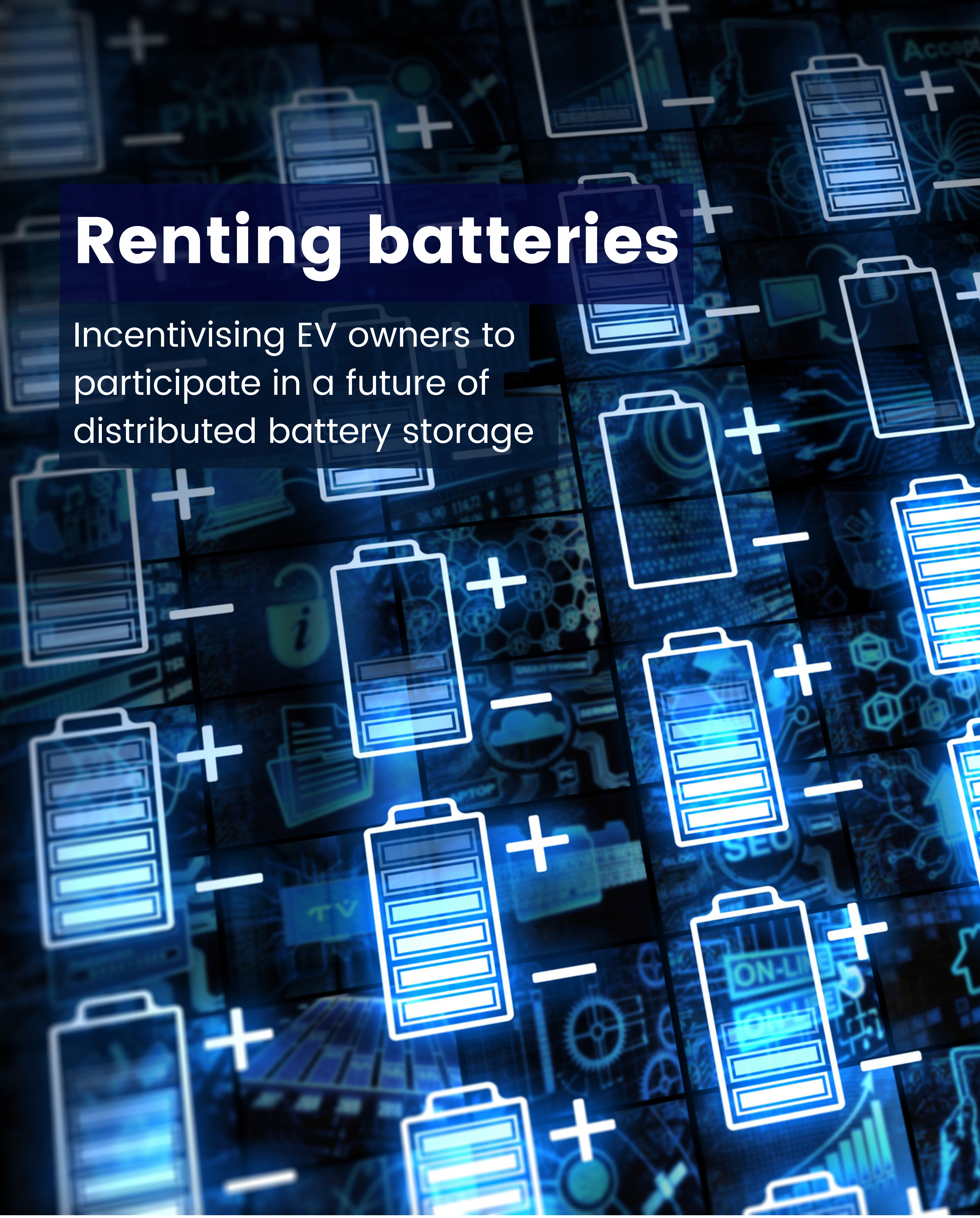


Renting batteries

Incentivising EV owners to participate in a future of distributed battery storage

NineSquared

ENDGAME ECONOMICS

vlc

Disclaimer

Nine-Squared Pty Ltd (NineSquared), Endgame Economics and Veitch Lister Consulting (the 'Authors;) have prepared this report taking all reasonable care and diligence required. This report provides high-level analysis only and does not purport to be advice on particular investment options or strategies. We have not necessarily independently verified any information provided to us or used by us that has come from a third party.

While the Authors have used all reasonable endeavours to ensure the information in this report is as accurate as practicable, the Authors, and any contributors, employees, and Directors shall not be liable whether in contract, tort (including negligence), equity or on any other basis for any loss or damage sustained by any person relying on this document whatever the cause of such loss or damage.

Published: December 2023

Authors

Simon Sagerer
Amelia Shu
Daniel Veryard
Ben Close

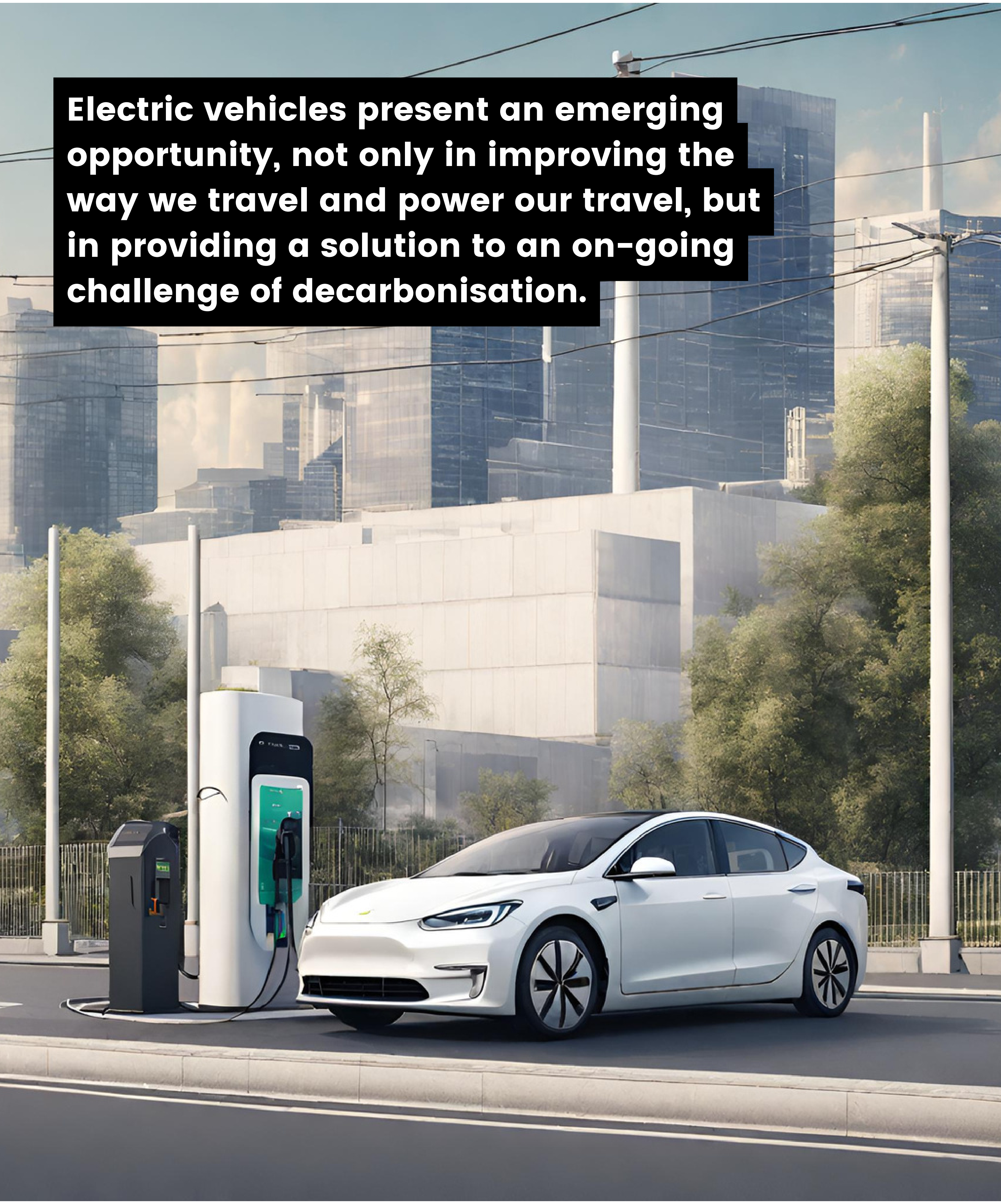
For more information

Simon Sagerer
Director, NineSquared
ssagerer@ninesquared.com.au

Daniel Veryard
State Director (NSW and WA), Veitch Lister Consulting
Daniel.Veryard@veithchlister.com

Ben Close
Consultant, Endgame Economics
ben.close@endgame-economics.com

Electric vehicles present an emerging opportunity, not only in improving the way we travel and power our travel, but in providing a solution to an on-going challenge of decarbonisation.



Renewable generation and electric vehicles (EVs) are essential components on the pathway to decarbonisation. One of the major impediments to a full transition to renewables is their unpredictability of generation and difficulties in rolling out appropriate energy storage infrastructure.

Together with the reliance on renewable energy sources, the need for load smoothing and short -erm dynamic storage is predicted to increase. At the same time, electricity consumption is likely to increase as EVs become the dominant mode of (personal) transport. Unless effective and efficient energy storage solutions are implemented, truly emission free EVs could remain an illusion for a long time.

The Australian Energy Market Operator's (AEMO) 2022 Integrated System Plan found that a significant proportion of grid stabilising (storage) capacity required by 2050 could plausibly come from small scale distributed sources including electric vehicle batteries. In the AEMO's view this is dependent on the effective alignment of EV charging periods, demand and renewables generation patterns.

EVs could reach full potential when their capacity for active storage is fully integrated into the grid.

Under the right conditions, our analysis indicates that reaching this full potential is not only possible, but economically beneficial. We have considered electricity grid effects, travel and charging patterns, and households' reactions to consumption incentives.

A coordinated roll out could create a distributed storage network of EV batteries that would contribute to smoothing the renewables load.

Providing low-cost storage capacity, the integration of EV batteries into the grid could accelerate the transition to renewables by smoothing loads. EV uptake could also be accelerated by offering an opportunity to offset the vehicles' operating costs. Not only would the purchase of an EV be attractive through a personal decarbonisation perspective, but stored energy could stabilise the grid and support the reliability of a high renewable penetration system. The avoided expenditure for storage infrastructure could then be used to further fund infrastructure needed for EVs such as charge points, and further facilitate their uptake.

Secondary beneficial impacts of this approach would include increased energy security as dependence on petroleum imports decreases and the opportunity to transition from fuel excise to a more sustainable form of road funding.

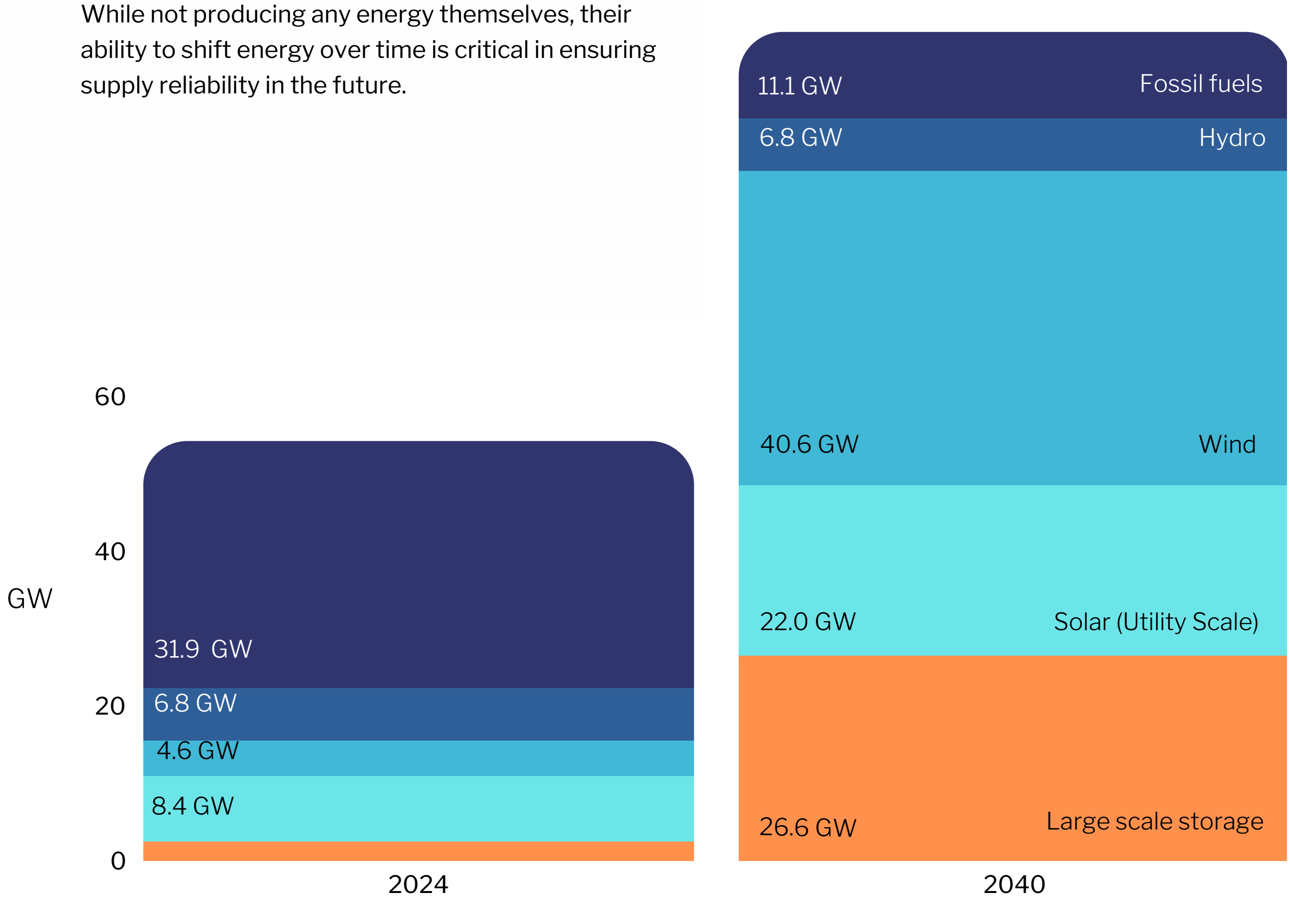
The idea of 'exporting' car energy is likely to be challenging to households but would benefit from incentives and education.

Appropriate incentives and guarantees will be needed to make households comfortable with sharing (a part of) the energy latent in their EVs. Monetary incentives possibly coupled with minimum guaranteed charge levels, could be used to overcome households' concerns. The Government's willingness to provide such incentives would be associated with the benefits storage and load smoothing have on reduced generation and network cost.

By 2040 most of Australia's electricity generation capacity will be solar and wind. This generation capacity will need to be supported by a combination of gas, large scale storage and pumped hydro.

Over the next decade, installed generation capacity in the National Energy Market (NEM) is expected to grow significantly while coal generation is phased out and replaced with renewables.

While solar and wind are generally cheap energy on their own, their output is dependent on weather conditions. Solar output is zero at night and significantly limited during cloudy periods. Wind output also has significant seasonal patterns and fluctuates over the course of the day. In a future high renewable penetration system, tens of billions of dollars in expenditures will need to be incurred in storage assets. While not producing any energy themselves, their ability to shift energy over time is critical in ensuring supply reliability in the future.



Storage (in orange) is set for a 10x expansion from 2.5 GW in 2024 to 26.6 GW in 2040

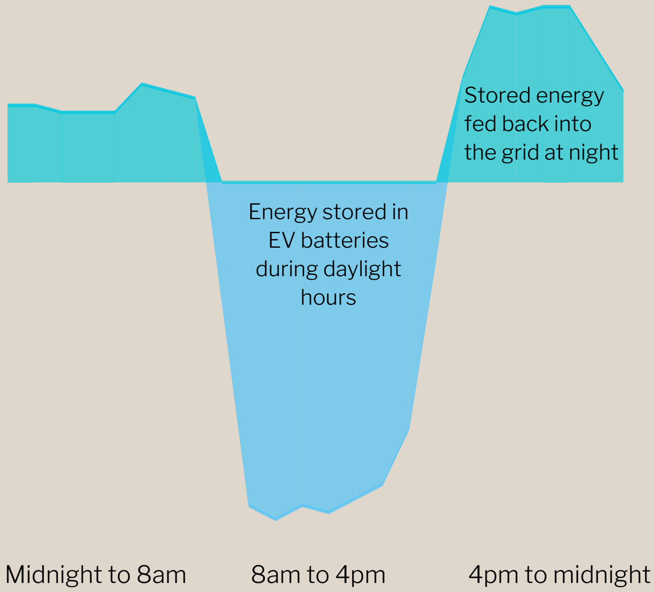
Expansion of large-scale storage capacity will require substantial investment. An expanding EV fleet provides an opportunity to introduce a distributed model of storage at a substantially lower capital cost.

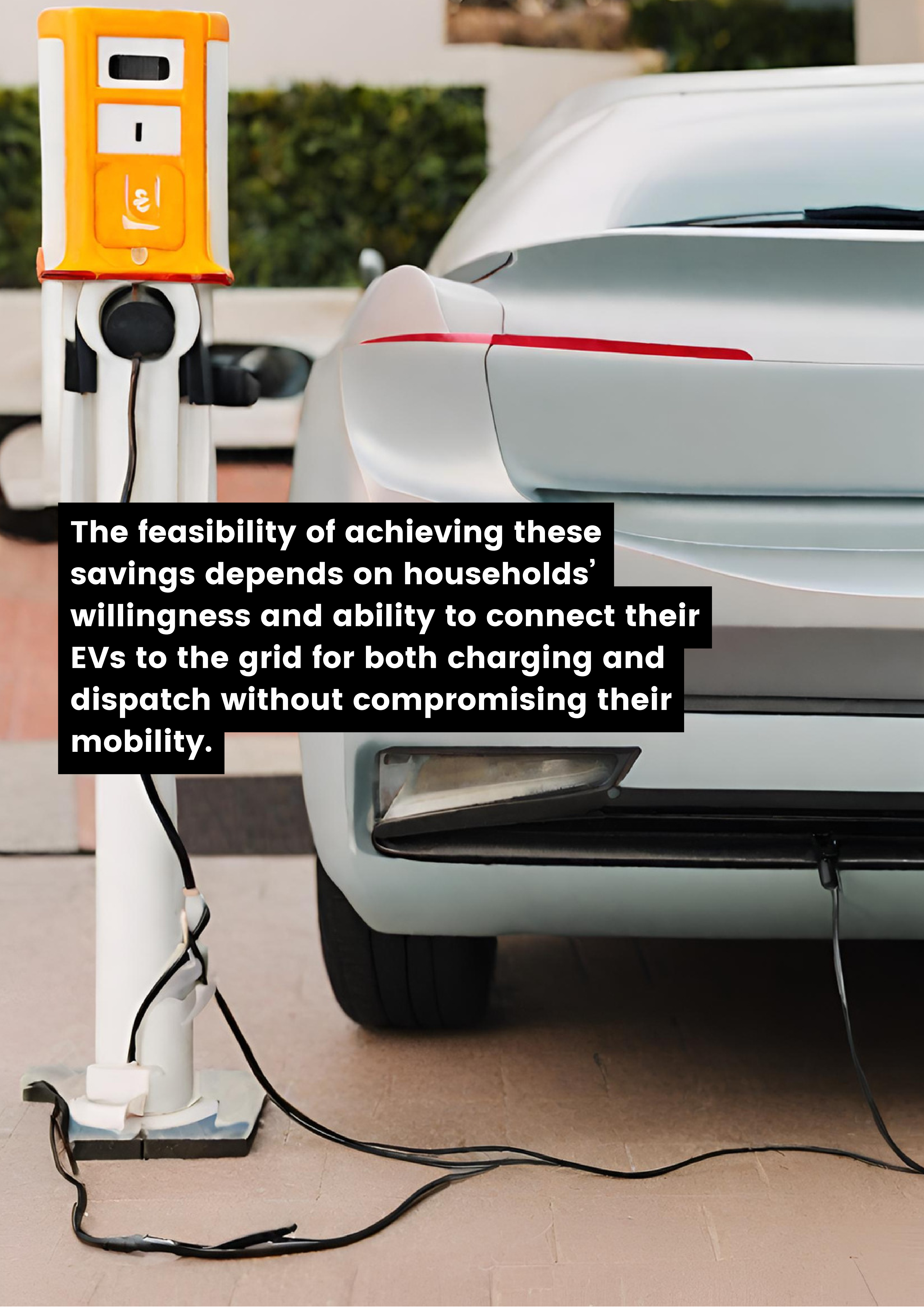
Using EVs as a source of distributed storage requires energy generated during the day to be stored in the EV batteries that are connected to the grid. This is then released at night for consumption. Because EVs are used to store energy during the day for night-time usage, solar generation can play a larger role in the energy generation mix reducing the need for more cost intensive wind.

Analysis by Endgame Economics suggests that an additional 1.7 GW of V2G availability and a NEM-wide average 1.8 GW increase in midday EV charging could lead to approximately $300 million benefits per year in the 2040s as a result of reducing the need for wind generation, large scale storage and pumped hydro.

'he chart below shows an example of a generation and load profile for V2G charging. It shows that EVs could absorb excess production during the day and release it back to the network at night.

Indicative charging and dispatch profile





The feasibility of achieving these savings depends on households' willingness and ability to connect their EVs to the grid for both charging and dispatch without compromising their mobility.

Households' EV charging decisions will be heavily influenced by their travel habits, their desire for reliable, on-demand mobility and by the incentives provided to encourage them to connect to the grid via a bidirectional charger.

Our analysis of travel patterns and demographics in Southeast Queensland indicates that there is the potential for EV owners to effectively rent part of their EV battery to the grid in sufficient quantities to make a difference. To do so, three things need to be considered.

1. **There needs to be enough cars that are stationary to allow them to be charged during the day and allow for the dispatch of energy at night.**
2. **The distances travelled by households connecting their vehicles to the grid needs to be lower than the distance enabled by the energy remaining in the vehicle after dispatch.**
3. **Households need to be willing and able to respond to incentives to connect their EVs to the grid for use as a distributed battery for their energy provider.**

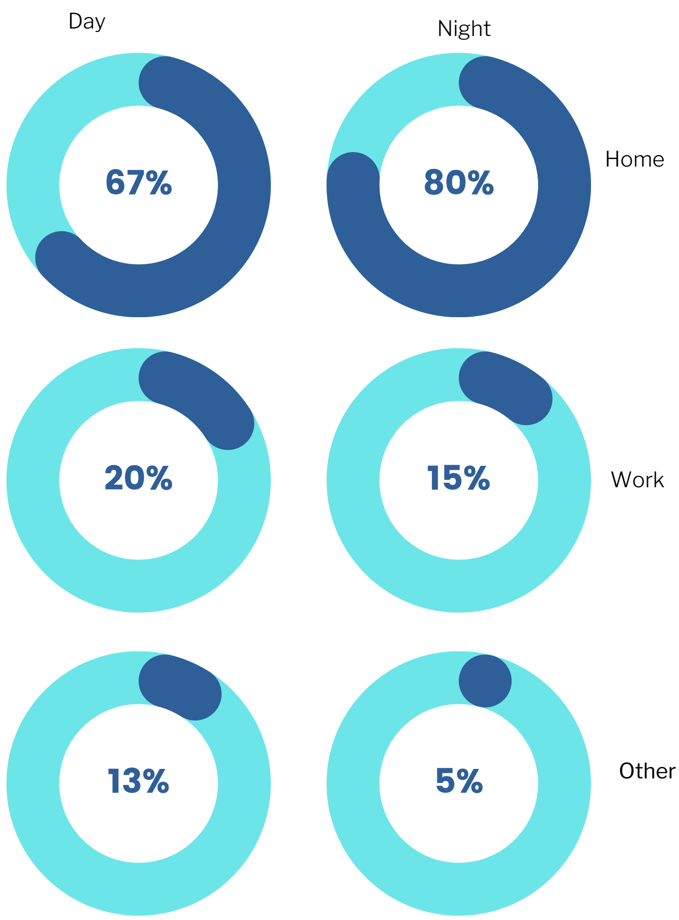
Point #1.

Most cars are stationary, most of the time.

VLC analysed the Southeast Queensland Household Travel Survey data to determine the extent to which cars are used throughout a day. The survey, which covers a period from 2019 to 2022 showed that cars are stationary most of the time. In fact, the 'average' Southeast Queensland car spends more than 13 hours every day parked at a home and more than 7 hours parked at work.

The graph below shows the location of cars that are stationary for more than two hours with some cars having multiple longer stops during day and night periods. During the day, two out of three cars that are stationary for more than two hours are parked at home. At night, this increases to four out of every five cars.

Location of cars that are stationary for more than two hours

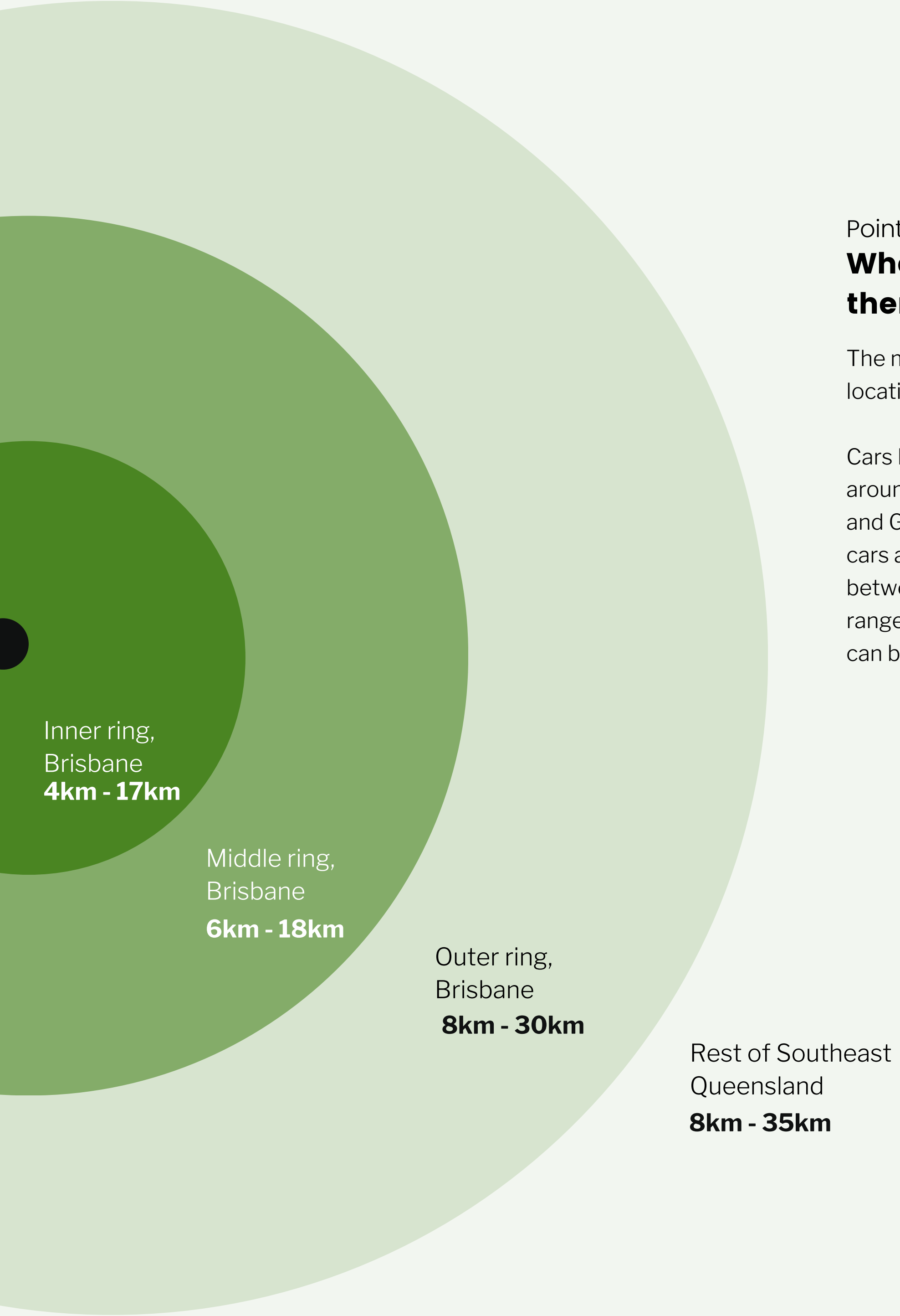


Point #2.

When cars are driven, many of them aren't driven very far.

The most important determinant of car use is home location.

Cars belonging to households in inner Brisbane travel around half the distance of households on the Sunshine and Gold Coasts. Even with longer drives, the majority of cars across the rest of Southeast Queensland travel between 8 and 35km each day - well within the current range of EVs on the market and significantly less than can be driven with a fully charged battery.



Daily driving distance increases as the distance of the home location of a vehicle increases from the city centre. Driving distance is also positively correlated with the number of persons in a household and the number of cars available to households. The figure shows the interquartile range (from the 25th to the 75th percentile) of the car travel distances among surveyed households.
Source; VLC analysis of the Southeast Queensland Household Travel Survey

Point #3.

Households are highly receptive to financial incentives when choosing the time to charge EVs.

Recent experimental studies provide first evidence that financial incentives can shift households' EV charging habits such that they align with grid requirements. For example, in their working paper *Incentives and Nudges to Shift Electric Vehicle Charge Timing*, Canadian researchers Bailey et al. (2023) find that the receptiveness to financial incentives can be five to ten times higher than that for general electricity consumption.

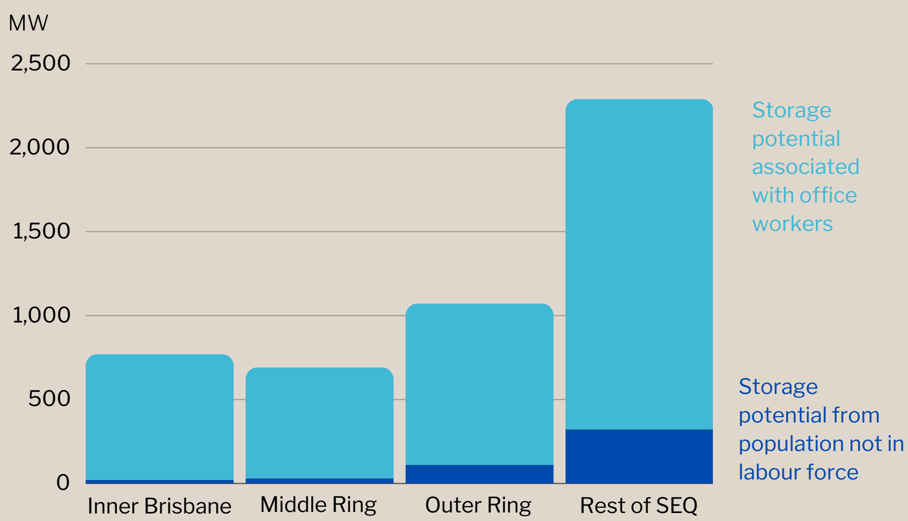
To estimate what it would take to incentivise Australian consumers to connect EVs to the grid, we used NineSquared's in-house synthetic population model.

In the synthetic population model, small geographic areas are populated with agents and having assigned consumption patterns allows us to derive localised expenditure profiles based on a small area's specific mix of agents. The model includes electricity price elasticities for groups of households (agents) associated with key demographic and socio-economic attributes.

Agents are allocated to specific geographic areas in the same proportion as the underlying population in those areas allowing detailed analysis of energy consumption at different prices and under different conditions.

To apply the synthetic population model, an estimate was first made about the likely number of EVs that would be available for connecting to the grid at the times required to meet the charging and dispatch requirements of the grid.

Energy storage potential from EVs available for connection to the grid, Southeast Queensland by 2040



Source: NineSquared Synthetic Population Model and AEMO EV Uptake Expectations

Megan R. Bailey, David P. Brown, Blake C. Shaffer, and Frank A. Wolak (2023): Show Me the Money! Incentives and Nudges to Shift Electric Vehicle Charge Timing; NBER Working Paper No. 31630

Employment is likely to play a key role in determining whether an EV is available to connect to the grid. Persons outside the labour force and unemployed people may have greater ability to align their travel most closely to time of day-based incentive payments while office workers who do not need to use their car during the day are also likely to have some flexibility in making a vehicle available for connection to the grid. Blue collar workers are assumed to have the least flexibilty as to how they use vehicles during the day, particularly if their employment requires travel between work sites. Each of these groups are assumed to have different behavioural responses to any incentive to connect an EV to the grid.

Even when excluding blue collar workers from the analysis, there remains a significant level of potential energy storage from the EV fleet. Continuing the focus on Southeast Queensland, it is estimated that by 2040, some 480,000 EVs will be operating in Southeast Queensland alone with a potential Vehicle to Grid storage capacity of 4,800MW.

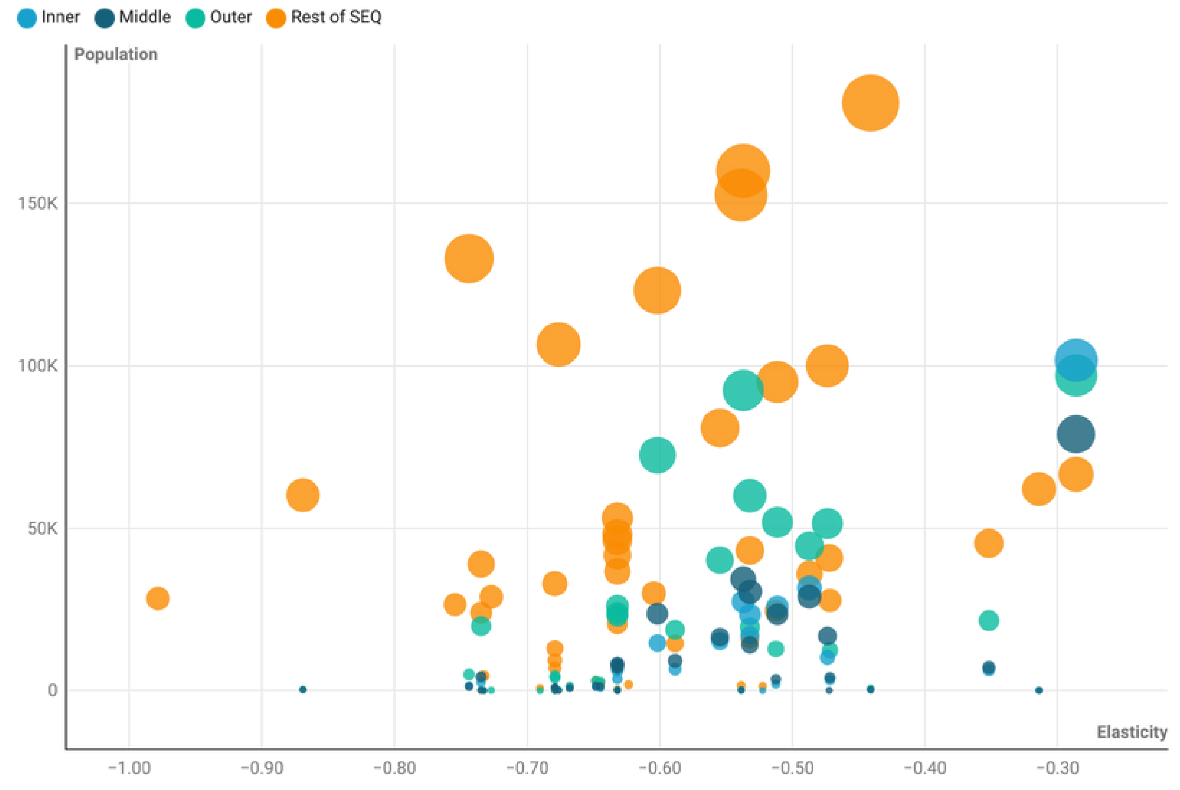
Applying the synthetic population model's electricity price elasticities to the target population shows that only small payments are required to shift charging to the time it is needed to meet the needs of a distributed storage strategy. Our calculations show that a payment from the grid manager to the EV owner of approximately 8% to 10% of the standard electricity price would be sufficient to incentivise enough EV owners to connect their EVs to the grid. Payments would be made while an EV was connected at the required time and while it was storing or dispatching energy in line with the storage and dispatch requirements of the grid. At other times, normal electricity pricing would apply.

With these incentives, on average, less than 4% of the EV fleet would have to be connected to the grid at any time to provide the required storage and generation capacity. Each EV would only need to contribute 7 kWh per day which could be charged and discharged in less than 2 hours.

Assuming an average residential electricity price of 40 cents per kWh, annual incentive payments would amount to $6.3 million each year - substantially lower than the potential savings in avoided investment in wind generation and large scale storage.

Sensitivity to electricity prices varies between synthetic agents in different locations

Price elasticity of demand with respect to electricity pricing by agent and agent population by location.
Research from Canada suggests that elasticities associated with charging time can be up to ten times higher than the elasticities for pricing that are shown in the figure below.



Source: NineSquared Synthetic Population Model • Created with Datawrapper

What's next?

More work needs to be done.

The scenario is predicated on 4% of EVs being connected to the grid at any time of the day via bidirectional chargers. With cars typically being parked in these locations for more than 20 hours per day, homes and places of work are the most promising locations for these chargers. Further work needs to be undertaken in relation to the following,

- The availability of bidirectional chargers in Australia is limited and currently most states prevent their usage. Also, not all EVs are compatible although this is likely to change in the future. Bidirectional chargers are more expensive than standard charging infrastructure. Analysis of incentive structures can shed further light on options and opportunities for consumers and businesses to invest in the additional functionality. Policy changes, R&D incentives and opportunities for local manufacturing could be further explored.

- Electricity market modelling assumed current charger technology and throughput capacities. The potential of V2G distributed storage could be even higher with more advanced charger and battery technology.

- Detailed transport demand modelling, ideally using an activity / agent-based model which tracks agents and vehicles throughout a day could better inform the choice of location. If sufficient vehicles can be expected to be parked at homes, they could be the only location where bidirectional chargers are needed. Pilots and trials combined with additional modelling could firm up the requirements.

Incentive payments will at least partly compensate for possible losses in battery longevity resulting from additional charging cycles. Payments could be augmented with education campaigns to further nudge households into re-thinking what their car can do. Small scale trials in Canada show promising results and relevant insights, they could be replicated in the Australian context to ensure future incentive levels are effective and efficient.

About us

NineSquared is a specialist economic consulting and commercial advisory firm focused on helping governments and companies make great decisions and achieve their goals and objectives. With our combined public and private sector experience we provide our clients with a deep understanding of both the public and private sectors and the interface between them.

For this paper we have explored the mechanisms that could incentivise households to make available their EVs as distributed storage using electricity price elasticities extracted from our Agent Based Consumption Model. In this model, small geographic areas are populated with agents defined by their socio-economic attributes from which we derive localised consumption patterns. The application can span the hundreds of goods included in the ABS' Consumer Price Index basket. To download more information about the Agent Based Consumption Model, please visit https://ninesquared.com.au/synthetic-population-consumption-model/

Veitch Lister Consulting (VLC) is a multi-disciplinary advisory firm, specialising in transport planning, analytics and modelling, policy and economics, and data science and visualisation. With our data and evidence-led approach, we help clients to make planning and policy decisions which support the creation of livable and connected communities.

For this paper we analysed de-identified household-level information from a travel survey conducted by the Queensland Government. Specifically, we explored the way that households' daily car travel differs by household composition, car ownership levels and location. This analysis informs the range required for future EV users and the location and duration of charging and discharging opportunities.

Endgame Economics is a firm focused on providing mathematical modelling and economic advice in the energy sector. Our firm brings together a unique combination of expertise in data analytics, strategy consulting, and deep domain knowledge in the energy and utilities industry. We have successfully delivered projects with a large variety of clients including governments, regulators, investors and commercial entities.

In this paper we have modelled the implications of varied EV charging profiles on the National Electricity Market. We examined how the required generation mix changes as a result of more and less co-ordinated EV charging behaviour. This model simulates the electricity system over the next 20+ years and identifies the generation mix to meet demand at least cost while considering relevant market and policy dynamics.