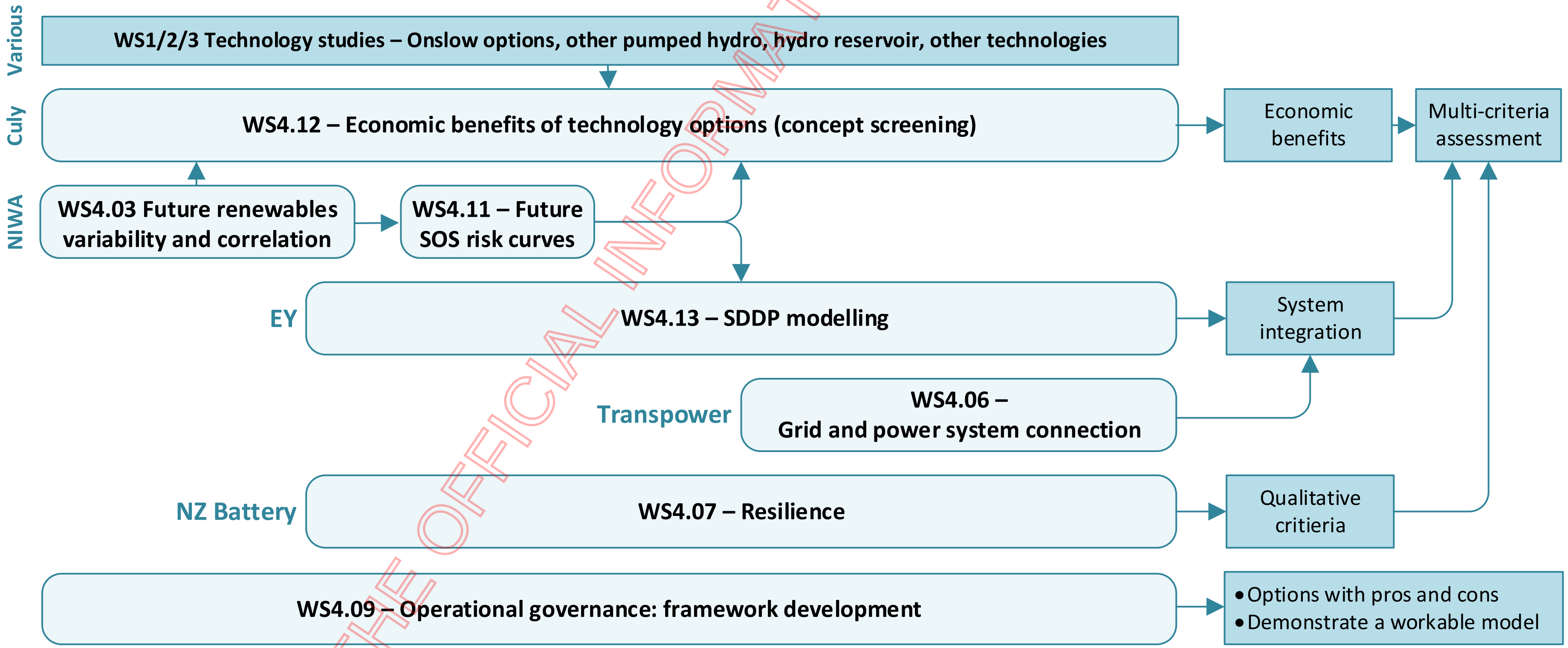
- Please provide feedback or observations, and be prepared to input as results start coming in

Next steps from here

- Implementing those pieces of work not already underway
- Delivering the results to support Phase 1 decisions and deliverables

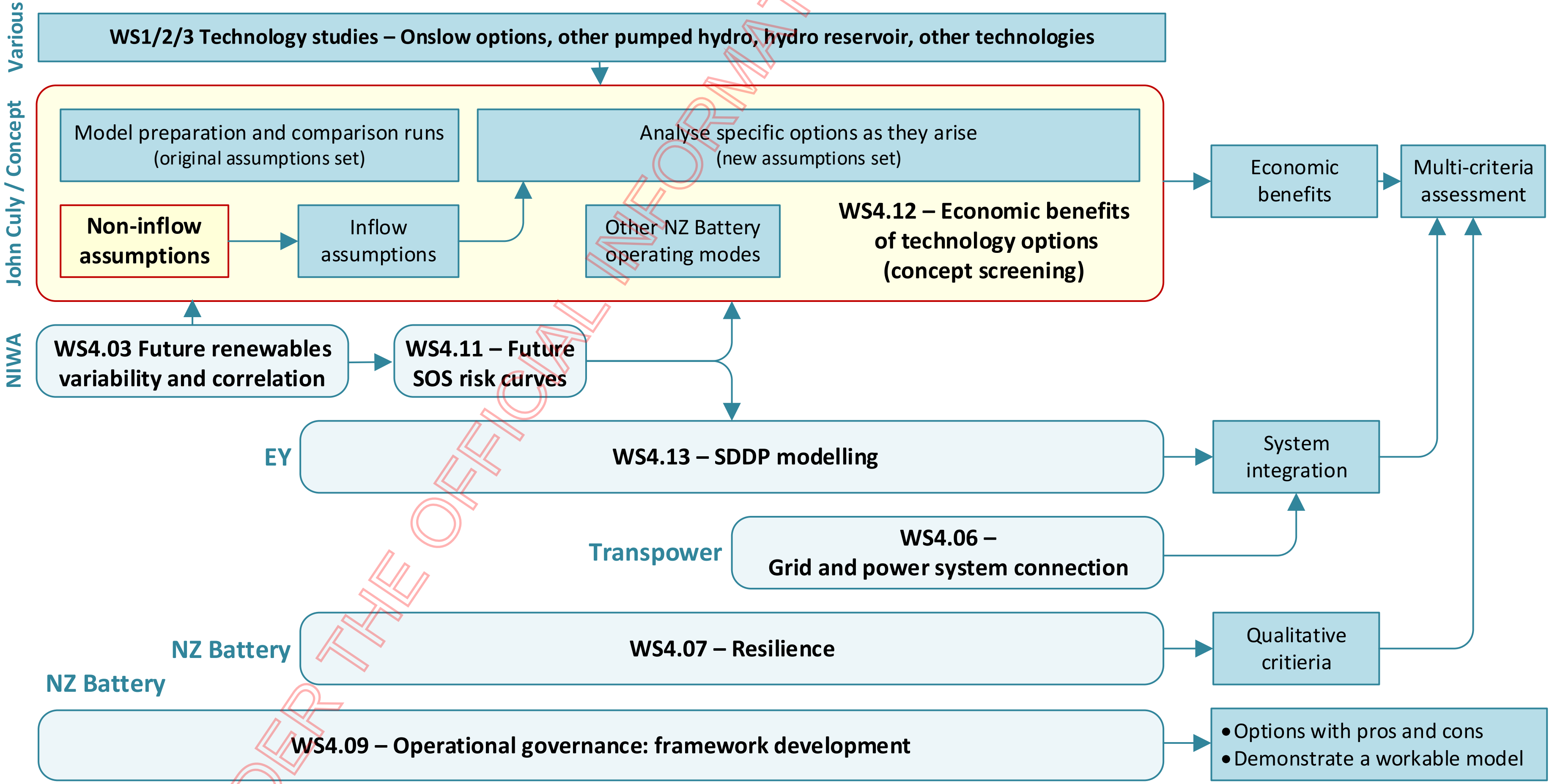
Workstream 4.12 – Market integration

- Economic analysis
- Wider system impacts
- Market integration



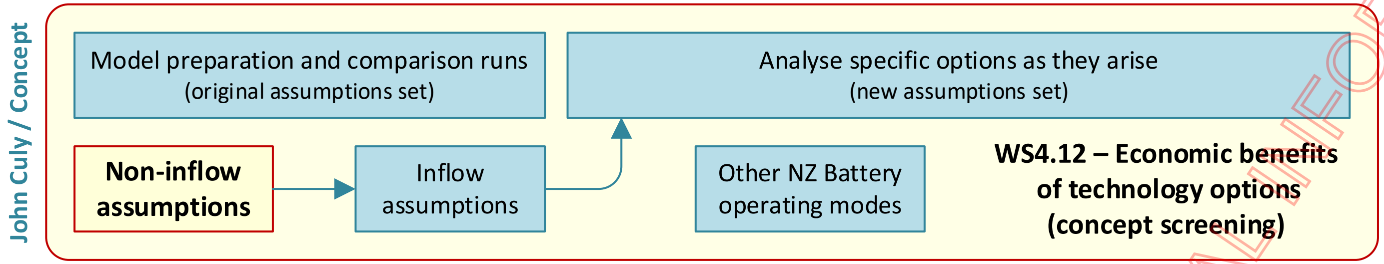
Workstream 4.12 – Economic benefits

- John Culy re-engaged
- Non-inflow assumptions workshops completed (next slide)
- Current priorities:
  - North Island pumped hydro
  - South Island reservoir expansion
  - Combinations thereof



Workstream 4.12 – Non-inflow assumptions

- Non-inflow assumptions reviewed NZ Battery / Culy / MBIE Markets (EDGS) / Transpower over three workshops and iterations
- Approach: Be mainstream

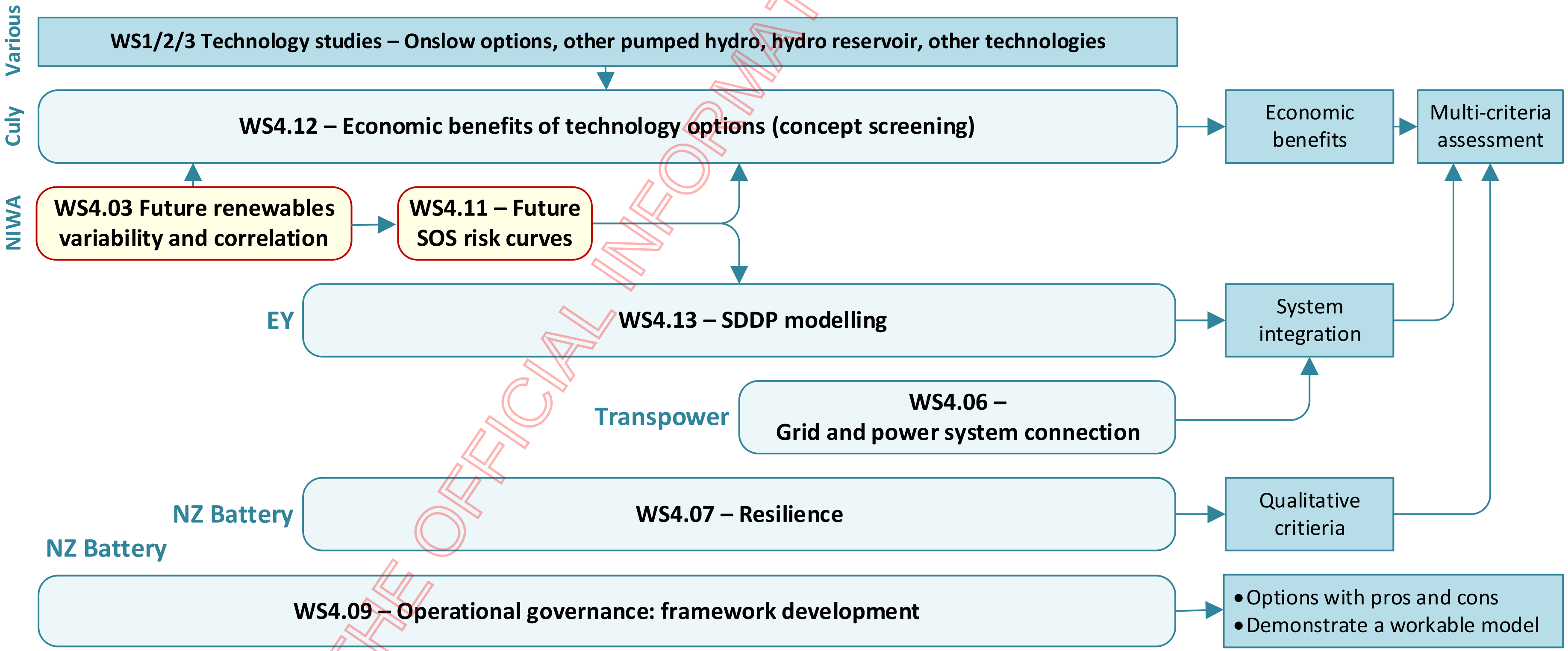


- Main changes:
  - Alignment of demand forecast with CCC
  - Specific rather than building-block geothermal costs
  - Wind, solar and Li-ion battery costs aligned with:
    - AEMO (primary)
    - NEL (secondary)
    - Other reports (supporting) including Allan's solar report
  - Result gives both wind and solar faster cost decline rates
  - Battery costs no significant change, but expressed a lifetime (rather than continual replacement) to make comparison easier


NZ Battery Project:
Updated Non-Inflow Assumptions
October 2021
Version 1.0

Workstream 4.03 and 4.11 – NIWA and Future SOS risk curves

- Considering implications of NIWA work on our rain, snow, wind and solar assumptions
- Maybe ANSA solar information and expanded Renewable Ninja data?
- These will feed into Economic and SDDP modelling and analysis of future SOS risk curves.
- That analysis possibly with EA and/or EnergyLink with Transpower review



Workstream 4.11 – Future SOS risk curves

1. NZ Battery storage will be added to the available storage
2. A ‘dunkelflaute’ low wind/solar event will cause the storage line to suddenly drop, due to the unforeseen use of stored energy
3. The spread and distribution of future energy inflows (rain, snowmelt, wind and sun) will change with:
   - Increased wind and solar
   - What rain, snowmelt, wind and solar inflow sequences we might expected in a climate-changed future
4. The storage level representing an X% risk will rise and change shape in consequence to the same issues as for (3), plus the removal of fossil fuels

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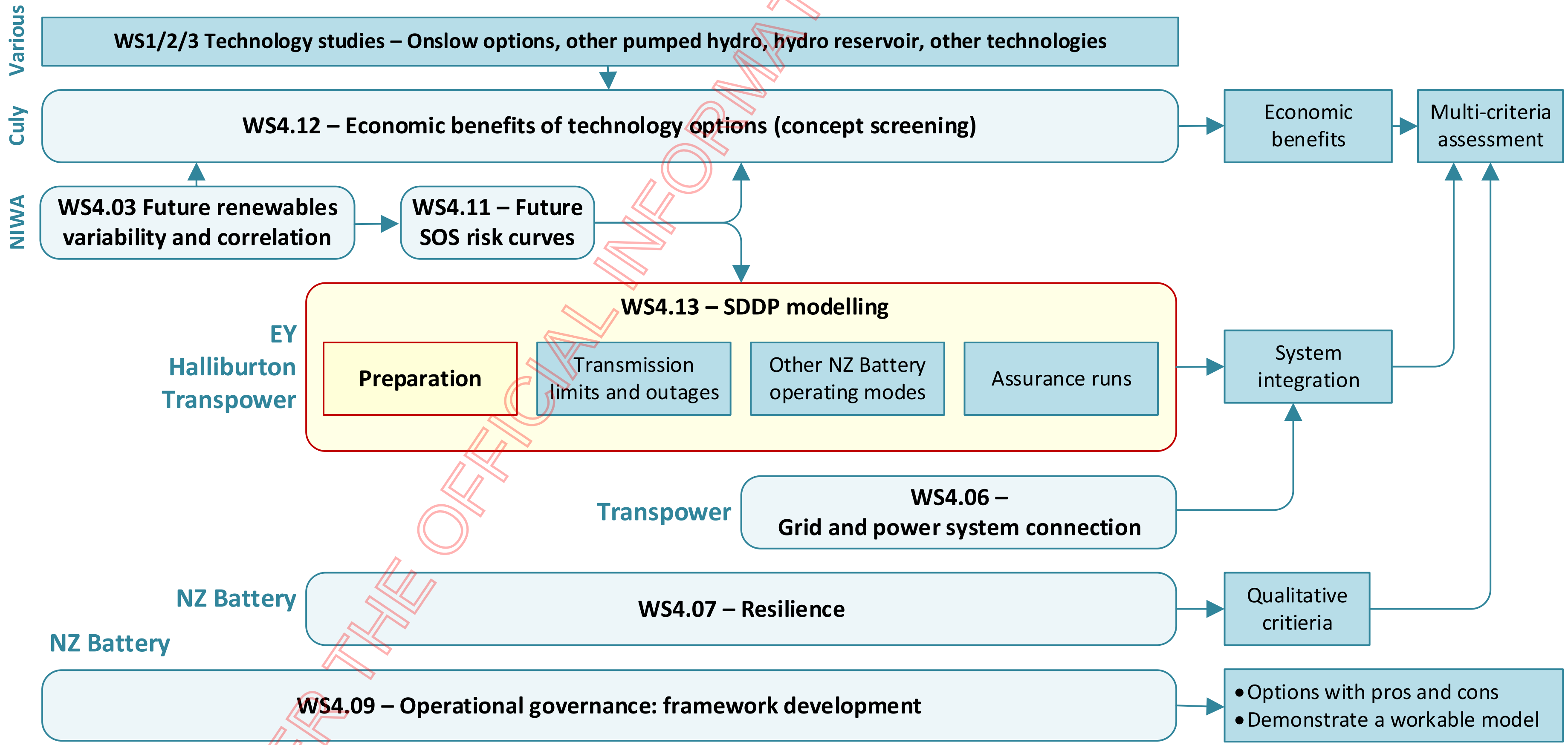
Workstream 4.13 – SDDP modelling

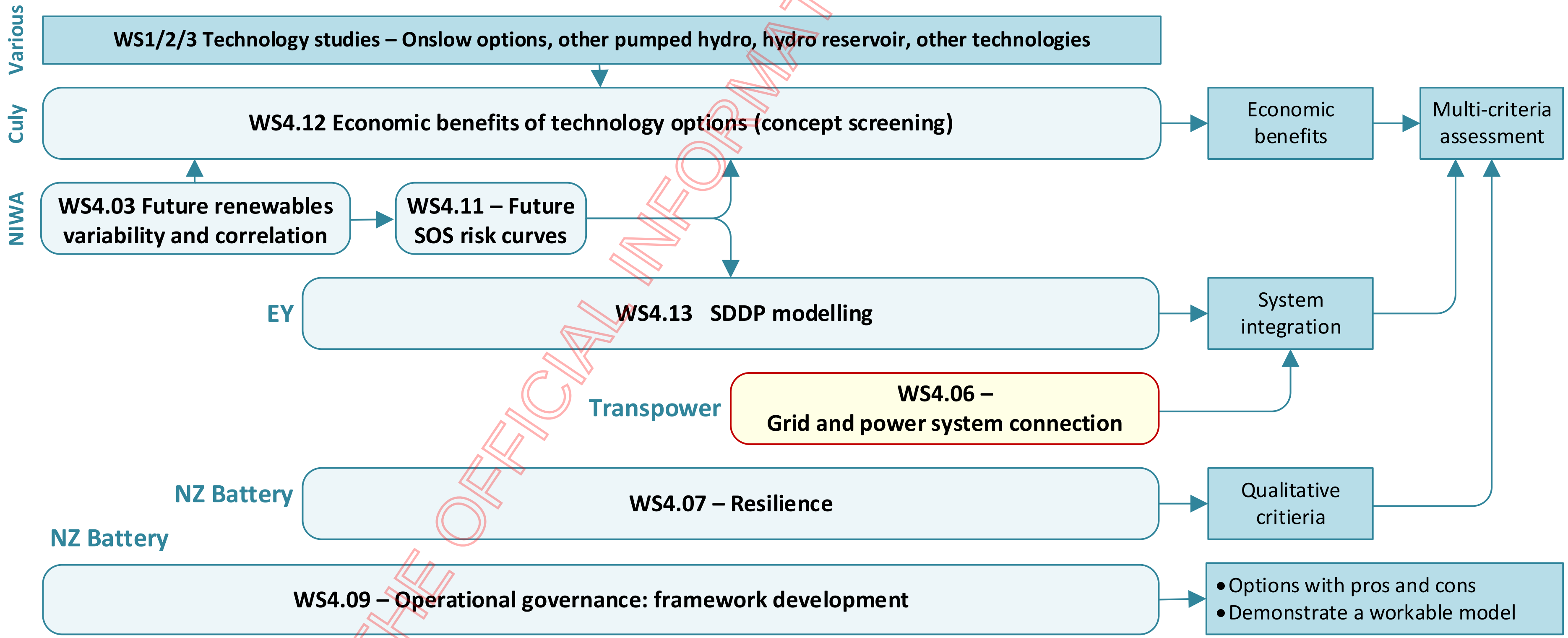
- Culy's economic model powerful but does not include full transmission representation or dynamic water values
- SDDP modelling now underway in preparatory stage for:
  - Transmission flows
  - Water values and NZ Battery operation
  - Assurance runs
  - Other NZ Battery options



Workstream 4.06 – Grid and power system connection

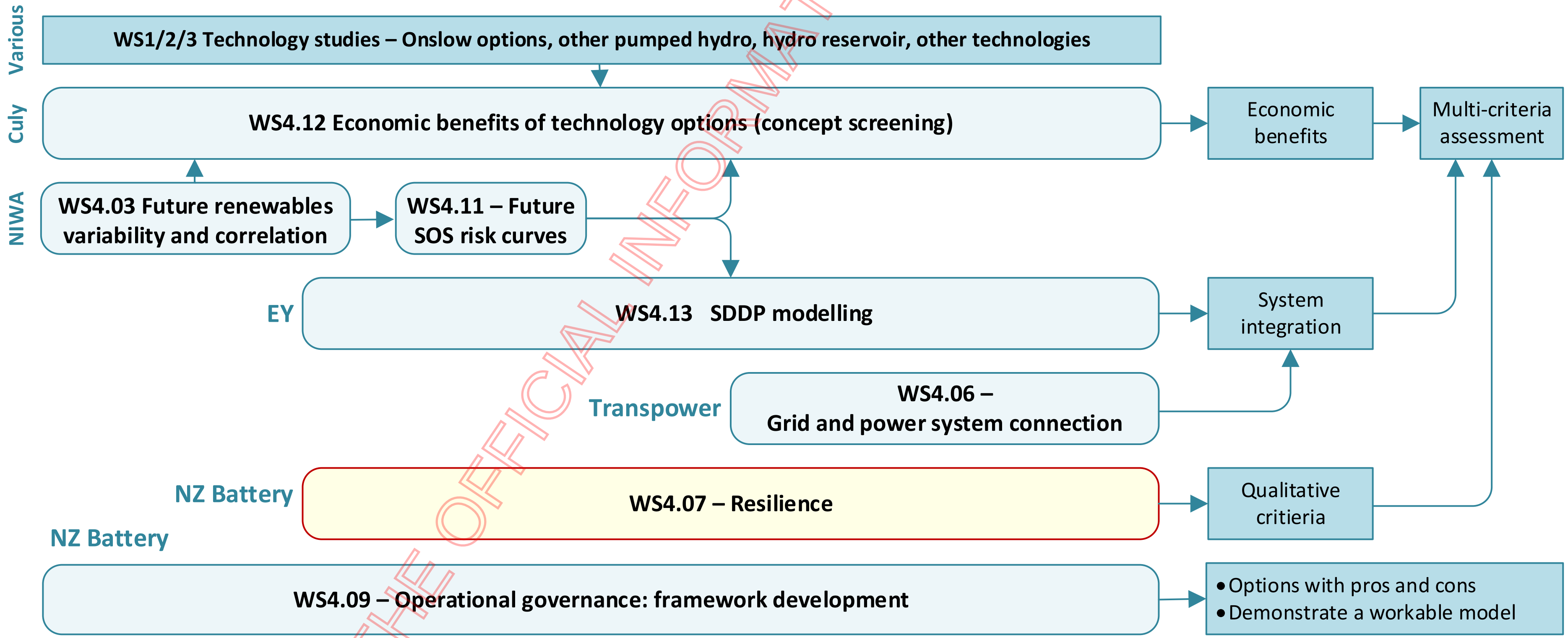
Transpower effort being booked in for Q1 2022 to address, with NZ Battery and TRM:

- Improved estimates of Lake Onslow connection costs
- Improved estimates of Lake Onslow grid upgrade requirements
- Power system requirements for turbines and electrical equipment
- Other grid and system issues related to any other NZ Battery options



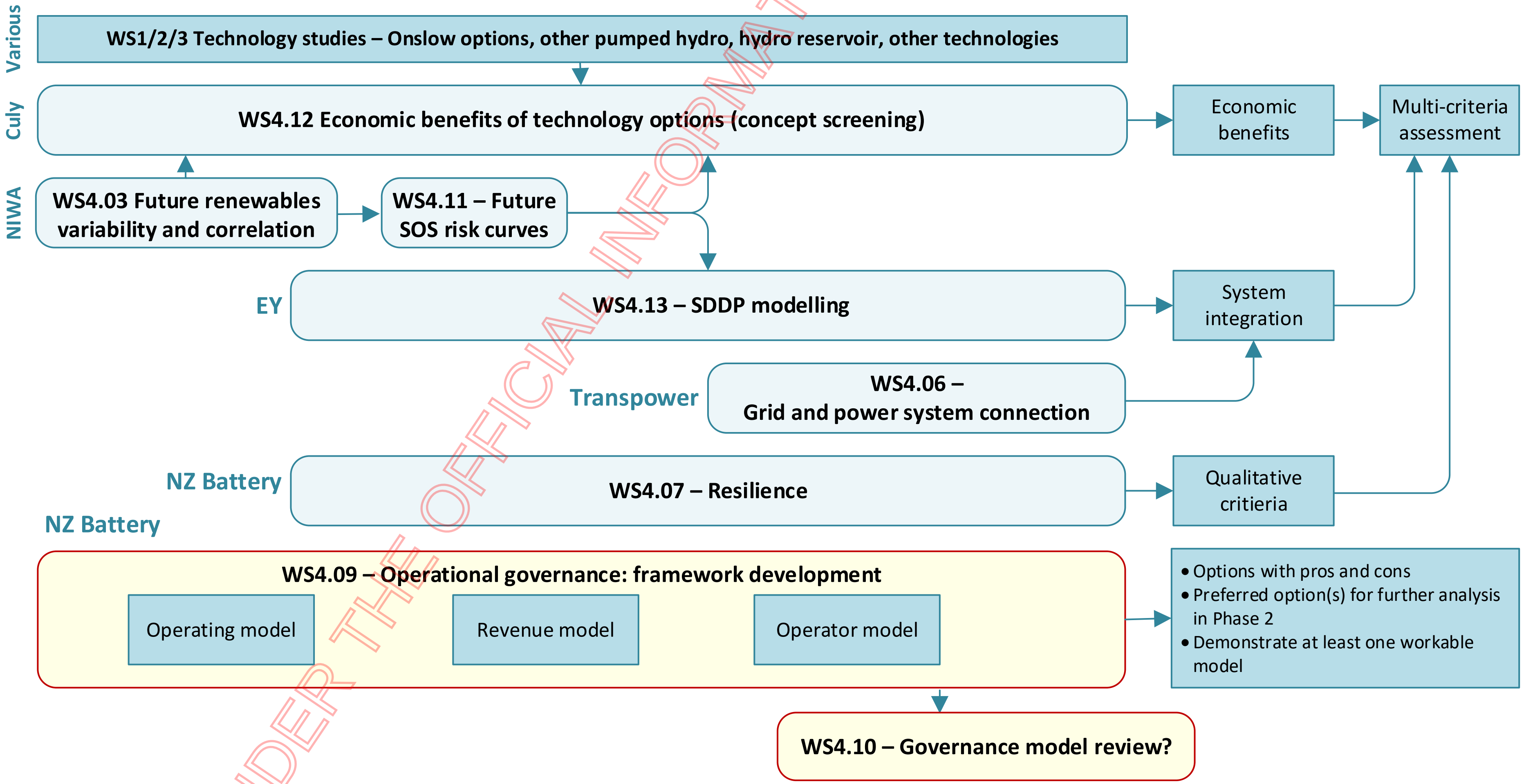
Workstream 4.07 – Resilience

- To address resilience of NZ Battery solutions to high-impact, low probability (HILP) events
- Starting with Transpower workshops on legislative requirements, their experience, and HVDC failures:
  - Cause
  - Capacity reduction
  - Restoration time
  - Design standard
- Excludes resilience of NZ Battery itself (TRM)



Workstream 4.09 – Operational governance

- Further development of NZ Battery hedging operating models (Steve and Allan)
- Discussion on revenue and operator models to commence (Eleanor)
- Consideration of possible external review
- Assumes NZ Battery operational: construction issues not considered in this workstream



Discussion

Market integration workstream 4 update