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Strategic Integration of Electrified Fleets for Mutually Optimised Systems: An Australian Analysis

Dr Charlie Hargroves[1], Dr Scott Dwyer[2], and Benjamin James[3]

[1] *Curtin University, Kent St, Bentley Western Australia 6102, karlson.hargroves@curtin.edu.au*

[2]*University of Technology Sydney, Australia*

[3]*Curtin University, Western Australia.*

Executive Summary

This paper will discuss the challenges and opportunities of electric vehicle (EV) uptake including improved resilience of transport and electricity systems, energy security and reliability, EV absorption into urban and transnational landscape, policy affecting this transition, and EV perception and anxiety. Focus on the growing Australian uptake of renewable energy and electrified transport provides unique opportunities for mutually beneficial strategies.

Keywords:V2G, Smart Grid, Fleet, Business Model, Demonstration.

1 Introduction

This paper analyses and anticipates how the electrification of transport fleets will pose new challenges for electricity and logistical management. Electrification of transport will increase loads on the grid, while changes to vehicle energy systems will impact how vehicles are used and trips are planned – however the challenges present opportunities for whole system optimisation [1][2]. As electricity systems undergo transition to renewable energy generation, smart load management (including batteries) will stabilise the increasingly fluctuating electricity generation, with EVs offering new options for ancillary service support.[3] The difference from internal combustion to EV logistical situations will require more thorough consideration of whole transport system design, resulting in greater focus on transportation of people and goods rather than vehicle throughput[3].

This paper will discuss strategic EV integration focusing on lessons from research and implementation, analysing world-leading case studies and how they inform emerging demonstrations and research. This paper makes analyses in an Australian context: uniquely operating one of the most geographically expansive grids in the world and a smaller grid around the most isolated capital city in the world, operated by a single provincial government (NEM and SWIS as shown in Fig 1) [4]. These different systems both anticipate an accelerating renewable generation transition – including world-leading utilisation of household solar generation – and significant increase in grid load with the electrification of Australian transportation. This paper highlights that the timing of this transition alongside the fourth (digital) industrial revolution presents the opportunity for intensive smart load management – enabling EVs to provide grid ancillary services to fluctuating renewable generation and support Australia to achieve net zero electricity grids [5].

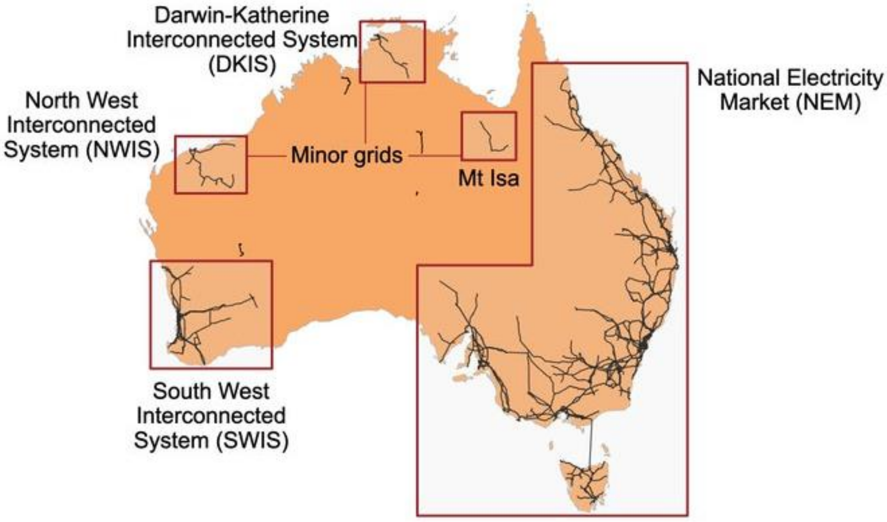

Figure1: Australia's major electricity networks [4]

This paper will present and analyse lessons from research and implementation of strategic EV integration for mutual benefits to national networks and individual owner, encouraging acceleration of support from all stakeholders. This paper will present findings from the development from state and municipal EV strategies particularly that of the Western Australian state and Lithgow municipality governments. This paper discusses investigations made by the authors for the Sustainable Built Environment National Research Centre identifying key factors affecting EV uptake in Australia and a range of mechanisms for increasing uptake – including green bonds, tailored government policy and subsidy schemes. Analyses of these cases are extrapolated in this paper into informative lessons for the delivery of more resilient national transport and energy systems [6][7].

1.1 Background

Rapid growth in uptake of Electric Vehicles (EVs) will create many opportunities across the energy sector, calling for industry engaged research efforts that are well informed, carefully evaluated, and the lessons learned quickly shared. The RACE for 2030 CRC provides a unique opportunity to bring together a diverse group of partners to work collaboratively on partner-led demonstration projects to enhance outcomes and inform efforts across Australia and around the world. This process, by its very nature, will require an action research approach, meaning that the outcomes are not initially defined, nor can they be fully foreseen. A unique aspect of the CRC is the emphasis on creating a platform for industry, government, civil society and research institutions to work together to identify, explore and share the findings from key areas of industry research.

The project will investigate in detail a selection of early-stage partner-led demonstration projects involving the integration of EVs and energy storage in Fleets, Precincts, and Regions, working in close collaboration with partners over an initial three year period. The project will seek to enhance each demonstration project through the design, implementation and review of Companion Research Plans (CRPs). The demonstration projects will be investigated using a set of research priorities which have been identified and scoped as part of Stage 1 of the project. Demonstration projects will be undertaken across multiple states and will feature a mix of customer types (both fleet and private vehicles), business and operating models, options for managed charging (with a focus on bidirectional charging in later stages when available), and interaction with a variety of co-located energy storage systems of different scales. The industry-led research is essential to inform our understanding of how EVs can be effectively, efficiently, and equitably integrated into the electricity grid, the wider built environment, and society as a whole. This research at demonstration level will then inform the development of a set of larger scale CRC follow on projects in this area.

Feedback from RACE for 2030 CRC Partners clearly calls for investigations into the strategic integration of EVs to take place within the wider context of the Distributed Energy Resources (DER) transition, rather than in isolation. In response, this project will explore how EVs interact with the grid, embedded networks, and buildings that involve a range of energy storage options (as per the 'N3 Research Roadmap'), and the development of specific regulatory reform proposals (as per the 'N4 Research Roadmap'), contributing to associated Commonwealth Milestones for each. Partners also strongly supported the recommendation from the Consultation Stage that projects should be selected from Partner projects that provide the opportunity to explore key research questions, calling for the creation of a 'Partner-led Embedded Research Approach' (PERA) as part of the project. This approach is intended to allow researchers to directly support partner-led demonstration projects while exploring specific testable hypotheses based on the key research questions in a manner that minimises duplication and captures synergies.

1.2 The Challenge

The adoption of Electric Vehicles (EVs) is growing worldwide, driven in part by the need to accelerate the decarbonization of the transport sector which is supported by increasing market pull from consumers, and by market push which is being led by new market entrants in the supply chain. As EVs reach price parity (first in terms of total cost of ownership, then in terms of list price) with internal combustion vehicles (ICVs), a number of fundamental challenges emerge for their successful integration. Tackling this cross-disciplinary challenge calls for new thinking, new approaches, and new collaborations that are applied to real world case studies. As other Distributed Energy Resource (DER) solutions (such a demand flexibility, rooftop solar and battery storage) are coupled with EV charging infrastructure (at homes, in buildings, and across urban grids), a range of new opportunities emerge that can create benefit and overcome existing and emerging challenges. The manner in which EVs integrate with the electricity system will have long-lasting implications and this calls for a strategic approach informed by close industry, government, and researcher engagement. If done well, strategic EV integration could be the catalyst needed for system-wide decarbonisation and decentralisation, while delivering a range of benefits. If done poorly, it could lead to substantial issues for the management of the electricity system.

1.3 The Research Gaps

Despite a growing body of theoretical literature on the implications of increasing levels of uptake of EVs and a growing number of practical trials, there remains limitations and research gaps that need to be addressed to inform strategic approaches. Based on the research undertaken as part of the Consultation Stage of this project, the following key gaps have been identified:

- *Beyond Early Adopters*: Previous research has often focussed on innovator and early adopter customer groups, providing a limited picture. This will require such results to be viewed within this context, and research approaches will need to be developed that can reach those customers more reflective of the early and late majority sections of the market.
- *Standards and Technology Nexus*: The immaturity of associated technology, along with legal and policy settings to support bi-directional charging, brings risks to trials that would seek to test the technology. As such current efforts need to focus on what is currently possible with an eye to what may need to change in order to accelerate efforts. For instance early efforts need to be focused on managed charging, and possibly vehicle-to-building, with a view to including the exploration of vehicle-to-grid options as soon as the technology and standards allow (expected from 2025).
- *Scalability*: There is a lack of projects and approaches that can unlock scalability and replicability, calling for careful consideration of how transferable structures and knowledge can be articulated and communicated. An approach that identifies and works in collaboration with partner-led demonstration projects is needed, along with a strategic approach to build on the lessons to inform wider efforts.
- *EV Grid Impacts*: There is a need to better understand the extent of the impact that EVs will have on Australia’s grid and both the energy and transport sectors from various levels of EV uptake, under various types of charging approaches, amidst different types of consumer behaviour, and combined with different forms and scale of energy storage and demand balancing options.
- *Real-world Benefit Cost Analysis*: There seems to be a lack of real-world evidence of the actual benefits and costs to customers, businesses, and communities relevant to Australia. Efforts to better understand and validate such costs and benefits will need to build on early demonstration projects.

2 Consultation & prioritisation outcomes

Stage 1 is now complete. This stage involved a nationwide consultation with CRC Partners, industry and other demonstration projects, combined with a review of associated literature to identify strategic EV integration priorities for inclusion in Stage 2.

Stage 1 identified the following priorities for Stage 2 that will all be considered during the selection of demonstration projects and development of subsequent Companion Research Plans: 1) Preferred categories and criteria for demonstration projects; 2) Partner preferred selection criteria; and 3) Research-based selection criteria.

A key recommendation from Stage 1 was to ensure that the selection of demonstration projects reaches a balance between the need to deliver partners direct value and the need to address a set of partner-preferred and research-based criteria.

2.1 Preferred criteria for demonstration projects

Within each category of 'EVs and Fleets', 'EVs and Precincts' and 'EVs and Regions', partner-led demonstration projects will be selected that are currently planned or are in the early stages of delivery that provide the opportunity to explore a number of areas, including:

- Multi-site demonstration of managed charging, V2B, V2H with a strategic pathway to V2G.
- A focus on both fleets and residential developments if possible for enhanced replicability.
- Understanding consumer behaviour, charging and driving, impact on network, energy demand in building, interaction with onsite generation.
- Examining the opportunities and challenges from the perspective of various stakeholders.
- Informing the customer value proposition and associated business models.
- Informing energy system modelling combined with user preferences/behavioural models.

Furthermore, consideration will be given undertaking a progressive approach that parallels the market availability and uptake of various technologies by selecting partner-led projects that:

- Focus on customer use cases that demonstrate a pathway to scale/replicability.
- Maximises the benefits of current technologies using managed charging.
- Include V2H/B when appropriate to test implications for owner, buildings, neighbourhoods and the grid.
- Include V2G when appropriate to test impact on grid and value streams.

2.2 Partner preferred selection criteria

1. What are the costs and benefits related to bi-directional charging for EV owners and fleet managers?

- How will costs and benefits affect uptake rates of EVs? Do we understand what the influential costs and benefits are? Is it too early to know?
- Are there interesting differences in various estimates that may identify bias?
- Where and when are people likely to want to charge their vehicles?
- What are the network costs and benefits of EVs?
- Avoid unsupported assumptions and ensure scope is fit for purpose for informing scalable outcomes.
- Ensure a focus on social science is included in assumptions around EV use patterns and perceptions of costs and benefits.
- How can understanding costs and benefits inform customer behaviour forecasting and inform network planning?

2. What is the best approach to standardisation in the sector?

- Given that the CCS charging standard is expected to become dominant from around 2025 to enable V2G, there may be limited value in running bi-directional charging projects that rely on the CHAdeMO standard.
- Seek to avoid issues experienced with previously in the solar industry, such as issues around the lack of capacity for laboratory testing as part of AS4777. Issues may include: state variations, lack of clarity on the future technology, and inability to distinguish if the connection is a load or storage.
- Is it likely that V2X is going to be managed inside the vehicle, in the EVSE, or in the BEM/HEMs? Does this present security concerns? Charging technology needs to be frequency sensitive and be able to facilitate complex tariffs, with communications and functionality to serve current and future needs of DNSPs, utilities, etc.

3. Will bi-directional EV charging be profitable over the longer term with increasing deployments of distribution and transmission scale storage?

- How will EVs influence investment in regulated asset base, and will this detract from greater utilisation of current options?
- Will behind-the-meter home and business storage have less barriers and faster uptake compared to in-front-of meter?
- Will the FCAS revenues be depleted for EVs when other forms of storage come online?
- Can the response time of EV storage offer advantages when combined with transmission scale deep storage options to reduce cost to manage load conditions?
- How will EVs impact on our daily patterns of energy consumption and generation, and can they be used to address challenges posed by intermittent renewable supply, such as renewables curtailment and minimum demand?

4. Will allowing managed charging degrade or enhance the battery in my EV?

- OEMs are very focused on battery impacts from interacting with loads such as buildings or the electricity grid, especially regarding implications for warrantees. This may mean that research in this area is less warranted, however some independent laboratory testing may be of use.
- What is the relative level of load from a house or the grid compared to accelerating 1-2 tonne vehicle? What is the likely utilisation of the EV battery by the grid?
- Independent and reliable findings are needed on the effect on the battery via laboratory studies that can simulate real word conditions.
- How can EV users be ‘nudged’ towards preferred charging behaviours using awareness raising, education programs, tariffs and managed charging?

III. RESEARCH SELECTION CRITERIA FOR DEMONSTRATION PROJECTS

a) Cost-Benefit Analysis Research

- The benefits and costs of V2X technologies will vary for different stakeholders, including: EV owners, EV manufacturers, transmission and distribution network service providers (DNSPs), fleet operators, and the general public.
- DNSPs can reduce the cost of infrastructure upgrades by smart scheduling and control of distributed energy resources (DERs), including V2G enabled EVs, assuming owners and managers allow.
- Successful customer engagement requires fair tariffs as well as deep customer-awareness about the reality of battery degradation.
- A significant proportion of business EV fleets are home garaged in Australia and may have different requirements than normal EVs in bi-directional charging.

b) Regulatory Reform Research

- Current tariffs can affect wholesale market prices and other market signals and incentivise night-time charging. How can this be addressed by tariff reform wholesale market signals?
- Can and should EVs interface with the electricity market other than as consumers, and to what degree does this interaction need to be facilitated and by whom?
- How can legislation incentivise DNSPs to build the type of grid best suited to accommodate EVs, and how will revenue or tariff settings influence these choices? Is a change in roles and responsibilities of network providers required, or the introduction of new roles?

c) Standards and Codes Research

- Vehicle industry standards should be updated to include V2G interaction. For example, currently in Australia, the majority of EVs use the Combined Charging System (CCS) technology which will support V2G bidirectional charging in 2025.
- Updates in the grid integration standards are required. A recent study in the ANU shows that AS/NZS 4777.2 does not support V2G regarding test procedures of bidirectional chargers and discharge ramp rate. Also, special consideration may be necessary for high-capacity inverters and high voltage connections not covered by AS/NZS 4777.2.
- There are gaps and compliance in interoperability standards. Although the AS4755.2 specifies the behaviour of DER devices that provide demand response services, the framework for communication between the remote agent and the DER device is left open. The recently published “ISO 15118-20:2022 Road Vehicles — Vehicle to Grid Communication Interface” requires comprehensive assessment before being adopted by Australia to fill the gap of interoperability.

3 Project Overview

3.1 Main Outcomes

A strategic pathway is needed if EVs are to be effectively, efficiently, and equitably integrated into the electricity grid, the wider built environment, and society as a whole. To do this, transdisciplinary approaches are required to bring industry, government, and academia together to combine expertise and experience in a range of areas and make them relevant to specific partner led demonstration projects. Based on the Consultation Phase of the project this includes the development of work packages in the following areas that are targeted at making meaningful contributions to each of the selected partner-led demonstration projects:

1. Project design and implementation.
2. Social and market research and trends.
3. Technology deployment and data analysis.
4. Value propositions and business models.
5. Legal aspects and regulatory reform.
6. Energy system modelling and network analysis.

The main outcomes of the project will be:

- *Research support for Partner-Led Demonstration Projects*: The project will seek to directly support a set of partner-led demonstration projects through the co-design and implementation 'Companion Research Plans' (CRP’s). The CRPs will seek to enhance the design, implementation, and assessment of the demonstration projects, while sharing valuable lessons with the industry. As such, RACE for 2030 Partners will see benefits across the full lifecycle of their project, working closely with expert researchers to inform co-design and implement that directly address their needs and challenges. This will include raising the profile of partners involved, while developing knowledge, resources, frameworks, and tools to support strategic EV integration.

- *Strengthen Value Proposition for EVs*: The project seeks to build understanding and confidence in the benefits of integrated EVs among consumers, industry, and policymakers, through the exploration of specific research questions as identified with CRC partners. This will assist RACE for 2030 Partners and the wider energy sector, by: informing the design of future demonstration projects, understanding social and market considerations, informing consideration of value propositions and business models, consideration of associated costs and benefits, identification of specific regulatory reforms, and providing new real-world data for modelling and analysis.
- *Inform Wider Practice*: The project will develop of a set of key findings drawn from active participation in a carefully selected set of practical partner-led projects to inform the strategic integration of EVs with energy storage. This will include commercial and economic understanding of managed charging and will inform future efforts to investigate the potential for bi-directional charging. This will include the development of detailed case studies for each of the selected projects to ensure that lessons learned are quickly and effectively communicated to the wider industry via a range of avenues including publications, TV ready videos and training modules.
- *Inform Regulatory Reform*: The project will develop regulatory reform proposals specific to each partner-led demonstration project to enhance strategic EV integration across the country with lessons for international adoption. This will involve state-specific regulatory reform proposals for each of the three demonstration projects. This will inform future regulatory change that is able to further leverage the strategic integration of EVs

3.2 Path to impact

Harnessing the full potential of integrated EVs and energy storage stands to deliver a wide range of benefits. The project will seek impact through demonstrating these functionalities and amplifying their impact through directly enhancing partner-led demonstration projects and subsequent knowledge dissemination. Learnings from demonstration projects will be captured in a range of ways for dissemination including the development of project reports, industry summary reports, high quality project videos, and capacity building modules to support future projects.

3.2.1 Expected short term impact (<5 years)

The current market immaturity of V2G means that it is not expected to make an impact in the short-term beyond laboratory trials or testing, with significant uptake expected to begin from 2025 with the onset of new standards (namely the international 'Combined Charging System' Standards - CCS). Managed charging is considered a closer opportunity, as is vehicle-to-load, although in a more limited capacity in the short term. The impact of managed charging although a short-term opportunity, is reliant on the uptake of EVs. In 2021 there were just over 20,000 electric vehicles registered in Australia, which is significantly less than the 63,884 projected in the low uptake scenario in the Energia analysis1. However, there is evidence to suggest that this difference in projected sales can somewhat be accounted for by recent supply chain constraints on the sale of EVs in Australia, with several market surveys estimating a demand of approximately 60,000 in 2022. Recent projections from CSIRO support this and show a more substantial uptake of EVs in the period 2025-2030, following the considerably lower uptake of EVs in 2022-2025.

3.2.2 Expected longer term impact (by 2034)

The ‘Australian Government Future Fuels and Vehicles Strategy’ estimates that by 2034 EVs will comprise almost 30 percent of the national light vehicle fleet, and research from the Australian National University (ANU) anticipates the EV fleet will be nearly totally V2G capable. Energeia’s analysis suggests there will be approximately 190,000 EVs sold per year in 2031, providing a conservative estimate of 1.2 million EVs in the national fleet. The ANU estimates up to 1.8 million EVs with V2G capability in 2030, consistent with Energeia’s upper estimates of EV fleet size. , Recent projections from CSIRO also support estimates in the range of 1-2.5 million EVs registered in 2030 based on a range of possible future scenarios.

This project will be complimenting a set of partner-led demonstration projects of managed charging in Fleets, Regions, and Precincts, all of which will contribute to an improved understanding of the potential for managed charging and the pathway to adoption of V2X technologies (including V2G and V2H). Managed charging of a growing EV fleet will allow for more efficient use of electricity infrastructure and reduced redundancies, with Infrastructure Victoria suggesting that EVs charging during off-peak times could allow for savings of $2.5 billion in infrastructure investment. Analysis in the ANU's 'A to Z of V2G' suggests that if all EVs in NSW as of 2021 had V2G capability, the fleet could provide a similar level of grid ancillary services as the Hornsdale battery in South Australia. Based on the lower projected uptake of EVs in Energia's analysis it is estimated that the network and generation benefits of managed charging compared to unmanaged charging in 2025 can reduce peak load by up to 1,360MW. As this project will be seeking to investigate the potential of managed charging across Fleets, Regions, and Precincts, it is estimated the project will inform efforts nationwide that stand to contribute to a 25 percent improvement in the uptake of managed charging.

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Presenters Biography

Dr Charlie Hargroves is a Senior Research Fellow at the Curtin University Sustainability Policy Institute, and is an experienced industry led research project leader, specialising in urban sustainability transitions involving new technologies in energy, transport, and digital solutions.

Charlie has worked with Curtin University to lead teams to work with Australian State Government's, companies, professional bodies and industry groups to research solutions to urban sustainability challenges with the Sustainable Built Environment National Research Centre in Australia. Since 2016 Dr Hargroves has provided expert advice to the United Nations Centre for Regional Development.

Dr Scott Dwyer is a Research Director at the Institute for Sustainable Futures at the University of Technology Sydney, working on issues relating to the transitioning energy system. His main interests relate to the opportunities and challenges posed by disruption within the energy sector, especially those relating to markets, customers, technologies, markets, policies, and business models.

Past and current projects include community microgrid feasibilities, electric vehicle business model development, Vehicle-to-Grid trials, and solar and battery VPP demonstration projects.

He holds a PhD in Energy and Buildings from the University of Ulster (Belfast), a Masters of Science in Energy Systems from the University of Strathclyde, and a Bachelors of Science (Honours) from Glasgow Caledonian University. He is a Fellow of the Australian Institute of Energy.

Ben James is a phd candidate with the largest Australian CRC to date RACE2030. His phd will investigate optimised use of DER in Australian electricity grids via new business models, to increase Australia's capability towards net-zero and abundant electricity via optimal use of the increasingly potent DER.

Ben has a background in electrical devices and electricity systems, having designed turnkey solar-battery powered off-grid devices, consulted on building efficiency improvements, investigating the nexus of electricity and transport systems – providing a foundation for his phd.

His industry and academic energy work spans internationally ranging from a start up to consultation with the UNCRD.