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Quantifying the green hydrogen demand across key sectors in Aotearoa New Zealand: Implications for electricity generation

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Abstract
The transition to green hydrogen presents a great opportunity for Aotearoa New Zealand to meet its long-term climate targets while decarbonising energy intensive sectors. With over 80% of electricity already generated from renewable sources, the country is well-positioned to produce green hydrogen through water electrolysis. However, the extent to which hydrogen demand may impact electricity generation capacity remains underexplored. This study quantifies projected hydrogen demand across four key sectors: steel, heavy-duty transport (trucks and coaches), methanol production, and fertilizer manufacturing, from 2025 to 2050. Historical production and activity data were collected from national and international sources and used to project future sectoral activity. Hydrogen demand was estimated under both ideal stoichiometric and real-world adjusted efficiency scenarios. These values were then converted into electricity requirements using efficiency benchmarks for Proton Exchange Membrane (PEM) and Solid Oxide Electrolyser Cell (SOEC) technologies. The results show that the transport and methanol sectors exhibit the highest hydrogen demand, followed by fertilizers and steel. Under real-world assumptions, electricity demand to produce hydrogen could reach between 30 and 55 terawatt-hours annually by 2050, potentially exceeding Aotearoa New Zealand's current generation capacity. The findings highlight the importance of aligning hydrogen development with renewable electricity expansion and infrastructure planning. The study provides a replicable modelling approach for emerging hydrogen economies, particularly in the Global South. It contributes to the evolving body of knowledge by offering a sector-specific assessment of hydrogen demand, integrating technological parameters with national energy system planning, and informing future hydrogen strategy development in Aotearoa New Zealand and beyond.

Keywords: Green hydrogen; Electrolyser technologies; Electricity demand; Sectoral modelling; Energy transition.

1. Introduction
The urgent need to decarbonize global energy systems has placed hydrogen at the forefront of clean energy discussions. In Aotearoa New Zealand, the commitment to reaching net-zero carbon emissions by 2050 has prompted increased attention to alternative fuels, particularly those suitable for sectors that are difficult to electrify using conventional renewable electricity. Despite Aotearoa New Zealand's strong renewable energy base where hydro, geothermal, and wind account for over 88.1% of electricity generation from renewable sources in 2023, which is the highest since 1981, fossil fuels still take up 57.2% of the nation's total energy supply (MBIE, 2024). This continued reliance on fossil fuels, particularly in transport and industrial processing, presents a barrier to meeting national climate targets. The urgent need to decarbonize global energy systems has placed hydrogen at the forefront of clean energy discussions.

Hydrogen, especially when produced through electrolysis using renewable electricity, which is called green hydrogen, has emerged as a promising alternative fuel for decarbonising these hard-to-abate sectors. This growing interest for hydrogen is driven by the need to secure sustainable energy sources that align with both environmental goals, and the evolving energy needs of a growing population. With potential applications including energy storage, industrial heating, chemical feedstock, and green fuel, hydrogen holds a vast potential as an alternative energy vector (Perez et al., 2021). Over 25 countries, including Aotearoa New Zealand, have released hydrogen strategies or roadmaps, demonstrating global momentum towards hydrogen adoption (Wappler et al., 2022). In 2019, the Ministry of Business, Innovation and Employment (MBIE) released the Green Paper: A Vision for Hydrogen in New Zealand, which laid the foundation for hydrogen integration into the national energy transition. This was followed by the Interim Hydrogen Roadmap (2023) and the Hydrogen Action Plan (2024), which collectively identify priority sectors and outline opportunities for green hydrogen deployment. However, existing national reports do not comprehensively model hydrogen demand nor assess the associated impact on electricity generation capacity.

The deployment of green hydrogen requires a robust understanding of sectoral energy demand, technology-specific electricity requirements, and feasibility within the constraints of the existing electricity grid. Countries like Germany, Norway, and Australia have begun to evaluate these relationships in detail, and Aotearoa New Zealand must similarly undertake a rigorous sector-level analysis to inform planning and investment.

This paper responds to the current knowledge gap by quantifying hydrogen demand across these sectors from 2025 to 2050 and assessing the associated electricity requirements under two electrolyser technology scenarios: Proton Exchange Membrane (PEM) and Solid Oxide Electrolyser Cell (SOEC). The findings provide essential insights into the infrastructure needs, investment priorities, and policy considerations necessary for integrating green hydrogen into Aotearoa New Zealand's low-emissions pathway. While renewable electricity generation in New Zealand is relatively strong, the extent to which it can support new hydrogen demand under future expansion scenarios, requires further investigation. Doing so is crucial for informed infrastructure planning, investment prioritisation, and policy development.

1.1. Objective of the paper

The paper undertakes a comprehensive assessment of the demand potential for green hydrogen in Aotearoa New Zealand, with the objective of understanding how this shift will impact both current and future electricity generation capacity. This study aims to:

- Identify hard-to-abate key sectors in Aotearoa New Zealand for the analysis for green hydrogen integration.
- Quantify and estimate the projected hydrogen demand in the identified sectors from 2025 to 2050.
- Advise on which sector needs priority for Aotearoa New Zealand's emerging green hydrogen roadmap
- Estimate the electricity demand required to produce the projected hydrogen demand using two electrolyser technologies: Proton Exchange Membrane (PEM) and Solid Oxide Electrolyser Cell (SOEC).
- Assess the implications of hydrogen driven electricity demand relative to Aotearoa New Zealand's current national electricity supply.
- Apply the findings and insights from Aotearoa New Zealand's hydrogen demand modelling to inform future green hydrogen strategies in Namibia, contributing to global body of knowledge.

By addressing these objectives, the study not only provides a robust understanding of green hydrogen's multifaceted role in Aotearoa New Zealand's sustainable energy transition but also lays the groundwork for strategic planning and policy development aimed at maximizing the benefits of this ever-evolving technology.

2. Literature review

This section reviews literature relevant to the role of green hydrogen in supporting Aotearoa New Zealand's decarbonisation efforts. It begins by examining the context for green hydrogen development, including policy ambitions, emissions targets, and the dynamics of the energy sector. The section then reviews key green hydrogen production technologies, with a focus on electrolysis and its associated electricity demands. This serves as a foundation as it identifies and evaluates the economic sectors with the most potential for green hydrogen in the country. This sector selection is informed by examining the national greenhouse gas emissions data, their energy use profiles, and technical feasibility based on existing literature and frameworks, such as the Clean Hydrogen Ladder. This literature-based prioritisation forms the basis for the sectoral modelling in subsequent chapters. Finally, the section reviews literature on the projected implications of hydrogen deployment on electricity demand, highlighting the need for coordinated energy planning. Together, these insights provide the conceptual and analytical grounding for the modelling approach used in this study.

The research was mostly influenced by the work of Ghadim et al. (2025), who provided a comprehensive analysis for the hydrogen demand across twenty applications in Aotearoa New Zealand and they were structured according to the Clean Hydrogen Ladder Framework. Their study served as a foundational reference, which helped shape the sectors and most importantly guide the modelling strategy.

2.1. Global and national context for green hydrogen

Globally, hydrogen has gained momentum as a key component of decarbonisation strategies, with more than 25 countries releasing national hydrogen plans Wappler et al., (2022). These plans are often tied to achieving net-zero emissions targets, diversifying energy portfolios, and reducing reliance on fossil fuels. Australia, for example, has developed one of the largest hydrogen project pipelines globally, supported by incentives such as the Hydrogen Production Tax Incentive. China has also institutionalized hydrogen in its 13th and 14th Five-Year Plans and national energy law drafts (Li and Taghizadeh-Hesary, 2022).

In Aotearoa New Zealand, the government has initiated the Interim Hydrogen Roadmap (2023) and Hydrogen Action Plan (2024). These documents highlight priority sectors for hydrogen integration, including heavy transport, industrial processing, and chemical feedstock production. However, as noted in the Electricity Demand and Generation Scenarios Report (2024), current electricity system planning does not yet fully account for hydrogen's role or potential uptake rates. This gap presents a challenge to long-term infrastructure and policy planning.

Despite Aotearoa New Zealand's high share of renewable electricity, over 55% of its total energy supply still comes from fossil fuels (MBIE, 2023), which emphasizes the need for broader electrification and decarbonisation strategies. Green hydrogen is increasingly viewed as a promising solution for hard-to-abate sectors, particularly where direct electrification is technically or economically infeasible.

2.2. Hydrogen production pathways

Among the available hydrogen production technologies, water electrolysis powered by renewables stands out as the most sustainable pathway. The main electrolyser types include:

- Alkaline Electrolysis (AEC);
- Proton Exchange Membrane (PEM);
- Solid Oxide Electrolysis Cell (SOEC); and
- Anion Exchange Membrane (AEM).

PEM and SOEC are the focus of this research due to their relevance in large-scale hydrogen production scenarios. PEM is commercially mature but less energy-efficient, while SOEC offers higher efficiency but is less technologically developed (Allgoewer et al., 2024; Zainal et al., 2024).

Studies in other countries illustrate the feasibility of using renewable-powered electrolysis. For instance, Bhaskar et al. (2022) evaluated a green steel plant in Norway powered by hydropower, while Akdağ (2024) demonstrated geothermal-powered electrolysis in Turkey. The Djibouti study by Awaleh et al. (2022) compared wind and geothermal hydrogen production, showing that wind-based hydrogen production could be more cost-effective.

While green hydrogen is often seen as a zero-carbon energy source, it is important to recognize that it is not entirely emissions free. The production and supply chain processes associated with green hydrogen, though significantly cleaner than those of fossil fuels, still involve some level of emissions. Acknowledging these emissions is crucial as we strive to balance the benefits of green hydrogen with the broader goals of achieving a truly sustainable and low-carbon energy future (Dawood et al., 2020).

2.3. Sector prioritization and clean hydrogen framework

The selection of sectors for hydrogen integration is a critical step. This study follows the Clean Hydrogen Ladder (Liebreich Associates, 2023), a framework for ranking hydrogen applications by necessity and feasibility. Applications such as steelmaking, fertilizer production, methanol synthesis, and heavy transport rank high due to their reliance on fossil fuels and lack of electrification alternatives.

Building on this framework, Ghadim et al. (2025) presented a comprehensive mapping of hydrogen demand across twenty sectors in Aotearoa New Zealand. Their work used a bottom-up modelling approach based on sector-specific activity data and process energy requirements. The present study draws from this model and focuses on a targeted selection of high-emission sectors aligned with both domestic policy and international best practice.

The MBIE Sector Dashboard (MBIE, 2023) further validates this selection by highlighting the economic and emissions contribution of key industries, ensuring that hydrogen modelling is grounded in real sectoral importance.

Based on an evaluation of the Clean Hydrogen Ladder, the modelling framework presented by Ghadim et al. (2025), the MBIE sector dashboard, and additional criteria such as sectoral emissions intensity, technical feasibility, and alignment with national policy documents, the following sectors were identified as high-priority candidates for green hydrogen deployment: steelmaking, heavy-duty transport (limited to trucks and coaches), and fertilizer and methanol production.

These sectors are critical in Aotearoa New Zealand's emissions profile and are central to this study. Other potential sectors such as domestic heating, aviation, and shipping were excluded due to lower relevance or data limitations.

The Interim Hydrogen Roadmap (MBIE, 2023) further validates the sector selection, identifying heavy transport, industrial chemical processes, and steelmaking as priority areas due to their high emissions and limited alternatives. Notably, steel contributes approximately 5% of gross national emissions and over 55% of industrial emissions.

2.4. Electricity demand and planning implications

Green hydrogen production requires substantial electricity input, especially when derived from water electrolysis. This presents both an opportunity and a challenge for Aotearoa New Zealand. The country's renewable energy supply is currently dominated by hydro and geothermal sources; it may not be sufficient to meet future demand without significant generation expansion, notably with wind and solar.

The required electricity also raises concerns about grid capacity and planning. The Electricity Demand and Generation Scenarios Report (MBIE, 2024) notes that hydrogen is not yet fully accounted for in national demand modelling, highlighting a key planning shortcoming

On the other hand, hydrogen also offers grid services, such as flexibility and seasonal storage, making it not just a challenge but also a potential asset for managing intermittent renewable generation (Borup et al., 2021).

3. Research methods

This study adopted a mixed-methods approach combining quantitative modelling and literature-based qualitative validation to assess the projected demand for green hydrogen in Aotearoa New Zealand's priority sectors and its implications for national electricity generation. The research followed a six-step framework shown in Figure 1.

The design was shaped by the work of Ghadim et al. (2025) and applies a bottom-up estimation method using real production and activity data to determine hydrogen demand across four sectors: steel, methanol, fertilizer, and trucks and coaches.

3.1. Data collection and Sources

Secondary data was sourced from official databases, government reports, industry publications, and literature. Historical production and activity data were obtained for each sector, covering the years 2000 to 2023, depending on data availability. Where gaps existed, regression modelling was used to estimate missing data points. The main key data sources included:

- Ministry of Transport, Stats NZ, MBIE, Methanex annual reports;
- World Steel Association, Fertiliser Association of New Zealand; and
- Academic sources (articles and journals).

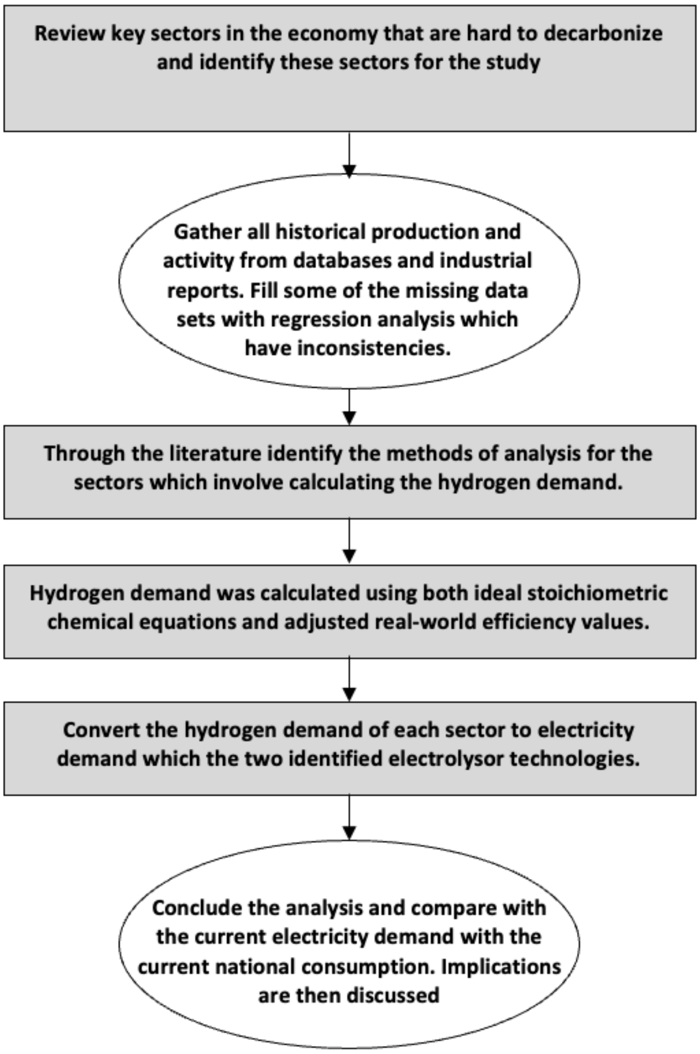

Figure 1. Six-step research approach

3.2. Sectoral hydrogen demand estimation

Ghadim et al. (2025) provide the technical coefficients used in hydrogen demand estimation. Specifically, their bottom-up modelling approach, hydrogen consumption factors, and electrolyser efficiency benchmarks offered a robust basis for comparative and scenario-based analysis.

Hydrogen demand was estimated using two methods:

- Ideal stoichiometric ratios derived from chemical equations (e.g., steel via DRI, methanol, ammonia); and
- Real-world adjusted values that account for system inefficiencies and energy losses.

Each sector's historical production and activity was multiplied by the corresponding hydrogen intensity (kg H_2/tonne or kg H_2/km) under both scenarios. All final demand values are presented in tonnes of hydrogen per year.

3.1.1 Steel sector

The hydrogen demand for steel was estimated based on a transition from traditional coal-based methods to hydrogen-based Direct Reduced Iron (DRI). Projected crude steel production was derived from historical data from the World Steel Association statistical yearbooks from 2000 to 2023 and extrapolated using linear regression. By using this annual production volume in tonnes, the regression model was used to project the future steel production trends through 2050, which served as a foundation for estimating and calculating the projected hydrogen demand. Hydrogen demand was based on projected crude steel production and DRI conversion assumptions (58 kg H_2/t ideal (Hall et al., 2021), 67.5 kg H_2/t adjusted).

To sum up the hydrogen demand both ideal and real-world cases were multiplied by the annual steel production by each respective H_2 intensity factor. The values were then produced in tonnes of hydrogen per year. Although Aotearoa New Zealand's steel industry is quite relatively very small, being included in the analysis is essential because of its high impact on the decarbonizing pathways.

3.1.2 Transport sector

As described by Ghadim et al. (2025), the vehicle kilometres travelled (VKT) quantification was used. Firstly, to establish the hydrogen demand for road freight, fleet statistics were obtained from Ministry of Transport from 2001 to 2023.

The data from the Ministry of Transport was utilized to estimate fleet size changes over time, accounting for the projected increases in heavy-duty vehicle numbers. The analysis included getting the tonne km, which was the divided by the average load in tonnes to get the annual VKT.

The VKT was used to analysis the data with two methods:

- Energy-based method using thermal energy demand per km and drivetrain efficiency (η = 0.42), and hydrogen's LHV (33.33 kWh/kg) sourced from Ghadim et al. (2025).
- A direct method using vehicle-based hydrogen consumption rate of 8 kg H_2 per 100 km (consistent with current fuel cell electric truck performance and literature estimates)(Perez et al., 2021)

Projected VKT was extrapolated using historical data from 2001–2023. Both approaches were applied to provide a range of plausible hydrogen demand outcomes for heavy-duty transport. Method 2 served as the primary scenario, following expert recommendation and validation, while Method 1 was retained as a comparative reference for illustrating how drivetrain efficiency and fuel characteristics affect hydrogen projections. Trendlines for both methods were developed through regression analysis to project demand from 2025 to 2050.

3.1.3 Methanol sector

Methanol production in Aotearoa New Zealand has recently declined due to natural gas constraints and temporary shutdowns at Methanex facilities. However, it was retained in this study to represent a future demand scenario. Methanol remains a strategic industrial product with growing global demand and is considered a viable hydrogen-based fuel and feedstock. The inclusion assumes that production resumes at or near historical capacity over time.

Production volumes (2021–2023) were sourced from Methanex reports and extrapolated to 2050. The production was then multiplied by the hydrogen mass requirement (ideal 188.8 kg H2/t) to get the projected hydrogen demand from 2024 to 2025. However, an adjusted analysis was also included with a real-world factor of 235 kg H_2/tonne, which is slightly higher than the ideal stoichiometric quantification. This assumes a return to full operational levels despite temporary shutdowns due to gas supply limitations.

3.1.4 Fertilizer sector

The analysis focused on three main nitrogen-based fertilizers: urea, ammonium sulphate (AS), and diammonium phosphate (DAP). Historical application volumes (2002–2019) were sourced from Stats NZ and extrapolated to 2050. The hydrogen demand was calculated using stoichiometric molar mass relationships and adjusted process efficiencies:

- Urea: 100.7 kg H_2/t (ideal), 130 kg H_2/t (real-world)
- AS: 45.8 kg H_2/t (ideal), 60 kg H_2/t (real-world)
- DAP: estimated similarly for AS

These values reflect the hydrogen input required to produce ammonia as a precursor in fertilizer synthesis.

3.3. Electricity demand conversions

To assess the impact on electricity generation, the total annual hydrogen demand (in kg) was converted into electricity demand using the specific energy consumption of two main electrolyser technologies (Allgoewer et al., 2024):

- PEM: 53.1 kWh/kg H_2
- SOEC:34.1 kWh/kgH_2

Electricity requirements were calculated annually and aggregated for each sector. The final results were expressed in terawatt-hours (TWh) and compared to Aotearoa New Zealand's current national electricity generation (~43 TWh/year).

3.4. Sensitivity analysis

To account for variation in fuel consumption assumptions, a sensitivity analysis was performed in the transport sector using three hydrogen usage rates:

- 5 kg/100 km (high efficiency)
- 8 kg/100 km (baseline)
- 10 kg/100 km (low efficiency)

This range was used to examine the impact of vehicle performance improvements or conservative planning assumptions on total hydrogen demand projections.

3.5. Assumptions and limitations

- The study excludes other potential applications such as aviation, hydrogen export, domestic heating, long-term storage, and so forth.
- Electricity modelling assumes constant electrolyser efficiency, with no learning rates or cost dynamics.
- Future changes are not incorporated.
- Scenario modelling (e.g., high/medium/low demand cases) was not included but is recommended for future studies.
- Methanol and fertilizer projections are based on limited recent data and assume stable long-term operations.

4. Results and discussion

4.1. Sectoral hydrogen demand projections (2025-2050)

Hydrogen demand in the steel sector is projected to decline over time, reflecting the downward trend in domestic crude steel production. Under the real-world scenario, hydrogen demand peaks at approximately 40,609 tonnes in 2025 and declines to 21,144 tonnes by 2050 (see Figure 2). Despite the relatively small size of Aotearoa New Zealand's steel sector, its inclusion is important due to its disproportionately high emissions and alignment with decarbonisation pathways such as hydrogen-based Direct Reduced Iron (DRI).

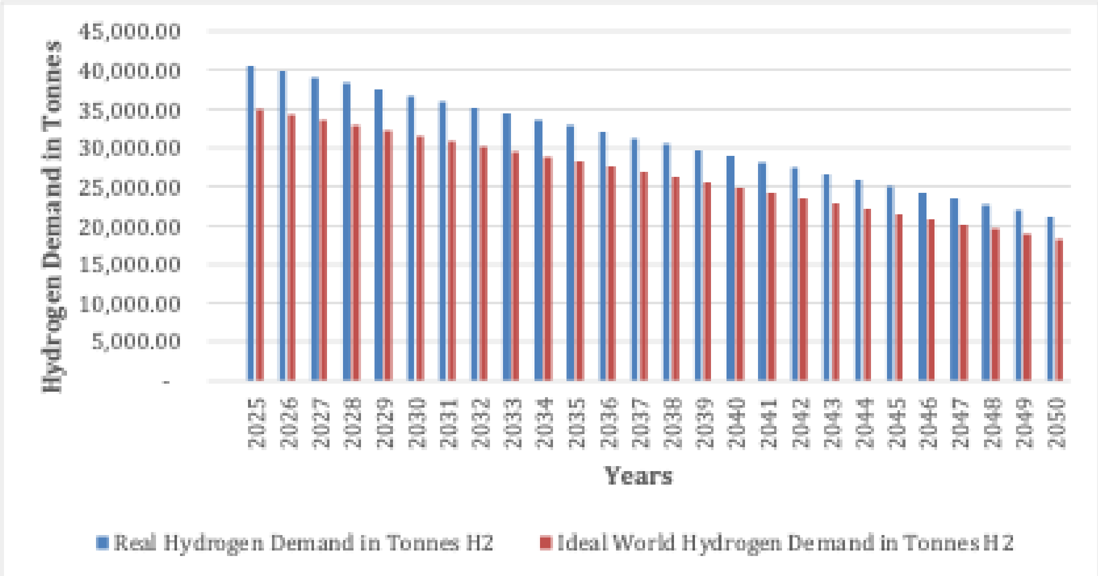

Figure 2. Projected hydrogen demand for the steel sector

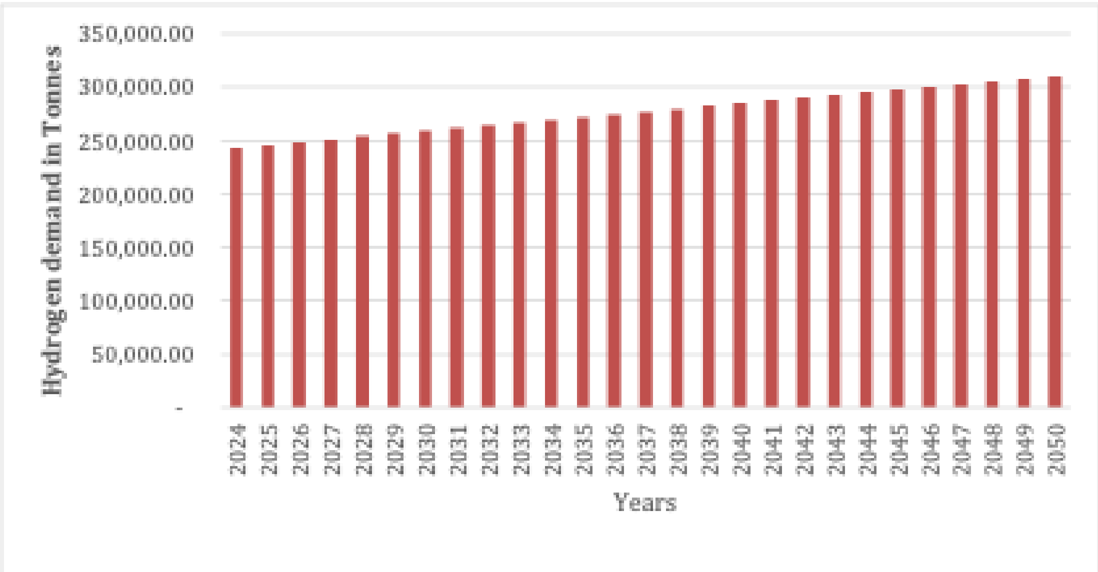

Figure 3. Projected hydrogen demand for the transport sector

Transport emerges as a leading sector for hydrogen demand, driven by rising freight activity and its limited potential for direct electrification. Using Method 2 (8 kg H_2/100 km), hydrogen demand increases steadily from 2025 to 2050 (see Figure 3). The projection aligns with expected growth in Vehicle Kilometres Travelled (VKT), economic development, and freight movement.

Although current methanol production is limited, this sector was retained to reflect future industrial demand should Methanex resume or expand operations. Under this assumption, hydrogen demand shows steady growth (see Figure 4). The real-world adjusted scenario projects over 328,000 tonnes of hydrogen required by 2050. These results provide a precautionary perspective for infrastructure planning, ensuring that the future industrial load is not underestimated.

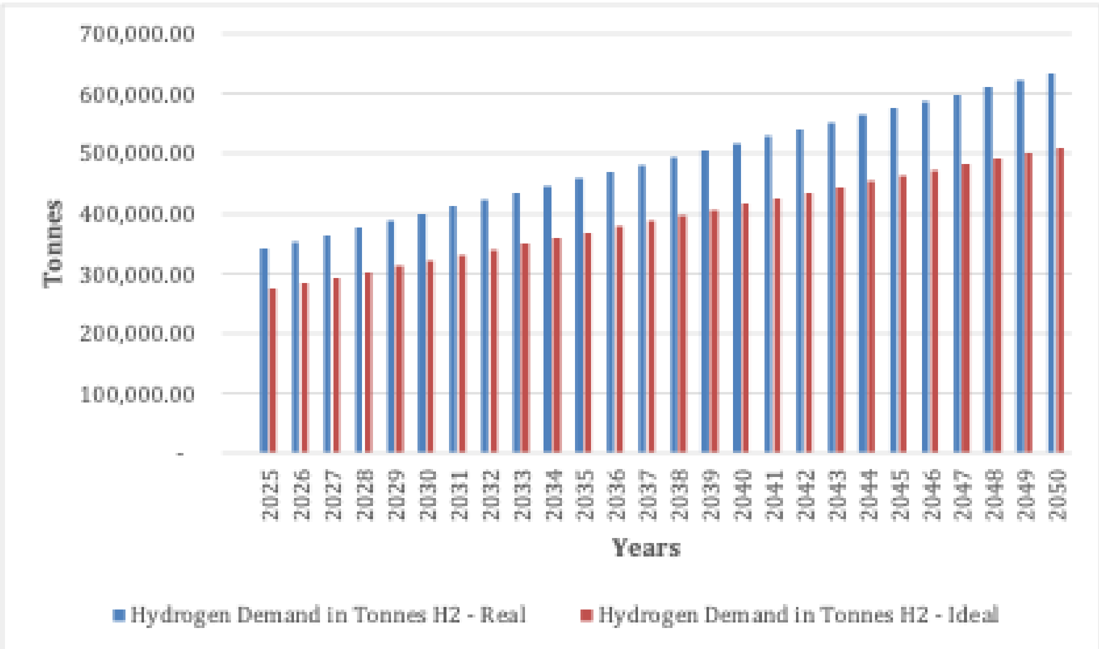

Figure 4. Hydrogen demand for methanol sector

Fertilizer production specifically for nitrogen-based compounds like urea, ammonium sulphate, and diammonium phosphate which accounts for significant hydrogen use. Among these, urea dominates demand, reaching around 69,000 tonnes by 2030. The adjusted efficiency scenario (130 kg H_2/tonne) reflects industrial process losses, providing a more realistic basis for electricity demand planning. Although demand growth is moderate compared to transport or methanol (see Figure 5), the fertilizer sector remains a key industrial hydrogen consumer.

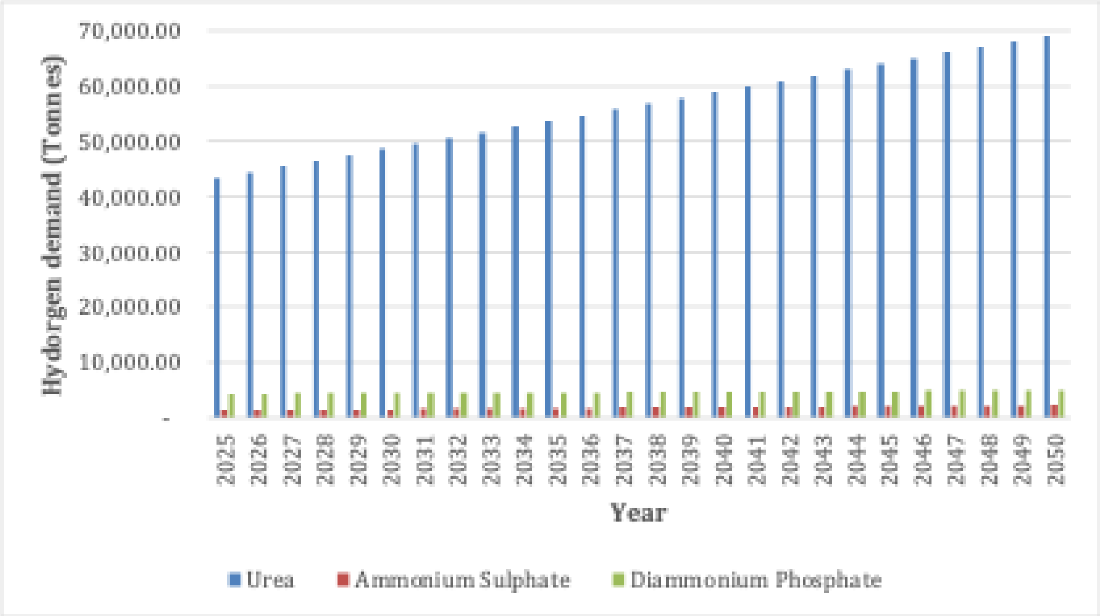

Figure 5. Hydrogen demand for three key fertilizers

Figure 6 compares the projections of the key sectors, which shows methanol as the sector with the highest projected hydrogen demand followed by transport, fertilizer, and steel.

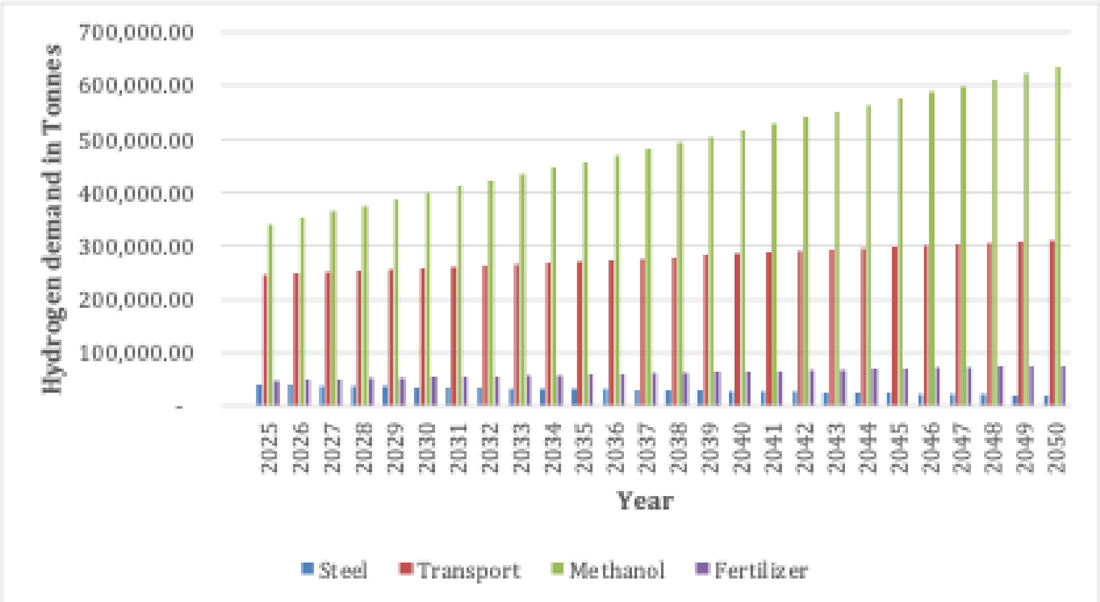

Figure 6. Hydrogen demand projection across key sectors

4.2. Electricity demand Implications

Figure 7 shows the overall electricity demand by technology type:

- Under the PEM scenario (53.1 kWh/kg H_2), electricity demand is projected to exceed 55 TWh by 2050.
- Under the SOEC scenario (34.1 kWh/kg H_2), demand peaks at approximately 35 TWh.

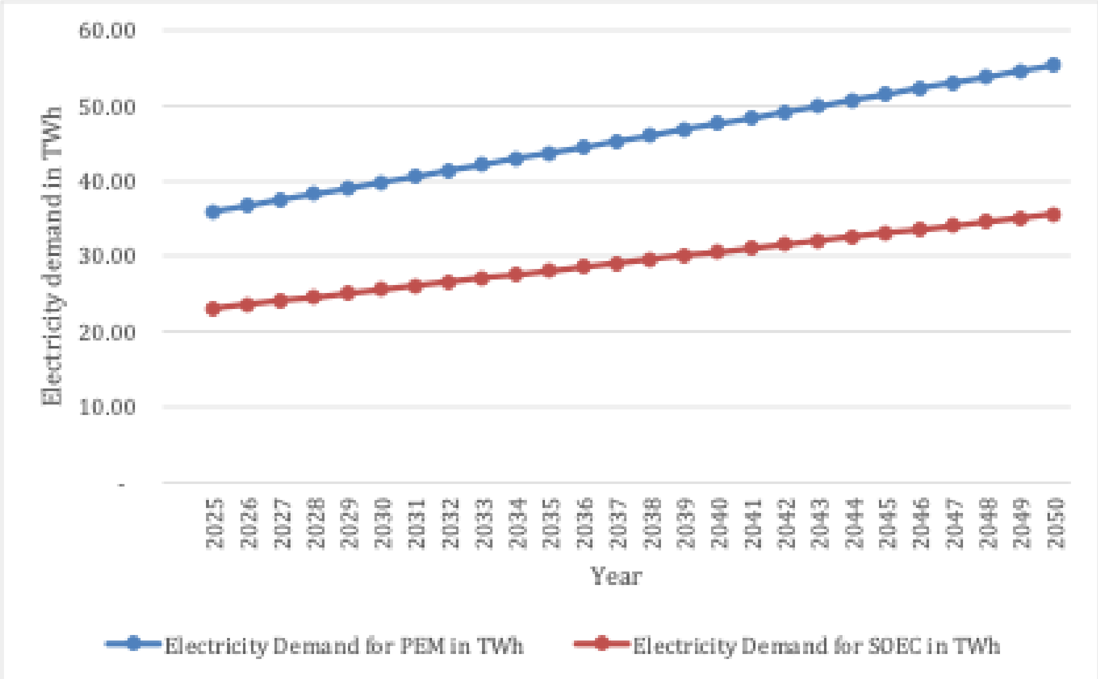

Figure 7. Projected electricity demand for both electrolysers

These values are significant, given that Aotearoa New Zealand's current total electricity generation is approximately 43 TWh/year (MBIE, 2023). The projections indicate that green hydrogen production could consume between 70% and over 120% of current national generation capacity, depending on the technology and sectoral uptake.

Methanol and transport are the dominant drivers of electricity demand due to high hydrogen consumption volumes. Fertilizers contribute a substantial but secondary load. Steel, while lower in volume, remains important for infrastructure transition scenarios.

The results highlight the need to align hydrogen deployment with electricity system upgrades, renewable energy expansion, and grid flexibility measures. They also demonstrate the trade-offs between electrolyser maturity (PEM is commercially ready) and efficiency (SOEC is more energy-efficient, but less mature).

4.3. Discussion

The results of this study demonstrate that sector-specific hydrogen demand in Aotearoa New Zealand which are particularly from methanol production and heavy-duty transport, could place substantial strain on the national electricity grid by 2050. When applying real-world energy consumption rates for electrolyser technologies, electricity demand could exceed the country's current total electricity generation of 43 TWh/year. These findings reinforce the critical need to integrate hydrogen demand planning with electricity infrastructure development.

The transport sector stands out more due to its rapid demand growth. This aligns with previous modelling by Perez et al. , 2021), who found hydrogen to be the most viable decarbonisation option for VHVs in New Zealand, given the limitations of battery electric alternatives. The vehicle-based hydrogen consumption approach used in this study (8 kg H_2/100 km) mirrors real-world conditions and provides transparent, policy-relevant results.

In contrast, methanol's inclusion offers a forward-looking insight. While Methanex operations have recently scaled back due to natural gas supply constraints, the resumption or repurposing of these facilities could revive hydrogen demand. Global projections (Fasihi and Breyer, 2024) suggest continued methanol growth as a clean fuel and hydrogen carrier, reinforcing the need to consider this sector in long-term national energy modelling even in the absence of short-term production trends.

Fertilizer manufacturing also emerges as a consistent and strategic hydrogen user. Although its total demand is lower than transport or methanol, the sector's dependence on hydrogen-derived ammonia ensures that any transition to green hydrogen will significantly impact agricultural emissions. As noted by Maganza et al., (2023), over 99% of hydrogen used in the fertilizer industry is currently fossil-based. Transitioning to green hydrogen could therefore yield meaningful environmental gains.

The steel sector, while showing declining domestic output, is important for a broader industrial decarbonisation challenge. Even though its demand is lower in absolute terms, its carbon intensity remains high. Griffin and Hammond (2021) and Bhaskar et al. (2022) support the use of hydrogen in DRI-EAF pathways, validating the inclusion of steel as a strategic, if smaller, sector.

Across all sectors, the choice of electrolyser technology plays a pivotal role. PEM electrolysers, while commercially mature and flexible in operation, are significantly less efficient than SOEC, which has the potential to reduce electricity demand by over 35%. However, SOEC's deployment at scale remains limited due to material degradation and high capital costs (Allgoewer et al., 2024). These findings highlight a trade-off between technological readiness and energy efficiency, which must be considered in hydrogen infrastructure decisions.

From a system planning perspective, these findings suggest that Aotearoa New Zealand will need to:

- Expand renewable electricity generation significantly, beyond business-as-usual scenarios;
- Invest in electrolyser deployment and grid capacity upgrades; and
- Integrate hydrogen demand into national energy forecasts and infrastructure blueprints.

5. Conclusion and recommendations

This study set out with the objective of identifying key sectors for green hydrogen integration in Aotearoa New Zealand, quantifying their hydrogen demand from 2025 to 2050, and assessing the implications of this demand for electricity generation capacity under two electrolyser scenarios (PEM and SOEC). These objectives have been comprehensively addressed through a structured modelling framework supported by empirical data and sector-specific assumptions.

The research has demonstrated that methanol production and heavy-duty transport are the largest future sources of hydrogen demand, followed by fertilizers and steelmaking. Hydrogen demand was calculated under both ideal stoichiometric conditions and real-world industrial efficiency assumptions, providing a realistic range of potential outcomes. These results were then translated into electricity demand using technology-specific conversion factors, revealing a projected requirement of 30 to 55 TWh annually by 2050 for hydrogen production alone. This electricity demand could exceed New Zealand's current generation levels, indicating that hydrogen integration will place substantial pressure on the national energy system.

In conclusion, the study contributes valuable insights into the integration of hydrogen and electricity planning, highlighting where infrastructure expansion, policy support, and technological investment will be most needed.

5.1. Recommendations

From the findings of this study, several specific recommendations can be made to guide both immediate action and long-term strategic planning in support of Aotearoa New Zealand's green hydrogen transition.

The results indicate that deployment efforts should prioritise high-demand sectors such as heavy-duty transport and methanol production, where hydrogen consumption is projected to be most significant by 2050. This involves directing early infrastructure investments toward hydrogen refuelling corridors for freight and exploring options for repurposing or reactivating methanol facilities like Methanex for future green hydrogen use. In parallel, regional and national electricity networks must integrate projected hydrogen demand into load forecasting and capacity expansion plans, ensuring that electrolyser loads are factored into future energy modelling. The co-location of electrolysers with renewable energy sources should be encouraged to maximise efficiency and reduce transmission losses. Furthermore, partnerships between industry players and government agencies should be promoted to accelerate the hydrogen-readiness of high-emission sectors such as fertilizer production and steelmaking.

For policy-making, it is essential that hydrogen demand forecasts are formally integrated into national electricity planning documents, such as the Electricity Demand and Generation Scenarios, to avoid underestimating future infrastructure requirements. Policy mechanisms should also support technology diversity by providing targeted funding for both mature technologies like PEM and emerging high-efficiency systems like SOEC, the latter of which shows strong potential for reducing overall electricity consumption in the hydrogen value chain. Sector-specific incentives, such as fuel substitution mandates for logistics companies or emissions credits for industrial users, could accelerate early adoption and improve commercial viability.

As green hydrogen becomes increasingly tied to international energy markets, policymakers should also ensure alignment between Aotearoa New Zealand's hydrogen strategy and global developments, particularly with respect to hydrogen-based exports such as green ammonia or methanol.

For future research, several areas warrant further exploration. Scenario-based modelling should be developed to complement the single-projection approach used in this paper, offering low-, medium-, and high hydrogen demand pathways and their corresponding infrastructure and investment implications. Future studies should also incorporate detailed techno-economic assessments to evaluate the cost-effectiveness of hydrogen deployment under various policy and market conditions, including carbon pricing. Beyond the four sectors explored here, underrepresented applications such as aviation, maritime transport, domestic heating, and seasonal energy storage offer promising areas for hydrogen integration and should be rigorously investigated. Lastly, researchers should examine how hydrogen can contribute to sector coupling and energy system flexibility, especially in scenarios with high renewable penetration, where hydrogen can serve as both a decarbonisation tool and a means of balancing grid intermittency.

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