RACE for 2030
RELIABLE AFFORDABLE CLEAN ENERGY

BT1: Research Report

24/7 TRUZERO

Tracking Renewables Utilisation for Zero Emission Reporting and Operation

Final report

Australian Government
Department of Industry, Science and Resources

Cooperative Research Centres Program

RACE for Business

Research theme BT1: Digitalising industry

ISBN: 978-1-922746-58-0

24/7 TRUZERO Tracking Renewables Utilisation for Zero Emission Reporting and Operation

Citation

Samarakoon, S., Kallmier, E., McConnell, D., Roberts, M., MacGill, I. and Bruce, A. (2024). 24/7 TRUZERO: Tracking Renewables Utilisation for Zero Emission Reporting and Operation for RACE for 2030.

July 2024

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An adjacent case study was undertaken with Plico/Starling Energy by Curtin University (Sumedha Rajakaruna, Ehsan Pashajavid, Shuying Lai, Mike Mouritz and Angie Silva) as part of this project, which does not form part of this report, but contributed to our thinking on 24/7.

Acknowledgements

The research team would like to thank the stakeholder reference group participants from the following organisations: AG, DCCEEW, Business Renewables Centre Australia, CEC, Coles, EPWA, Google, Green Energy Markets, Horizon Power, Renewable Energy Hub, and UTS. We would like to acknowledge contributions to open-source tools development by George Furrer, Declan Heim, Shayan Naderi and Nick Gorman from the Collaboration on Energy and Environmental Markets, and time generously given by the research participants.

Project partners

Acknowledgement of Country

The authors of this report would like to respectfully acknowledge the Traditional Owners of the ancestral lands throughout Australia and their connection to land, sea and community. We recognise their continuing connection to the land, waters and culture and pay our respects to them, their cultures and to their Elders past, present, and emerging.

What is RACE for 2030?

RACE for 2030 CRC is a 10-year co-operative research centre with AUD350 million of resources to fund research towards a reliable, affordable, and clean energy future. https://www.racefor2030.com.au

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About CEEM

The UNSW Collaboration for Energy and Environmental Markets (CEEM) undertakes interdisciplinary research in the design, analysis and performance monitoring of energy and environmental markets and their associated policy frameworks. CEEM's research focuses on the challenges and opportunities of clean energy transition within market-oriented electricity industries. It does so through collaborations between UNSW researchers from the Faculty of Engineering, the Business School and the Faculty of Arts, Design and Architecture, working alongside Australian and International partners.

CEEM aims for impact through close engagement with energy stakeholders, development of open-source tools and submissions to relevant Australian policy and regulatory processes.

More details of this work can be found at our website. We welcome comments and suggestions and potential collaborations on this research and related tools development, and all our work in this area.

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Executive Summary

Context

- Driven by limitations of current carbon accounting and certification approaches, there is increasing interest in time-matching within corporate renewable energy PPAs and certification.
- Businesses and coalitions aiming to provide leadership in renewable energy procurement are going beyond net 100% targets and committing to renewable energy matched every hour with demand ('24/7 Carbon Free Energy').
- Standards are under development globally, and through the Renewable Energy Guarantee of Origin (REGO) framework in Australia, to include granular (usually hourly) timestamping in certification of 'green' products and renewable energy.
- However, as yet, there is no established mechanism to validate renewable generation matched with demand hour by hour, and there is very limited experience of PPA contracts requiring time-matching.
- In general, businesses currently lack visibility on how their renewable energy purchasing decisions, related firming contracts and onsite energy management impact their energy costs and risks and especially the carbon-intensity of their electricity use.

Research Scope

This project explored the opportunities and challenges of matching and tracking renewable energy purchasing by Commercial and Industrial (C&I) customers in the Australian context. Enosi's Powertracer platform demonstrated renewables matching and tracking in a PPA for several case studies, and three parallel research streams were undertaken:

1. Stakeholder interviews and analysis of submissions to the REGO policy consultation were undertaken to better understand the motivations for and dynamics of renewable energy procurement decisions by C&I customers in Australia, and specifically their views on 24/7 procurement arrangements and certification, and the opportunities and challenges they present.

2. Tools were developed for improving matching of renewables purchasing of large energy users with their demand through different procurement and on-site flexibility approaches, and for analysing the cost, emissions and risk outcomes. Using these tools and data from the case studies and project partners, potential renewables products and contracting approaches were assessed for a range of different C&I customer types.

3. A model was built to explore capacity investment in a future NEM with high uptake of '24/7' contracting by C&I customers.

Summary of Findings

1. Understanding Corporate Renewable Energy Procurement and the Role of Time Matching and Certification

   - **Key Corporate Drivers** - C&I customer interest in renewable energy contracting was primarily motivated by the confluence of sustainability goals (net zero or 100% renewable targets, ESG goals) in response to evolving stakeholder expectations, and internal imperatives to reduce cost and risk through stable electricity prices.

- Our findings revealed the following key arguments in support of time-matching:
  - Time-matched renewable energy procurement would facilitate targeted investment in green firming, storage, and demand management and help drive decarbonisation.
  - Certified time matched renewable energy represents a valuable form of differentiation from ubiquitous 100% renewable and net-zero claims (and shield against potential greenwashing claims).
  - The emerging market for green hydrogen (locally and internationally), with its strict temporal, spatial and additionality requirements, is expected to support the growth of time matched renewable energy procurement.
  - Evidence of load-matching in contracts and a variety of demand management initiatives reflect an appreciation of the temporal and spatial attributes and value of renewable energy.

- Our findings revealed the following key arguments about barriers to temporal matching:
  - Limited interest due to existing PPAs up to or beyond 2030.
  - Prevailing uncertainty regarding the impact of REGOs on the value of LGCs, and the broader role of corporate renewable energy procurement under the expanded CIS may stymie corporate interest in ambitious procurement initiatives.
  - Time-matching may be perceived as a bridge too far in terms of complexity (in contracting and certification) for most companies.
  - Senior management (and other stakeholders) may not appreciate the substantive difference between 100% renewable and 24/7 CFE claims, and thus decide against the cost and complexity the latter entails.
  - The main barriers to additional renewable energy capacity required for transition are not related to a lack of price signals. Rather, they relate to planning approvals, global supply chains, and transmission infrastructure.

2. Assessing Customer Outcomes with Time-Matched Renewable PPAs

- Aims, methods and data:
  - Modelled 51 different C&I loads under 8 PPA structures to assess matching, emissions and financial outcomes.
  - Used linear optimisation to create optimal hybrid portfolios for each scenario, and to perform load flexibility and behind-the-meter battery functionality.

- Key results:
  - Contracting specifically around time-matching (24/7 contracting) improved matching and emissions outcomes.
  - Compared to conventional pay-as-produced PPAs, shaped, baseload and particularly 24/7 PPAs likely come with substantial additional costs associated with providing the contract shape, particularly under high risk-premium assumptions and 24/7 matching requirements. However, 24/7 contracts provide a more comprehensive hedge for the buyer.
  - Portfolio optimisation alone (creating a hybrid portfolio to maximise the match between load and generation) has a significant positive impact on emissions and matching outcomes.
  - The addition of demand management strategies (flexibly shifting load or adding a behind-the-meter battery) improved time-matching and helped reduce emissions further but had little impact on final costs.

3. Potential Impact of Time-Matched PPAs on Investment in the Australian NEM

- **Aim, methods and data:**
    - Analyse the electricity system-level impacts of 24/7 carbon-free energy procurement (24/7 CFE) on the Australian power system.
    - Utilise capacity expansion modelling based on AEMO's ISP scenarios to analyse the impact different CFE procurement goals by Commercial and Industrial loads.

- **Our findings**:
    - Cost:
        - Achieving 90-95% 24/7 CFE goals incurs a relatively modest cost premium.
        - Higher CFE percentages are achievable but come with increasing cost premiums as they approach 100%.
        - The procurement cost for the rest of the system decreases as the costs for participating consumers rise.
    - Emissions:
        - Participating consumers can significantly reduce their overall carbon emissions, almost eliminating them with CFE procurement strategies.
        - Voluntary CFE procurement helps decarbonize the entire electricity system, achieving more than without CFE procurement.
        - The system-level emissions impact is somewhat limit due to the assumed amount of participating Commercial & Industrial procurement and the grid's relative emissions intensity in 2030.
    - Generation mix
        - Increasing the CFE percentage for C&I customers raises the required storage capacity and changes the renewable energy technology mix with in the procurement portfolio.
        - Batteries are valuable for all matching scenarios, with capacity needs increasing with the CFE percentage.
        - As the CFE percentage increases, solar's relative contribution rises while wind's contribution decreases.
        - C&I procurement of storage results in a commensurate reduction in the need for flexible resources to meet residual load in the rest of the system.

Conclusions and Future Work

- **Conclusions**:
    - There are currently a small number of businesses with an interest in taking leadership in RE procurement via 24/7 contracting, motivated largely by high transparency that can be achieved through via temporal and locational provenance and contribution to grid transition.
    - C&I customers and stakeholders in Australia generally have limited understanding or motivation for more complex PPA structures, including 24/7 CFE.
    - 24/7 contracting results in better hedging and emissions reductions than other PPA structures, but likely at significant additional cost compared to pay as produced.

        - Other PPA types can offer some of the emissions and hedging benefits, but portfolio optimisation is key, regardless of the PPA type.
        - Load shifting can improve emissions outcomes.
    - Regarding the role of 24/7 contracting for driving energy transition:
        - The renewable energy industry holds concerns that the complexity and cost associated with 24/7 might present barriers to transition.
        - The role of voluntary procurement is uncertain in the current Australian policy context with significant government procurement through the Capacity Investment Scheme.
    - Customers will determine the future of 24/7 contracting:
        - There is increasing interest from corporate sustainability perspective.
        - Customer PPA requirements are evolving, and future certification requirements may drive demand for time-matching.
        - Retailers and developers will need to meet their needs, for example with more tailored portfolios and focus on temporal aspects of emissions.

- Future Work:
    - There is a need for a better understanding of the diversity of C&I customer renewable energy procurement strategies and certification requirements across different specific sectors.
    - In particular, the characteristics and value of flexibility in C&I customer demand, how this fits into their procurement and carbon strategies, and associated grid impacts.
    - The electrification of new large industrial loads, which may be exposed to temporal certification requirements in international markets, is not well understood.
    - The impact of 24/7 on emissions under 'hydrogen superpower' and massive datacentre growth scenarios is an important research area, as these potential large loads may have significant emissions impact.
    - Open source tools developed through this project are available to be used and further developed by industry stakeholders and researchers to explore the impact of time matching in PPAs, and at the system level, and extended to related research areas.

Contents

1 Introduction

Globally, corporate renewable energy power purchase agreements (PPAs) are a key part of corporate strategies to reduce electricity-related (Scope 2) emissions and are playing an important role in facilitating the financing of additional renewable energy capacity beyond mandated targets. However, there is an increasing mismatch between system-level renewable energy generation and demand, leading to renewables integration challenges. Escalating concern around corporate greenwashing and the use of offsets for meeting climate targets is also driving calls for more integrity and transparency in the use of certificates; including the renewable energy certificates typically used to demonstrate consumption of renewable energy in these PPAs. In particular, electrification of large new loads such as hydrogen electrolysers, which could otherwise increase grid emissions, are attracting high levels of scrutiny and stringent requirements on certification to demonstrate their renewable energy provenance. Businesses and coalitions aiming to provide leadership in renewable energy procurement are going beyond net 100% targets and committing to renewable energy matched every hour with demand ('24/7 Carbon Free Energy'). More closely temporally matching renewable energy purchasing with demand can in general help businesses improve their energy cost, risk and carbon emission outcomes. Advocates argue that '24/7' PPAs and certification requirements, which track the percentage of load matched with renewable energy within the same hour, would also incentivise development of clean firming or demand flexibility and thereby contribute to improved system-level integration of renewable generation.

Standards are under development globally, and under the Renewable Energy Guarantee of Origin (REGO) framework in Australia, to include granular (usually hourly) timestamping in certification of 'green' products and renewable energy. However, as yet, there is no established mechanism to validate renewable generation matched with demand hour by hour, and there is very limited experience of PPA contracts requiring time-matching. In general, businesses currently lack visibility on how their renewable energy purchasing decisions, related firming contracts and onsite energy management impact their energy costs and risks and especially the carbon-intensity of their electricity use. While there have been a handful of international studies on the potential impact of 24/7 renewables contracting on investment in generation capacity, and the extent to which it might impact emissions and drive investment in clean firming, this has not been studied in the context of the Australian NEM.

This project explored the opportunities and challenges of matching and tracking renewable energy purchasing by commercial and industrial (C&I) customers in the Australian context. Enosi's Powertracer platform demonstrated renewables matching and tracking in a PPA for four case studies, and three parallel research streams were undertaken:

1. Stakeholder interviews were undertaken to better understand the motivations for and dynamics of renewable energy procurement decisions by C&I customers in Australia, and specifically their views on 24/7 procurement arrangements and certification and the opportunities and challenges they present. Beyond the scope of the contracted research, analysis of submissions to the REGO policy consultation were also undertaken to ensure relevance in the context of new policy developments.
2. Tools were developed for improving matching of renewables purchasing of large energy users with their demand through different procurement and on-site flexibility approaches, and for analysing the cost, emissions and risk outcomes. Using these tools and data from the case studies and project

partners, potential renewables products and contracting approaches were assessed for a range of different C&I customer types.

3. A model was built to explore capacity investment in a future NEM with high uptake of '24/7' contracting.

1.1 Summary of Project Scope and Outputs

1.1.1 Powertracer Trial: Implementation and demonstration trial of Renewable Energy matching in Australia

Time-matching of renewable energy generation with consumption was implemented in Enosi's Powertracer platform and demonstrated with a number of case studies and associated knowledge sharing.

- The Powertracer implementation includes energy and emissions tracking functionality for energy supply contracts
- Demonstration of the technology through four case studies
  - Momentum energy -> Mirvac
  - Simply Energy (with Buildings Alive) -> Google
  - Photon Energy -> EG Funds
  - Sunraysia Solar Farm -> UNSW
- Knowledge sharing through the International EnergyTag website

1.1.2 Research Stream 1: Understanding Corporate Renewable Energy Procurement and the Role of Time Matching and Certification

Stakeholder engagement to understand views on the role for time matching in Renewable Energy PPAs and certification in the Australian context, including the motivations, objectives and requirements of customers and renewable energy project developers, within a changing policy and certification context.

- 22 stakeholder interviews and 3 focus groups with 14 participants
- Analysis of submissions to two DCCEEW's consultation on the REGO policy options
- Focussed policy workshop: "The future of voluntary procurement under the Capacity Investment Scheme (CIS) and the Renewable energy Guarantee of Origin (REGO)", 19th April 2024
- A research paper describing the methods, results and implications of the study

1.1.3 Research Stream 2: Open-Source Contract Assessment tools and analysis of the impacts of time-matching in C&I customer PPAs

Development of modelling and analysis tools to facilitate improved decision-making around increased renewables matching in PPA contracts. The tools developed optimise a quantify the match between C&I load profile and renewables, likely emissions and energy cost savings, and the costs and risks of different contractual arrangements and zero emissions firming strategies including battery storage and load shifting.

- Renewable energy portfolio optimisation to increase renewable energy matching
- Assessment of costs, risks, emissions-intensity under a range of portfolio scenarios and contract structure options

- Modelling of the potential for demand shifting to improve energy costs and emissions outcomes.
- Published open source code with documentation and example code notebook with user interface and guidance for modelling and analysis of use-case examples
- A research paper describing the modelling and analysis methods, results and implications

1.1.4 Research Stream 3: Model for Exploring Impacts of 24/7 Contracting on Investment in the NEM

Development of a modelling approach to assess the potential impact of 24/7 contracting on investment in renewable energy and clean firming in the Australian NEM.

- Open source capacity expansion model constructed
- NEM Integrated System Plan (ISP) scenarios modelled
- Demand trace for 24/7 C&I contracting developed
- Publication of two academic conference papers and a research paper for peer review, describing the model, results and policy implications

1.1.5 Project knowledge sharing:

Results from the project are summarised in this report and disseminated through:

- Collaboration by the project team on three policy submissions to the Commonwealth Department of Climate Change, Energy, Environment and Water (DCCEEW)'s REGO consultation
    - **24/7 TRUZERO submission -** Response to DCCEEW's Policy position paper for renewable electricity certification under the Guarantee of Origin scheme and for economy-wide use, Feb 2023: https://consult.dcceew.gov.au/aus-guarantee-of-origin-scheme-consultation/have-your-say-on-renewable-electricity-certification/view/64
    - **Enosi submission -** Response to DCCEEW's Renewable Electricity Guarantee of Origin Approach paper: https://consult.dcceew.gov.au/aus-guarantee-of-origin-scheme-consultation/have-your-say/view/54
    - **CEEM submission -** Response to DCCEEW's Renewable Electricity Guarantee of Origin Approach paper, Oct 2023: https://www.ceem.unsw.edu.au/sites/default/files/documents/CEEM%20REGO%20Policy%20Approach%20Submission%20Oct%202023.pdf
- Participation in 5 industry presentations/panels
    - **BRC-A Webinar**: 24/7 renewables and additionality – Anna Bruce and Steve Hoy https://businessrenewables.org.au/events/24-7-renewables-additionality/
    - **CEC Clean Energy Summit:** True Zero – the rise of 24/7 time matched renewables – Anna Bruce https://australiancleanenergysummit.com.au/recap/program-2023/
    - **CIBSE Seminar:** Pathways, Stairways and Highways – Anna Bruce and Craig Roussac https://www.cibse.org/get-involved/regions/2023-anz-seminar-series/programme
    - **GBCA Transform Conference:** Demand, load and the energy landscape – Anna Bruce, Craig Roussac https://gbcatransform.org.au
    - **Solar and Storage Live:** Innovations in solar technologies for commercial and industrial applications - Anna Bruce https://www.terrapinn.com/exhibition/solar-storage-live-aus/conference.stm
- 2 project workshops

    - "The future of voluntary procurement under the Capacity Investment Scheme (CIS) and the Renewable energy Guarantee of Origin (REGO)", 19th April 2024
    - "Knowledge Sharing Seminar: 24/7 TRUZERO: Tracking Renewables Utilisation for Zero Emission Reporting and Operation", 19th June 2024
- Research outputs:
    - 2 academic conference papers
        - George Furrer, **System Level Effects of 247 Matching in the NEM,** Asia Pacific Solar Research Conference, Melbourne, December 2023 - Abstract: https://apvi.org.au/solar-research-conference/wp-content/uploads/2023/12/Furrer-System-Level-Effects-of-247-Matching-in-the-NEM.pdf
        - Dylan McConnell, **System-level impacts of 24/7 Carbon-Free Electricity procurement in Australia Dr Dylan McConnell (UNSW Sydney),** ERICA Conference, January 2024 - Abstract: https://www.erica.org.au/_files/ugd/22dcd7_b29ba54c380c4c3797a1e529e799427f.pdf
    - 3 academic research papers for peer review
        - Samarakoon, S., Roberts, M., McConnell, D., Kallmier, E., MacGill, I., Bruce, A., **The right time for real-time? Perspectives on the emergence of 24/7 CFE procurement from Australia**, Draft for submission to Energy Research and Social Science
        - Kallmier, E., Roberts, M., McConnell, D., Samarakoon, S., MacGill, I., Bruce, A., **Temporal matching in Corporate PPAs: Portfolio and demand flexibility opportunities for increasing matching and the implications for cost, risk exposure and emissions**, Draft for submission to Applied Energy
        - McConnell, D., MacGill, I., Roberts, M., Kallmier, E., Samarakoon, S., Bruce, A., **System level Impacts of 24/7 CFE contracting on Capacity Expansion pathways in the Australian National Electricity Market**, Draft for submission to the Electricity Journal
- Open source PPA modelling tool with time matching functionality
    - Available at: https://www.ceem.unsw.edu.au/open-source-tools

1.2 Report Structure

This report summarises key objectives, research methods, outputs and conclusions of the research undertaken within the Race for 2030 24/7 TRUZERO project (0250). Section 2 provides brief background on the status of and motivations for time-matched renewable energy procurement by C&I customers, and the international and Australian policy and certification context. Sections 3, 4 and 5 report on the aims, methods and outcomes of the 3 research streams, respectively:

- Section 3: Stakeholder consultation on understanding C&I renewable energy procurement and the role of time matching,
- Section 4: Open-source contract assessment tools and analysis of the impacts of time-matching in PPAs, and
- Section 5: Modelling impacts of 24/7 procurement on the NEM.

Section 6 provides a summary of the research outputs and findings and discusses the policy implications, limitations of the work and next steps for research in this area.

2 Background

2.1 Commercial and Industrial Renewable Energy Procurement

In recent years, voluntary renewable energy procurement beyond mandates has been an important driver for investment into new renewable energy capacity across the world (Bloomberg NEF, 2022; IEA, 2022). The opportunity to reduce exposure to volatile electricity prices, along with growing stakeholder pressure to improve corporate sustainability credentials (O'Shaunessy et al, 2021), and increasingly critical attention on the integrity of traditional carbon offsets (Carbon Market Watch, 2024) have played a large part in motivating interest in corporate renewable energy procurement.

In Australia, voluntary renewable energy procurement through both state government and corporate PPAs has played an important role in underwriting new renewable energy projects, especially amid an environment of uncertain and insufficient policy over the past decade (Simshauser & Gilmore, 2022; Nelson et al, 2022). However, in recent years, there has been a decline in corporate PPAs underwriting new projects, with most PPAs attached to existing renewable energy generation assets or underwritten by state-owned utilities (CEC, 2024). While record breaking PPAs have been signed by Rio Tinto in 2024 (Energetics, 2024), broader market dynamics and shifts in policy direction suggest that the role of corporate PPAs in driving new renewable energy capacity is entering a new phase (BRC-A, 2023).

2.2 Temporal Matching – Drivers and Status

While corporate net-zero and 100% renewable energy targets are becoming ubiquitous, there is growing scrutiny of the limitations of current approaches to carbon accounting and renewable energy certification regimes (Miller et al, 2022). In this context, the temporal and spatial attributes of renewable energy are receiving important attention; facilitating a more precise assessment of the emissions impacts of electricity, and potentially more targeted investment to address temporal gaps in the availability of carbon-free energy (Miller et al, 2022; Riepin & Brown, 2023). This recognition is reflected in the emergence of 24/7 carbon free energy (CFE), an ambitious form of corporate renewable energy procurement that aims to match energy demand with renewable energy generated within the same hour and the same electricity grid or balancing area. Championed by the United Nations '24/7 Carbon-free Energy Compact' (UN Energy, 2021) and the EnergyTag coalition (Energy Tag, 2021), 24/7 CFE first emerged as renewable energy procurement leadership initiatives of multinational corporations (WRI, 2023) with energy-intensive operations such as Microsoft (2020) and Google (2022). These businesses have outlined 24/7 CFE roadmaps and advocated for its broader adoption, including through support for the UN 24/7 CFE Compact and EnergyTag.

The electrification of large new industrial loads and processes, in particular production of hydrogen, has increased focus on transparent renewable energy provenance, since emissions associated with these activities may otherwise either increase through electrification or displace renewable energy consumption by other energy users. New EU and US green hydrogen standards include stringent requirements on granular time and location matching of renewable energy with load, as well as additionality. The EU will require first monthly then hourly matching for green hydrogen by 2030 and the US Green Hydrogen Tax credit will require hourly matching from 2028. Timestamping requirements are also being introduced or under discussion for renewable energy certification, PPAs and retail products are emerging to meet customer demand for 24/7 CFE, and registry platforms are being established to facilitate time-matching, for instance by the US National Renewable Energy

Certification Center and PJM Environmental Information Services. The potential importance of temporal matching was bolstered further in December 2021, when President Biden signed an executive order requiring that all U.S. federal agencies procure 100% renewable energy and 50% time matched CFE by 2030 (White House, 2021).

2.3 Australian Policy Context

Through decades of political struggle over climate and energy policy, the Renewable Energy Target (RET) is widely considered Australia's only long-term (and successful) federal emissions reduction policy for the electricity sector (MacGill, 2010; Simshauser & Gilmore, 2022; Nelson et al, 2022). The RET is a renewable energy certificate scheme, which requires electricity retailers and large energy users buying directly from the wholesale market to surrender certificates each year equivalent to their share of the target. Under the scheme, one large-scale generation certificate (LGC) can be created for each MWh produced by eligible renewable energy generators, providing an additional stream of revenue to support development of renewable energy projects. The target was ramped up from 2001 to 33,000 GWh by 2020 of "large scale" renewable energy generation per year, nominally around 20 per cent of electricity. While the RET achieved its 2020 target more than a year ahead of schedule in 2019, the target and the annual LGC requirement remains in place until 2030.

Despite meeting the target, the success of the RET has been threatened by almost continuous policy uncertainty and the market power of retailers as oligopolistic buyers in the scheme. These challenges led to stalled investment at times and downwards revision of the RET from 41,000 GWh/year to its ultimate 33,000 GWh target. With the RET target falling behind both Government and community ambition, and driving no additional renewable energy generation beyond 2020, starting with the ACT Government in 2012, State Governments have turned to Contract for Difference (CfD) PPAs awarded via competitive tender or auction to drive additional renewable energy capacity. Such PPA auction schemes are attributed a key role globally in bringing down the cost of renewable energy below that of energy from fossil fuel plants, in large part due to revenue certainty provided over the contract period, which reduces the financing costs of these capital-intensive projects. However, whereas the RET provided an additional revenue stream on top of the wholesale market value of renewable energy, fixed price PPAs insulate developers from temporal and locational price signals in the spot market and hence risk exacerbating mismatch between renewable energy generation and electricity demand.

Historically, electricity consumers in Australia wishing to go beyond the RET's percentage target could invest in behind the meter (rooftop) solar or buy accredited Greenpower. As renewable energy generation has become increasingly competitive and electricity prices higher and more volatile, corporate PPAs have also increased in popularity as a means for business to lock in a competitive price for bulk electricity and to meet sustainability objectives. Alongside state government contracts, these corporate PPAs have played an important role in creating bankable renewable energy projects during periods of RET uncertainty when retailers were not signing PPAs with projects that would compete with their existing generation assets. Since business must cover their load through the PPA and firming around the contract, unlike government contracts, corporate buyers are exposed to the underlying value of the renewable energy and, to a greater extent than state government PPAs, corporate PPAs hence tend to retain underlying temporal and locational incentives on renewable energy developers.

In Australia, as globally, increasing scrutiny has been brought to bear on corporate sustainability claims, with new requirements for transparency in corporate emissions reporting and a recent investigation by the Australian Competition and Consumer Commission (ACCC) into greenwashing by businesses in Australia. With Scope 2 emissions reductions often the low-hanging fruit, many businesses have committed to net zero and 100% renewable energy targets. Within both government and corporate procurement via Greenpower or PPAs, retirement of LGCs has historically been used as the mechanism to prove additional renewable energy has been 'consumed', but without any temporal link between the electricity generation and consumption. However, with the RET approaching its end of life and ambitions to create an export industry for hydrogen and other 'green' industrial products produced with renewable energy, the Australian government has pursued reform of the renewable energy certification framework.

In December 2022, 7 months after the project start, the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) launched consultation on a new national Renewable Energy Guarantee of Origin (REGO) certification scheme. Currently in its final stages of design before its planned launch in January 2025, the REGO scheme aims to provide an internationally consistent renewable energy certification program to track and verify renewable energy claims for both domestic and export purposes. REGOs are being designed to eventually replace LGCs when the RET sunsets in 2030. To accommodate emerging certification requirements for green products in international markets, and to facilitate more transparent and strategic procurement, they will include granular attributes such as the location, time, commissioning date and technology class of electricity produced from renewable energy or storage technologies. Of particular importance to the development of 24/7 CFE procurement, the design requires each MWh of renewable energy to be timestamped. As we explore in our research findings, the impacts of this new certificate, particularly its interactions with LGCs and potential market value post-2030, are a matter of ongoing debate in the sector.

Also announced in 2023, the expansion of the Capacity Investment Scheme (CIS) is the long-awaited federal Government policy response to slower than required growth in new renewable energy capacity to meet the national targets of 82% renewable energy and 42% emission reductions by 2030. The CIS was originally conceived as a mechanism to drive investment in the dispatchable capacity required to firm renewables and was extended to also meet the need for renewable capacity to provide bulk electricity to meet resource adequacy needs as well as renewable energy targets. The announcement also came with the decision not to extend the RET, so the CIS is expected to be the main policy mechanism to drive renewable energy deployment at the scale and pace required to achieve a national target.

The CIS involves bi-annual competitive tenders administered by the Federal Government to add 32 GW of additional renewable energy capacity (23 GW renewable energy capacity and 9 GW clean dispatchable capacity) by 2030 (DCCEEW, 2024). The current design features a revenue floor and /or ceiling for selected projects. The revenue floor is intended to provide investors with a government-backed safety net to decrease costs and risk for new renewable energy projects. The revenue ceiling will require projects to pay back the Federal Government a percentage of revenue above the agreed ceiling, thereby allowing citizens to share in the benefits of the scheme their tax dollars are funding. This floor and ceiling risk/benefit sharing approach exposes participants to some extent to temporal and locational price signals which were obscured in earlier state government PPA auctions. The CIS scheme will also make decisions on the preferred technology mix based on factors such as reliability, affordability, and emissions reduction. The expansion of the CIS brings into focus the role of the State, relative to voluntary markets, in driving the decarbonisation of electricity. With the first auction held in late May 2024 and bids currently under assessment, the impact of the CIS scheme and the parallel transition to the REGO certification framework on corporate renewable energy market is yet unclear.

3 Understanding Corporate Renewable Energy Procurement and the Role of Time Matching and Certification

3.1 Introduction

In recent years, voluntary corporate renewable energy procurement has played a salient role in driving investment into new renewable energy capacity in Australia. This has been primarily motivated by a combination of rising stakeholder expectations around corporate sustainability, and opportunities to hedge against volatile electricity market prices through medium to long term contracts such as PPAs. However, as 100% renewable energy and net-zero targets become increasingly commonplace in commercial and industrial sectors across the world, some large corporations have raised their renewable energy procurement ambitions, as reflected in initiatives such as the United Nations 24/7 CFE Compact (UN Energy, 2021) and the EnergyTag coalition (Energy Tag, 2024). The impetus behind this focus on the temporal and spatial attributes of renewable energy being to further reduce emissions from electricity use and to signal investment into an optimal mix of renewable energy technologies, storage, and demand management to drive decarbonisation. Within this landscape, our qualitative research sought to understand:

- The broad dynamics of renewable energy procurement in Australia; including core drivers, preferences, and challenges.
- Stakeholder perspectives on time-matched renewable energy, and the potential role that corporate 24/7 CFE procurement might play in the decarbonisation of electricity in Australia.
- Stakeholder perspectives on significant changes in policy direction, particularly the introduction of the REGO certification scheme and the expansion of the CIS.

3.2 Methods

In this stream, we drew on qualitative research methods to develop a nuanced understanding of stakeholder perspectives on the broader dynamics of C&I renewable energy procurement, temporal matching, granular renewable energy certification, and relevant changes in policy direction. As outlined in Table 1, primary data for this study was collected through 60 -minute interviews and 90-minute focus groups (conducted online) with experts and decision-makers across a range of stakeholder groups including renewable energy developers, gentailers, intermediaries such as brokers and consultants, and a mix of C&I buyers. NVivo 14 software was used to conduct a thematic analysis.

Table 1. Breakdown of interview and focus group participants by stakeholder group

Stakeholder Group	No. of Interview participants	No. of Focus Group participants
Renewable Energy Developers	3	3
Energy Retailers and Gentailers	3	11
Green H2 Developers	2	-
Brokers/Market Analysts and Policymakers	3	-
Renewable Energy Buyers	12	-
Total	23	14

Our qualitative research was also complemented by a thematic analysis of public submissions to the consultation on the Renewable Energy Guarantee of Origin (n = 57). This was an additional component to the research project, beyond the original scope, which broadened the base of perspectives and in particular informed our findings on stakeholder views on temporal matching and renewable energy certification.

3.3 Findings

Overall, our qualitative findings indicate that C&I customer interest in procuring renewable energy was primarily motivated by (i) sustainability goals in response to evolving stakeholder (e.g. shareholder and customer) expectations, and (ii) the intent to hedge against price volatility in the electricity market. Reflecting dynamics observed by BRC-A (2023), corporate renewable energy procurement was generally seen as a complex undertaking, often necessitating the expertise of intermediaries, and better suited to large and experienced buyers.

The voluntary market for time matched renewable energy is currently at a nascent stage in Australia and stakeholders expressed a diverse range of views on its outlook. While most buyers valued better matching of renewable energy to their demand profile to reduce their requirement for firming, and some were keen to take a leadership role by undertaking more ambitious contracting approaches, most stakeholders in Australia, including buyers and developers, to date have only a basic level of awareness and limited interest specifically in hourly time-matching clauses within renewable energy PPAs. A number of project developers and advocates expressed concern about the additional complexity and risk posed by time-matching in PPAs and especially in certification schemes, which is viewed as a distraction and a threat to the central decarbonisation task of building additional renewable energy capacity. Below is a summary of some key insights from our research, organised in terms of support for and barriers to the broader adoption of time matched renewable energy through 24/7 CFE PPAs.

Table 2. Summary of insights on 24/7 CFE PPAs

Support	Barriers
- The purchase of time matched RE provides a signal for investment in green firming, storage, and demand management, which is not provided by existing RECs with no temporal attribute. - Corporate leaders can commit to paying for more expensive clean firming as well as cheap bulk renewable energy.	- General market uncertainty about the impact of the REGO scheme on the value of LGCs could stymie interest in new PPAs due to a "wait and see" approach. - Similarly, The Capacity Investment Scheme's primary role in driving additional RE capacity up to 2027 may temper the voluntary market's appetite to take on ambitious voluntary efforts.
- Allows for differentiation from ubiquitous net-zero and 100% RE claims by companies. - Avoids potential greenwashing perceptions of claiming net zero while using energy actually generated at times of high emissions intensity.	- The perceived value of 100% RE vs time-matched RE – scepticism around whether stakeholders would appreciate the nuanced benefits of time-matched RE as a 'deeper shade of green' than current RE PPAs, and so whether it is worth potential additional cost and complexity.
- Green H2 is a potential source of demand for time-matched RE due to the strict temporal, spatial and (in some jurisdictions) additionality requirements for green certification.	- Time-matching may introduce an additional layer of complexity (in contracting and certification) to an exercise that is already challenging and largely the domain of large 'sophisticated' buyers.

- 24/7 RE as a journey – some companies recognise that progressively improving the spatial and temporal alignment of procured RE with their consumption can be both a “shield” from financial risk and a more progressive sustainability outcome. This may not be framed as “24/7 RE” but reflects similar sensibilities in practice.	- Price signals for alignment of generation with demand already exist in the spot price and are not the key challenge - the bottlenecks to additional RE capacity are elsewhere in the system i.e. global supply chains, slow planning approvals, and the coordination of transmission infrastructure.

3.4 Discussion

Drawing on the insights from our study, here we discuss the potential role of 24/7 CFE procurement in driving the decarbonisation of electricity in Australia in terms of questions around timing, scale, and approach.

In terms of timing, we considered 2 questions. Firstly, in the context of the current dynamics of corporate renewable energy procurement and Australia’s changing policy environment, when are we likely to see the emergence of a significant market for 24/7 CFE PPAs? We found the current market to be limited by a range of factors, including lack of customer awareness, the tenure of existing PPA contracts, prevailing uncertainty in the PPA market, limited perceived value in raising renewable energy contracting ambition beyond net zero, and the nascent stage of the Green H2 sector. From the perspective of buyers’ self-interest, there is currently limited incentive to embrace the additional cost, complexity, and potential risk of 24/7 procurement when annual matching is ‘green enough’.

Secondly, when would be the appropriate time for development of 24/7 CFE procurement, such that it might have a significant positive impact on decarbonisation of the electricity system? One of the motivations for 24/7 CFE is that it can drive development and deployment of the technologies, such as green firming, demand management and storage, needed to achieve a fully decarbonised network. Proponents argue that neglecting the temporal aspect of generation could result in over deployment of solar and wind generation, without developing these technologies when they are needed, and consequently increase the cost of achieving decarbonisation.

However, with renewable energy currently accounting for only 40% of generation in Australia, there is an urgent need to install large quantities of solar and wind capacity to achieve a target of 82% by 2040. Development of 24/7 CFE procurement does not address key barriers to renewable deployment, such as supply chain challenges or delays to building transmission infrastructure. There is a perception that, enacted too early, introduction of timestamped certification (seen by many as a short step away from mandatory timestamping) could add administrative complexity and further delay deployment.

In terms of scale and approach, we considered whether voluntary procurement of 24/7 CFE is an appropriate mechanism for system-wide decarbonisation. One question is whether matching of supply and demand is best achieved at the scale of individual customers or whether, given the need for combining generation from multiple generators, as well as battery storage, it is more appropriately undertaken at the scale of large retailers or gentailers (and whether this could entrench the power of big incumbents in the market).

This also touches on the evolving role of voluntary procurement relative to government action in an Australian setting. The expanded CIS is generally expected to be a key driver of additional renewable energy capacity in Australia up to 2027. While most stakeholders expect that PPAs could play a complementary role in de-risking project bids into the CIS, corporate PPAs have played a less influential role in underwriting new projects in recent years (BRC-A, 2023, CEC, 2024) – this surfaces a potential transition in the role of the State relative to voluntary markets in driving the decarbonisation of electricity. The expansion of the CIS also presents potential tensions between 24/7 CFE efforts that would prioritise optimisation at the scale of individual C&I customers, and broader imperatives to prioritise a renewable energy technology mix at a system-level based on factors such as reliability, affordability, and emissions reduction.

Relatedly, opinions are divided on whether the inclusion of timestamping in the Renewable Energy Guarantee of Origin (REGO) scheme is necessary. Some stakeholders maintain that the existing alignment of wholesale spot price with emissions intensity provides sufficient incentive to drive development of green firming and storage and therefore renders timestamping unnecessary. However, development of new domestic and international markets for green products, including but not limited to green hydrogen, supposes a mechanism for documenting the provenance of renewable energy used to make the products. It is unclear whether requiring certification of timestamping and additionality at this time could result in an additional administrative (and cost) burden, what impact this might have on a nascent hydrogen industry or whether it is necessary to avoid greenwashing.

In summary, our findings suggest that the market for 24/7 CFE contracts is still at an embryonic stage of development and is thus unlikely to play a salient role in the decarbonisation of electricity in Australia before 2030. Cost, complexity, perceived value, existing long-term PPAs, and infrastructural bottlenecks constraining renewable energy deployment were some of the most salient factors that led to this conclusion. The emerging Green H2 sector and developments in renewable certification and emissions reporting present potential incentives for time matching but have yet to drive significant interest in 24/7 CFE procurement. Furthermore, significant change in energy policy is reconfiguring the role of voluntary procurement in the decarbonisation of electricity in Australia, with government schemes such as the expanded CIS expected to play a central role.

Nevertheless, C&I customers are in general looking for renewable PPAs that provide maximum coverage for their load as a hedge against future electricity prices and in some cases spot exposure, which may take new forms such as shaped, baseload or 24/7 renewable PPAs; businesses wanting to take a leadership position on carbon emissions may be increasingly attracted to the direct temporal link between renewable energy and consumption in 24/7 style PPAs, as awareness of these products grows; and producers of products such as hydrogen and steel for export may encounter increasing pressure for time matching from destination certification schemes.

A more detailed account of our qualitative findings and discussion can be found in an upcoming journal article: ***Samarakoon, S., Roberts, M., McConnell, D., Kallmier, E., MacGill, I., Bruce, A., The right time for real-time? Perspectives on the emergence of 24/7 CFE procurement from Australia, Draft for submission to Energy Research and Social Science.***

4 Assessing Customer Outcomes with Time Matched Renewable PPAs

4.1 Introduction

Recent studies have highlighted the importance of employing more granular renewable energy contracting to achieve significant grid emissions reductions (Xu et al., 2023; Riepin & Brown, 2022). Power purchase agreements (PPAs) are an increasingly popular approach engaged by corporates to procure renewable energy and contribute to net-zero targets, but most PPAs still take an annual approach to contracting renewable volumes and offsetting emissions. Many large energy users such as commercial and industrial (C&I) customers do not have a detailed understanding of renewable energy procurement, and as such prefer straightforward contracting options that may have sub-optimal emissions outcomes. Only a few C&I buyers have started to engage with innovative shaped, baseload or 24/7 time-matching PPA structures; these are predominantly large energy users that have internal resources to model and assess outcomes for these more complex contracting methods.

For companies aiming to meet net-zero targets efficiently and effectively through procuring time-matched renewable energy, a number of contracting features need to be considered. The creation of hybrid technology portfolios, oversizing contracted renewable energy volumes, and in some cases the addition of storage contracting have all been explored in the literature as methods to increase time matching. However, the role of load flexibility and demand-side participation is yet to be considered in this space, despite the growing body of literature highlighting the potential benefits of demand flexibility in integrating high levels of VRE to the grid.

To date, no studies have been undertaken in the Australian market context to compare the emissions and cost outcomes for different renewable energy contracting options, and prior to this project, no tools publicly available to users to facilitate detailed analysis of these PPA outcomes.

4.2 Methods

To address these research gaps, we developed an open-source tool to help potential buyers assess the performance of different PPA contracting methods across time-matching, emissions, and cost. We then used this tool to model a range of PPA contracting scenarios for over 51 different C&I loads (derived from a larger, publicly available set of 120 Queensland C&I half-hourly load profiles for the year 2014/15, collected by CSIRO (Berry et al, 2015)), exploring portfolio optimisation and demand management strategies to maximise the match between the PPA and demand.

The tool uses linear optimisation to first create an optimal hybrid portfolio of renewable energy generators and then calculate the time-matching, emissions and cost outcomes for each load profile under one of a Pay as Produced, Shaped, Baseload or 24/7 PPA contract structure. The optimisation objective for creating the renewable portfolio is to minimise the total cost of meeting the contract shape, including the energy purchased through the PPA for each generator plus the wholesale market value of any unmatched energy within the contract. Each of the modelled PPA structures are set up in the tool with specific clauses around the delivery of contracted renewable energy, management of contracted renewable energy in excess of demand in a given period, and seller penalties or costs for contract undersupply. Under the 24/7 contracts and one

Baseload contract scenario an extra penalty was applied during the hybrid portfolio optimisation to incentivise better matching to the guaranteed energy trace despite oversizing.

Table 3 Description of contract definitions and assumptions used in modelling and analysis.

Contract	*Description*	*Undersupply*	*Excess*
Pay as Produced	Also known as run-of-plant. The buyer purchases all output of the portfolio at all times.	NA	On-sold by the buyer at spot market value.
Shaped	An optimal portfolio is created from the monthly P90 profiles of each generator. From this portfolio a daily shape and volume in each month are guaranteed to the buyer.	The seller is subject to make good any undersupplied energy and LGCs at their spot value.	On-sold by the buyer at spot market value.
Baseload	A set amount of renewable energy is guaranteed to the buyer for every hour, adjusted monthly to meet the buyer's consumption.	The seller is subject to make good any undersupplied energy and LGCs at their spot value.	On-sold by the buyer at spot market value.
24/7	An average hourly time-matched % is chosen, and the seller guarantees supply to meet this hourly match in each month.	If the guaranteed % is not met in a month, the seller is subject to make good time-matched renewable energy to reach the required % (modelled as a penalty).	NA

For every contract, it was assumed that firming energy was purchased on the wholesale market under each of three scenarios: full exposure, exposure with $300 caps purchased at $10/MW/h, or exposure with $300 caps purchased for $30/MW/h. A floor price of $0 was applied for all contract settlements.

The strike prices for each contract were calculated by taking a combination of the levelised cost of energy (LCOE) for each generator in the portfolio (from CSIRO's 2019-20 GenCost report (Graham et al, 2020)), applying a risk premium for oversized portfolios and a penalty to cover required make-good payments and penalties.

Linear optimisation is also employed to model load shifting for each scenario to allow exploration of the potential benefits. Due to the range of C&I loads to model, and the need for this load shifting model to be applicable to many varied companies, the operation is fairly constrained. For each C&I customer and contract type we conducted six demand flexibility scenarios with varying levels of allowed flexibility. We also added a simple behind-the-meter battery model to the tool, with users able to control the size and duration of battery to add. This battery model is formulated as a mixed-integer linear programming optimisation and is set to charge only from excess contracted renewable energy under each contract and discharge to minimise the cost of unmatched load. In our modelling we considered five battery sizes for each customer and contract scenario.

Though not explored in-depth in our modelling results, the open-source PPA assessment tool can also be used to analyse potential outcomes under different types of firming contract, whether that be a traditional retail contract with structured tariffs or involve spot exposure depending on the risk appetite of the user.

4.3 Results

Results from this modelling found that specific contracting to meet time-matching requirements (i.e., under a 24/7 PPA contract) generally improved the average percent of load matched to generation on an hourly basis.

Figure 1 shows a general positive trend between hourly matching and emissions reductions, with the 24/7 PPAs again outperforming the other contracts in all cases. The spread of results for emissions reduction across all contracts even at high levels of matching suggests that it is not only the fact of time-matching but also when the matching occurs that impacts the emissions outcomes for a customer.

While 24/7 PPAs provided higher rates of hourly matching and greater emissions reductions, the increased cost of procuring such contracts may still be prohibitive to some buyers. Relative final costs in $/MWh are shown in Figure 2, showing that under conservative risk premium scenarios (medium and high strike price scenarios in Figure 2), 24/7 costs can be significantly higher than the next most expensive Baseload contracts, particularly for 24/7 contracts with higher guaranteed matching percentages. Despite having lower matching and emissions outcomes than the 24/7 PPA, other contract types may be alternatives of interest to buyers to achieve reasonably high levels of matching (>75%) and emissions reduction (>70%) while, in the case of hybrid Pay as Produced contracts, also keeping final costs significantly lower per MWh than procuring energy from the wholesale market. One of the key takeaways from this analysis is the positive impact that simply creating a hybrid portfolio optimised to match the customer's load shape can have on matching, emissions reduction and final costs.

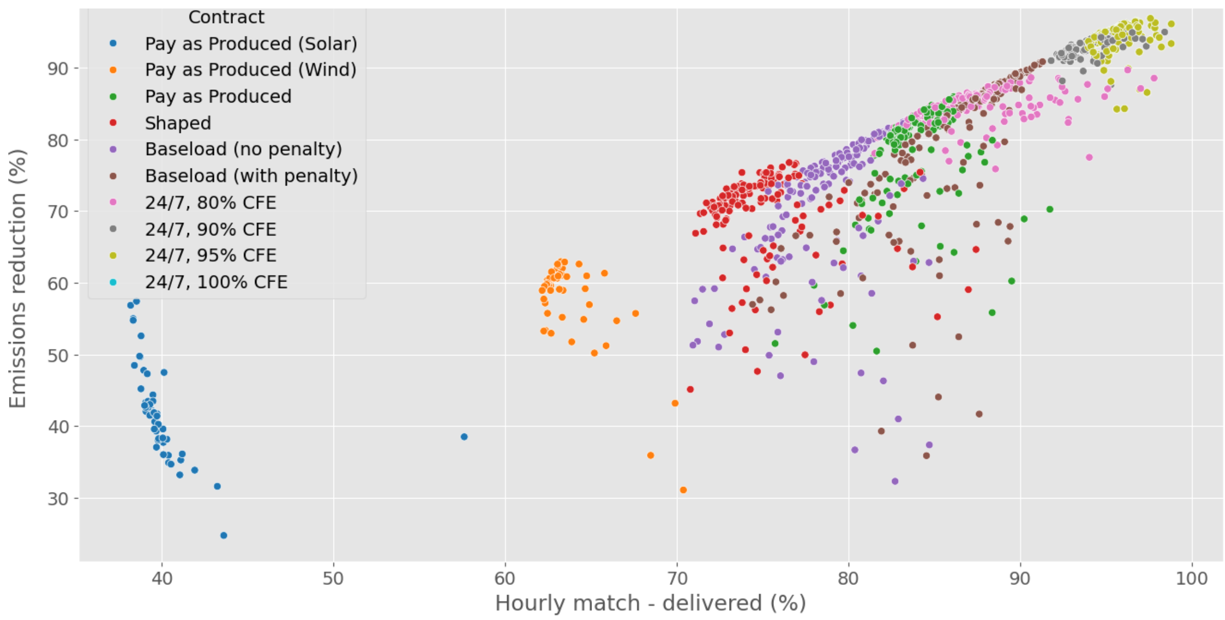

Figure 1. Emissions reduction as compared to purchasing all energy from the grid against average hourly match.

In general, the addition of any demand management strategy improved all emissions and matching and outcomes across the scenarios (Figure 3), with a much smaller impact seen on final costs. The extent to which each strategy benefitted the customer across outcomes was dependent on several factors including the level of load flexibility afforded to the customer load, and the contract type. For example, contracts with already high matching saw much smaller cost reductions than others with a lower initial match. On average adding a battery saw a greater positive impact on each of the modelled metrics than load shifting, perhaps highlighting a limitation in the highly constrained flexibility model.

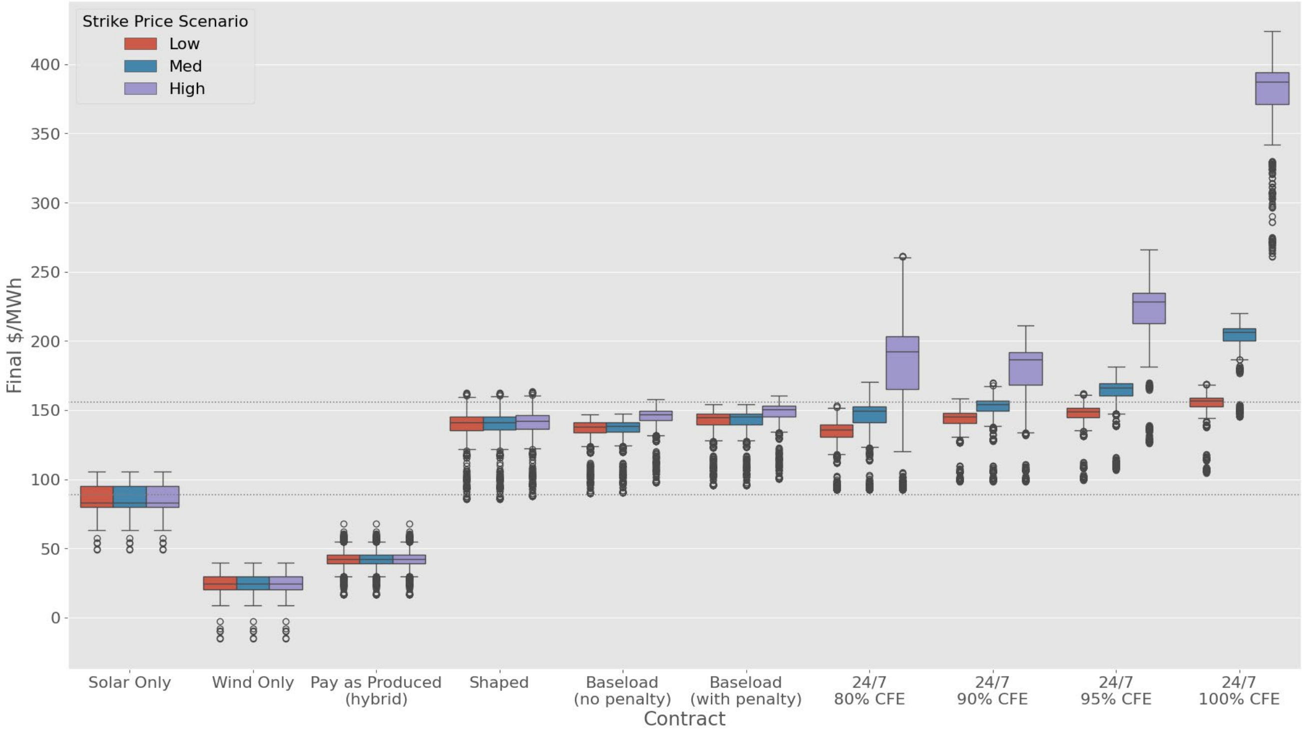

Figure 2. Final costs in $/MWh of each PPA type under different strike price scenarios. Two horizontal grey dotted lines show low and high bounds for contracting the same MWh of energy and LGCs from the wholesale market with no PPA.

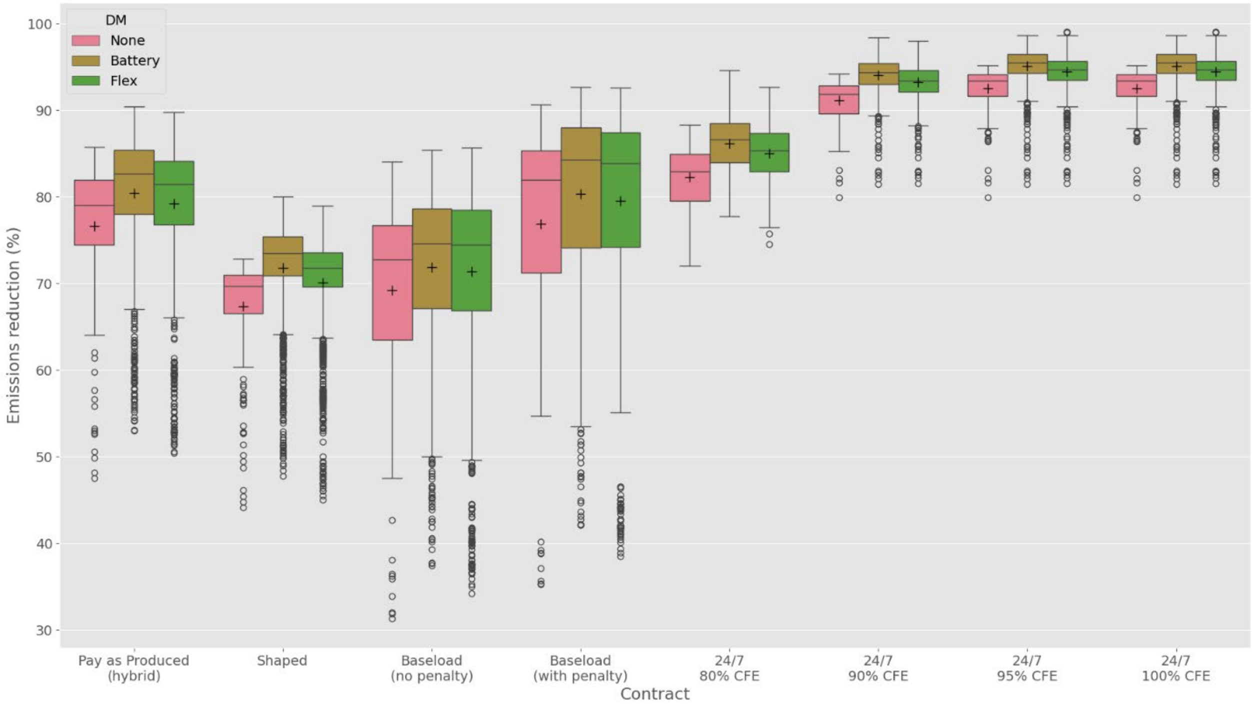

Figure 3. A comparison of the emissions reduction outcomes under a range of contract structures with different demand management strategies applied.

An important feature of this modelling is that we calculated results over four years of data including 2022, a particularly volatile year for energy prices. Variations in results across the different years are explored in our upcoming journal article.

The tool produces a "bill" style outcome broken down into each cost component for each settlement period, as well as values quantifying the time match in each settlement period and the emissions due to firming energy in the local grid region.

4.4 Discussion

Results from our scenario modelling confirm that contracting specifically around 24/7 time-matching is the most effective option to reduce emissions, and that engaging demand management such as load shifting or storage can further improve emissions and matching outcomes under a PPA. However, the potentially significant premium associated with 24/7 time-matching contracts may be a deterrent to buyers, although with high levels of matching, these contracts can provide a comprehensive hedge against spot prices. Our results show alternative contracting methods and in particular careful portfolio design can also meaningfully reduce emissions. The load patterns of buyers and their goals in contracting renewable energy will determine the best path forward.

A positive correlation between hourly matching and emissions reductions was clear from the modelling, although it appears that even at high levels of matching (>90%) it becomes less important that the matching exists, and more important that the time (and possibly grid location) at which matching occurs is considered. After the easily attainable hourly matches have been addressed, meeting customer demand in periods during which grid emissions intensities are higher might require a more targeted approach or higher levels of demand-side participation.

The development of an open-source tool that is accessible to users with low levels of coding experience should increase transparency in the voluntary corporate procurement space, allowing companies to quickly and easily explore their options when it comes to PPA contracting. Outputs from the tool are presented clearly and in simple terms to make understanding renewable energy contracting outcomes easy to understand for non-energy professionals looking to reduce their corporate Scope 2 emissions. Further work to improve the load shifting model and incorporate sensitivity testing functionality to the tool would further improve the value of this tool to potential end users.

A more detailed description of our methods and findings can be found in an upcoming journal article: ***Kallmier, E., Roberts, M., McConnell, D., Samarakoon, S., MacGill, I., Bruce, A., Temporal matching in Corporate PPAs: Portfolio and demand flexibility opportunities for increasing matching and the implications for cost, risk exposure and emissions, Draft for submission to Applied Energy****. The tool is available at* https://www.ceem.unsw.edu.au/open-source-tools.

5 Potential Impact of Time-Matched PPAs on Investment in the Australian NEM

5.1 Introduction

In Australia, as in many parts of the world, the shift towards clean, carbon-free energy has been partly driven by voluntary commitments from both public and private energy consumers. These initiatives have played an important role and have spurred additional renewable capacity beyond formal policy mandates. Historically, these commitments have typically been achieved through mechanisms such as Power Purchase Agreements (PPAs) or the acquisition of renewable certificates. These arrangements generally aim to match renewable energy generation with consumption on an annual basis, often without regard to geographic constraints. This approach does not align the spatial and temporal characteristics of renewable energy production with actual consumption patterns.

This misalignment poses significant challenges. It can create perverse incentives and introduces risks in procurement and the broader development of the electricity system. Energy consumers remain vulnerable to price and volume risks, as they must still rely on local generation which may include carbon-emitting sources. The challenges are exacerbated when energy is procured far from the point of consumption, leading to limited financial linkage and increased risks of delivery disruptions due to network constraints or curtailment.

At the system level, individual participants pursuing the lowest-cost routes to meet voluntary renewable energy goals may lead to sub-optimal deployment of new capacity. Projects that offer low-cost certificates but are poorly matched to consumption profiles and geographic locations can result in higher emissions and costs, both for the system and the consumer. Additionally, issues of reliability and capacity adequacy become dependent on the broader electricity system, effectively outsourcing critical aspects of energy security and environmental impact.

There is now growing interest in the private sector meeting their consumption with carbon-free energy (CFE) supply on a truly a truly 24/7 basis (CFE 24/7) as well. This approach involves matching a buyer's electricity demand, hour-by-hour, with corresponding electricity generation from within the same region.

Internationally, studies from the United States and the European Union have specifically investigated the 24/7 carbon-free energy (CFE) model. These studies have explored both the methods and costs associated with 24/7 procurement for companies in a selection of European countries and assessed the system impacts for the rest of the European electricity system. However, the international findings are not directly transferable to Australia due to the lack of firm, carbon-free energy sources like nuclear and geothermal, alongside a sparser energy network with different resource diversity.

This study analyses the electricity system-level impacts of 24/7 CFE on the Australian power system, investigating the impact of voluntary commercial and industrial investment (C&I) procurement in renewable energy, storage, and clean firming technologies on the emissions trajectory of the National Electricity Market (NEM). Some of the specific research questions include whether 24/7 CFE procurement leads to increased renewable energy generation, lower emissions for both the buyer and the system, reduced needs for system flexibility, and changes in costs for the rest of the electricity system.

5.2 Methods

The United States and European studies investigating the costs, benefits, and system-level impacts of 24/7 CFE matching utilise modified capacity expansion modelling. The modifications allow the impact of voluntary clean energy procurement from some proportion of C&I load to be assessed. A similar approach to these studies is used in this investigation, with a version of the open -source power system model PyPSA adapted for the Australian context.

Capacity expansion models typically minimise the system-wide costs of meeting electricity demand of a network over time, while adhering to reliability requirements, and other objectives such as carbon constraints. The solution to such models typically output the optimal timing and location of new generation and storage assets, as well as details on the operation and dispatch of both new and existing assets.

A base implementation of PyPSA was developed for the Australian National Electricity Market (NEM). Where possible, it aims to align with the Integrated System Plan (ISP), the main system planning process developed by the Australian Energy Market Operator. This alignment includes drawing on the same input and assumption data for generator and storage capital costs, demand traces, network expansion options and renewable energy resource traces. Similarly, a 10 -node network model is used, in line with the ISP sub-regions. There are some simplifications, including the use of 5 -year investment periods, and only considering the system out to 2040.

For this study, additional constraints were then introduced to the model to represent voluntary procurement of time-matched clean energy (24/7 CFE consumers). Using an iterative approach, the model optimises the operational and investment decisions to meet the demands of these consumers, as well as the rest of the system. This approach is consistent with that used by Riepin and Brown et al (2022) and Xu et al (2023).

A fraction of C&I load is committed to procuring clean energy with a desired level of 24/7 matching (or "CFE score"). This CFE score represents to the degree to which real-time electricity consumption is matched with carbon free electricity generation (for example, a CFE score of 100% would mean that every kilowatt-hour of electricity consumption is met by CFE sources at all times). Constraints are introduced that ensure the proportion of CFE consumers meet the desired CFE score. Any excess generation is used by the rest of the system (but does not contribute to the CFE score). This matching strategy was also compared against a counterfactual, where the 24/7 consumers have no commitments and purchase all their power from the grid.

5.3 Results

Key result 1:

The cost premium of achieving 90-95% 24/7 CFE goals is relatively modest. Higher fractions can be achieved, but they come at increasing cost premiums as the CFE approaches 100%. The procurement cost for the rest of the system declines in concert with the rising costs for the participating consumers (see Figure 4). However, the costs are not simply fully offset, there is a net increase for total system cost. This is consistent with international results. Riepin and Brown (2022) found that the last 2% of hourly matching more than doubles the costs. Xu et al (2023) also found significant cost premiums in some jurisdictions as CFE scores approached 100%.

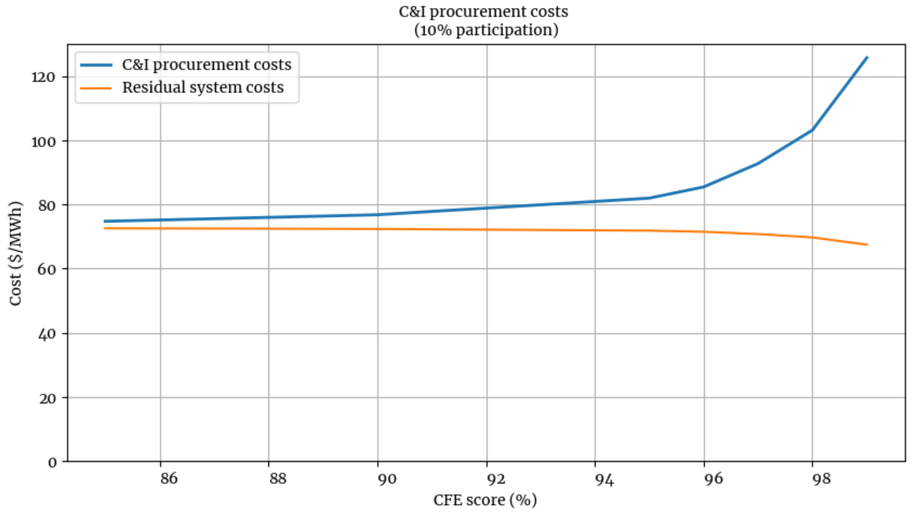

Figure 44. Procurement costs for C&I customer voluntarily participating in 24/7 CFE, alongside the costs for the rest of the system, relative to the CFE score.

Key result 2:

The overall carbon emissions for participating consumers can be significantly reduced, and almost eliminated with CFE procurement strategies (see Figure 5). The emissions intensity is calculated by dividing the total CO2 emissions linked to the 24/7 consumers' consumption by their total electricity consumption. This voluntary procurement also helps decarbonise the electricity system as a whole, and goes beyond decarbonisation achieved in the absence of a CFE procurement.

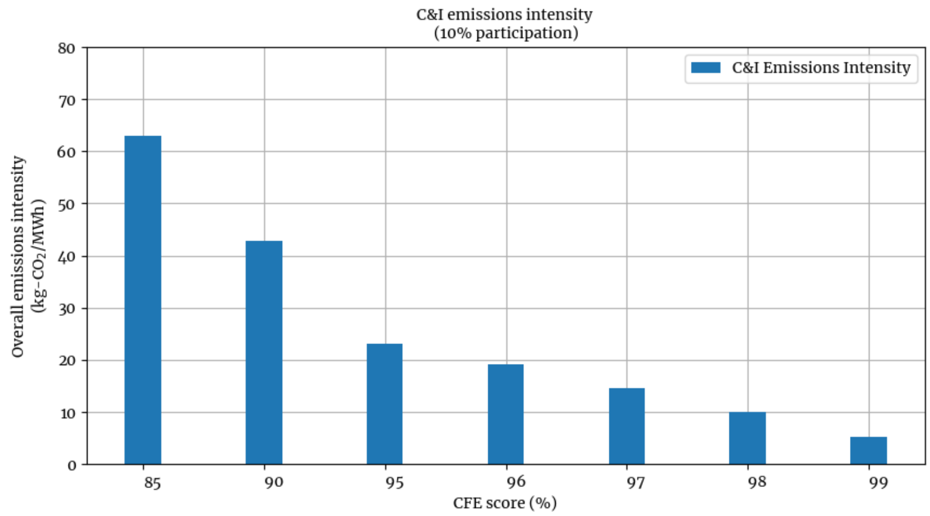

Figure 55. Overall emissions intensity of energy procured across the C&I procurement portfolio, at different CFE scores.

Key result 3:

Increasing the CFE score of the C&I customers increases the required storage capacity, and changes the mix of renewable energy technologies (Figure 6). Batteries have some value for all matching scenarios, but the capacity increases with the CFE score. Interestingly, as the CFE score increase, the relative contribution of solar increases, while onshore wind decreases. This is discussed further in the next section.

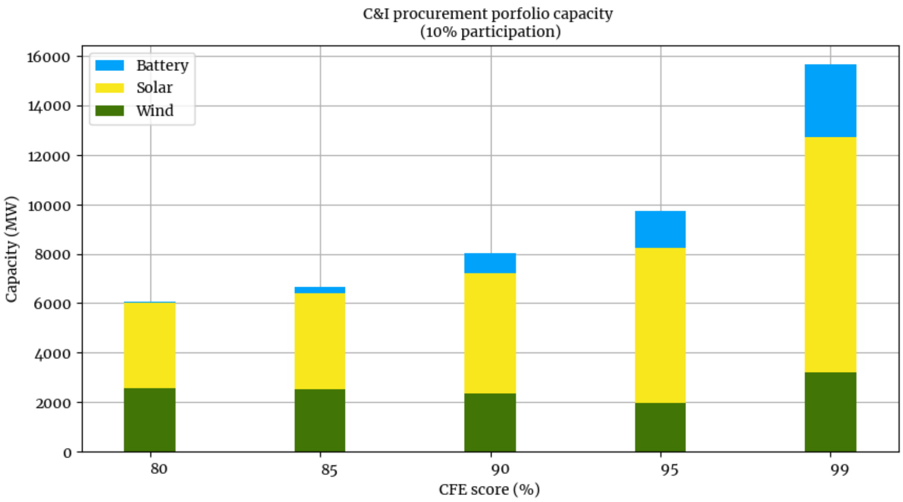

Figure 66. Capacity of different resources within the C&I procurement portfolio, at different CFE scores. The battery capacity required increases inline with the CFE score, and considerably with high fractions.

5.4 Discussion

These findings are broadly consistent with existing studies investigating the impact of CFE procurement at a system level. The analysis suggests that hourly matching of demand with clean energy can reduce the emissions of both the electricity consumer, and the system as a whole. While possible, the cost premium can be considerable for high CFE fractions. The results also indicate that investment in clean, non-RE capacity (storage) is, in part, brought forward, which can help with more broadly pushing these technologies along their cost curves.

A natural consequence of this voluntary procurement, and in particular the investment in storage is a commensurate reduction in the need for flexible resources to meet residual load in the rest of the system. Specifically, there is less investment in gas-fired peaking capacity and less need for batteries in the rest of the system. This is consistent with findings from both Xu et al (2023) and Riepin & Brown (2022). This could be understood as C&I load cross-subsiding firming capacity, and supporting new or emerging technologies that are important in the longer term.

The findings must also be understood within the limitations of the approach used. A significant limitation is the treatment of the 24/7 consumers as a single entity, with a regular consumption profile. This consumption profile was based on a set of commercial and industrial load profiles from Queensland (QLD) Australia, collected as of the National Feeder Taxonomy Study (Geth 2021). In practice, participating consumers might be expected to pursue hourly matching strategies independently and based on their own load profiles. As shown by Riepin & Brown (2022), the shape of consumption profiles affects the optimal technology mix required for achieving a certain CFE target (but with little impact on the overall procurement costs). It is understood that the load profile used in this work is, in part, driving the decrease in wind capacity as the CFE fraction increases. The regular C&I profile used has higher demand in solar hours and is well suited to a solar and battery dominated system.

Another important limitation is the selection of technologies used. Consideration of novel or emerging technologies (particularly so-called long duration storage energy technologies – LDES) could materially change both costs and technology mix (Riepin & Brown, 2023). In addition, no demand-side management is currently considered – an inflexible demand profile is assumed. C&I customers in particular have some degree of demand flexibility, which could significantly reduce costs, particularly as CFE score approaches 100%.

The full study is reported in our upcoming journal article: ***McConnell, D., MacGill, I., Roberts, M., Kallmier, E., Samarakoon, S., Bruce, A., System level Impacts of 24/7 CFE contracting on Capacity Expansion pathways in the Australian National Electricity Market, Draft for submission to the Electricity Journal***.

6 Discussion and Conclusion

6.1 Discussion and Policy Implications

There are a small number of corporate electricity customers in Australia aiming to take a leadership position on renewable energy procurement and include time-matching in their renewable energy contracting strategies. These customers are motivated in part by the desire for high levels of transparency in response to concerns around greenwashing. In this respect, a direct temporal and locational link to renewable energy purchases can strengthen claims of measurable emissions reductions and allow corporations to contribute to grid transition by paying for the clean energy required to meet their consumption, including more expensive energy at times of scarcity.

Future certification requirements may also obligate businesses targeting export of 'green' industrial products to engage in time-matching or require emissions accounting to include time matching for scope 2 emissions. For example, to ensure Australian products are compliant with tariff-free access to EU markets under Europe's Carbon Border Adjustment Mechanism (CBAM). In this context, value derived from complying with real-time matching requirements may reduce costs to consumers or taxpayers for meeting the policy targets.

However, most C&I customers, along with their key stakeholders such as shareholders and customers, to date have very limited understanding or awareness of time-matching in renewable energy contracting and, despite increasing scrutiny on emissions claims, as yet little motivation to go beyond net annual renewable energy claims to more complex renewable purchasing arrangements. While buyers are open to forms of contracting that can reduce their firming exposure, these come at a cost and complexity that are too high for most. Sleeved retail supply agreements such as the Matched Energy Supply Agreement (MESA) recently facilitated by Enosi (Foley 2024), and premium 24/7 Greenpower products may have a role to play to reduce cost and complexity for customers.

Our results show that renewable energy PPA contracts with time-matching requirements result in better hedging and emissions reductions for C&I customers. Compared to conventional pay-as-produced PPAs, shaped, baseload and particularly 24/7 PPAs likely come with substantial additional costs associated with providing the contract shape, particularly when modelled under high risk premium assumptions and 24/7 matching requirements. However, 24/7 contracts can provide a more comprehensive hedge for the buyer. While the best emissions reduction results in our study were achieved with 24/7 style PPAs, optimised portfolios and alternative contract structures might provide simpler means of reducing emissions than 24/7 PPAs at significantly lower cost, while there are also opportunities for load shifting to improve outcomes. Overall, there is increasing awareness of the temporal aspects of electricity generation and consumption and tracking of temporal emissions and exploring opportunities for improving matching and reducing emissions through flexibility are attracting more attention within corporate sustainability circles.

Regarding the role of 24/7 contracting for driving renewable energy transition, many industry stakeholders expressed concerns that additional complexity and cost associated with time-matching would present barriers to PPAs and hence the renewables build needed, but we note that misgivings around time-matching mostly relate to mandatory timestamping in renewable energy certificates, rather than voluntary 24/7 approaches. There was also acknowledgement that customer demands are changing, and developers and retailers will need to meet these needs.

The role of voluntary procurement in driving transition may be diminished in the context of additional policy action from Governments to drive electricity sector transformation and emissions reductions. For example Xu et al. (2023) found that "emissions matching strategies have zero or near-zero long-run impact on system-level CO_2 emissions", on the basis that voluntary procurement simply displaces other carbon-free energy. This finding is partially supported by our modelling of system transition with 24/7 procurement. In the Australian context, the expanded Capacity Investment Scheme involves underwriting both new renewable (32 GW) and storage capacity (9 GW). While it is unclear how voluntary procurement will interact with the scheme, concerns that 24/7 contracting and in particular certification might delay RE build may be allayed by the CIS ambition. On the other hand, prior to the CIS expansion, policy to drive investment in clean dispatchable energy was a clear policy gap where 24/7 CFE may have had an important role to play, but the CIS may substantially fill this gap with its 9GW storage target and the marginal value of voluntary 24/7 procurement may therefore be diminished.

6.2 Next Steps

There is a need for a better understanding of the diversity of C&I customer renewable energy procurement strategies and certification requirements across different industry sectors. In particular the characteristics and value of flexibility in C&I customer demand, how this can be leveraged in their procurement and carbon strategies, and to manage associated grid impacts. The electrification of new large industrial loads, which may be exposed to temporal certification in international markets, is not well understood, and the impact of 24/7 on system-level emissions under 'hydrogen superpower' and massive datacentre growth scenarios is an important research area, as these potential large load may have significant emissions impact.

Open-source tools developed through this project are available be used and further developed by a range of stakeholders to explore the impact of time matching in PPAs, and at the system level, and extended to related research areas.

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