Accelerated pathway to 100% Renewable Electricity and Energy Resilience via Next-Generation Distributed Microgrids

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Introduction

Thank you for the opportunity to comment on the green paper *"Working together to ensure our electricity system meets the future needs of all New Zealanders."* We welcome the Electricity Authority's initiative to engage on the opportunities and challenges of decentralised electricity systems. This submission reflects insights from work at NIWA, particularly in environmental modelling and energy system resilience, and aims to support the development of a future-ready, equitable, and secure electricity system for Aotearoa, New Zealand. NIWA, GNS Science and Metservice will soon be joined into one institute, Earth Sciences New Zealand (ECNZ) with research and applied science capability across most aspects of the energy system.

1. The Case for Distributed Renewable Microgrid Systems (RMGS)

Government aims to reach 100% renewable electricity generation by 2030 [1] and net-zero greenhouse gas emissions by 2050 [2,3]. **Presently, renewables provide 82% of current total electricity generation; however, <u>only 28% of total energy consumption, including transport and heat, is from renewable sources</u>** [4].

Meeting these goals requires substantially increased renewable electricity generation – to replace the ~14% of electricity presently coming from non-renewables and coping with demand increases from population growth and electrification of transport and process heat.

Analysis from industry, end-users and the Climate Change Commission demonstrates that *smart whole-of-system evolution* is the preferred pathway for decarbonisation of Aotearoa-NZ's electricity system [4]. This pathway involves '**deploying a range of technologies including batteries, distributed energy resources (DERs), and demand response**'.

However, to truly achieve net-zero goals, we must go significantly beyond 100% renewable electricity at current levels of electricity use. We need to prioritise **energy resilience**, where the addition of stable, locally-generated electricity is sufficient to replace much of our current fossil fuel use for heating and transport. A proactive, fast-tracked approach is necessary – especially given that ***"the current just-in-time approach to network investment won't be suitable for the expected rapid electrification and renewable generation development"*** [4].

We propose a collaborative research–industry effort to unlock the potential of distributed Renewable MicroGrid Systems (RMGS). Rapid, widespread adoption of next-generation RMGS could significantly enhance the performance, resilience, and sustainability of Aotearoa's energy system.

2. Key Knowledge Gaps and Research Needs

As highlighted in the green paper, realising the potential of DERs and RMGS requires addressing regulatory, socio-economic, and physical system challenges. Overcoming these challenges and knowledge gaps – as well as enabling the rapid uptake of DERs in New Zealand's energy system – will require both leveraging previous R&D investments and initiating new efforts to advance key technical issues and close existing knowledge gaps.

We focus on the following science and implementation gaps, identified both globally and in New Zealand [5-13]:

a) Energy system Integration

- How and where to integrate RMGS into the main grid while **managing intermittency** of renewables and demand loads at micro-scales;
- Developing a comprehensive control system for ***normal*** **and** ***contingency*** **conditions** without idealistic assumptions [14,15];
- Developing a leading-edge **peer-to-peer trading algorithm**.

b) Weather and climate Considerations

- Where RMGS would best be located, e.g., with respect to large-scale and micro-scale climate conditions [16-18]
- Improving **forecasts of household electricity demand and generation**, via advanced numerical weather predictions and sophisticated downscaling methods;
- Advancing understanding of impacts of **climate change and extreme weather**, via micro-bioclimate mapping and life-cycle assessment.

c) Real-world implementation

- Prototyping RMGS in case-study areas with our iwi/hapū partners and industry collaborators;
- Developing a socio-economic and behavioural model of electricity regulators, distributors and consumers, to guide improvements in regulations and policies.

3. Our Approach: Physics-Based RMGS Design

At NIWA, in collaboration with national and international partners, we have designed a research workplan to develop a ***physics-based microgrid operational system***. This will include:

- Cutting-edge very-high-resolution multi-scale and multi-horizon numerical weather prediction (NWP) models dynamically downscaled to local contexts.
- Multi-scale agent-based control systems, enabling reliable operation under both normal and contingency conditions.

Meteorological conditions determine the weather-reliant renewable resource availability as well as providing RMGS users' load demand but "***Despite this, weather information plays a secondary role in most of microgrid studies***" [16]. Thus, current RMGS designs are crude due to reliance on synthetic climate forecasts derived from historical data, typically using just one climate variable and assuming deterministic demand load and/or forecasts. This limits their operational value and adaptability.

It is necessary to predict and manage microgrid uncertainty and energy scheduling for RMGS integration with the national grid [19]. *Existing methods are insufficient* [4]:

- **Offline deterministic modelling** with stochastic programming uses limited operation scenarios [20], and thus cannot capture the highly volatile load profile and time-changing conditions expected for RMGS;
- **worst-case condition analysis** is overly conservative and uneconomic [21]; and
- **real-time optimisation/scheduling** is computationally expensive and has a limited look-ahead window that prevents effective scheduling [22].

Moreover, the export limit in current microgrid scheduling models is either limited only by *physical constraints*, e.g., [23], or entirely *ignored* [24], which is unsuitable for real-world applications [9].

A key RMGS implementation challenge is developing *comprehensive control methods* to provide and ensure sufficient, stable and reliable real-world operation. Current control methods are unsuitable due to their strong idealistic assumptions in peer-to-peer trading and scheduling models, such as the lack of real-time forecast horizons and not considering grid policies and regulations.

4. Vision and Potential Impact

We envision *distributed RMGS* as a vital complementary component of Aotearoa-NZ's future electricity system.

By addressing the science and implementation challenges identified here, RMGS can:

- Strengthen system **resilience** during extreme weather and disruptions
- Support faster, more equitable **electrification** of transport and heating
- Enable **local economic empowerment** and participation in energy decision-making
- Deliver smarter, more **efficient energy use and flexibility**

Our proposed research agenda will enable *smart whole-of-system* evolution (Figure below), and transition to a decentralised, low-carbon energy future—fully aligned with the Electricity Authority's goals.

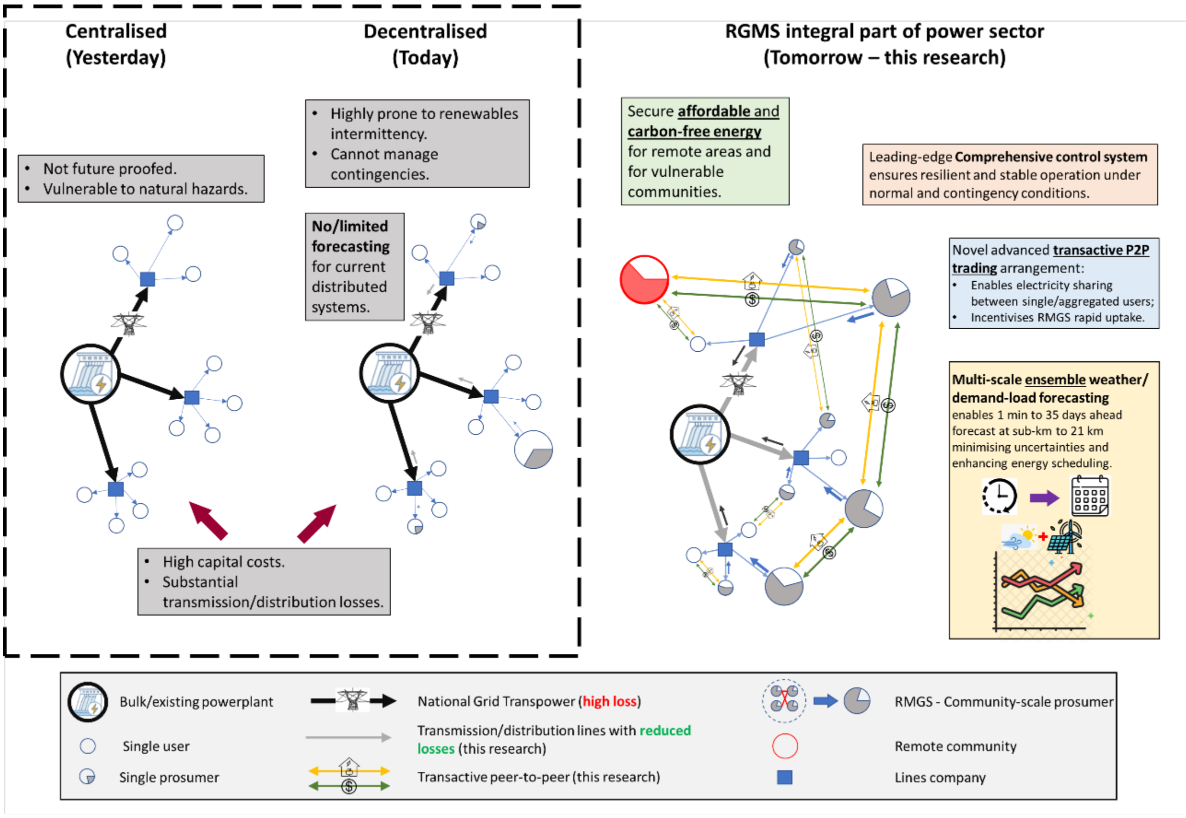

Figure – The proposed research aims to transform New Zealand's electricity sector and enable rapid uptake of RMGS by incentivising and providing benefits (i.e. electricity availability and financial) to users and communities.

5. Conclusion and Alignment with Consultation Questions

This submission supports the green paper's direction and vision, and offers a research-backed path toward implementation. Specifically:

- Q1 & Q2: We support the definition and expected benefits of decentralisation, and highlight RMGS as a key enabler of affordability, resilience, and equity.
- Q3: We identify technical, regulatory, and operational challenges that must be overcome for RMGS and DERs to be effective.
- Q4: We agree with the 2040 opportunity statement and propose practical next steps for achieving this vision.
- Q5: Our submission outlines what a decentralised energy system could look like, how it could benefit New Zealanders, and what R&D and partnerships are needed.
- Q6: We propose case studies involving iwi/hapū and industry collaboration to demonstrate RMGS feasibility, resilience, and impact.

We welcome further discussion on how research and modelling capabilities—particularly in climate science, grid integration, and real-time system control—can contribute to shaping New Zealand's decentralised electricity future.

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