



Battery Storage and
Grid Integration
Program

An initiative of The Australian National University



Crossing sectors

A how-to guide for putting V2G into practice

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June 2022



This report has been created for knowledge sharing as part of the Realising Electric Vehicle to Grid Services project. This Project received funding from ARENA as part of ARENA's Advancing Renewables Program. The views expressed herein are not necessarily the views of the Australian Government.

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Executive Summary

The Realising Electric Vehicle-to-grid Services (REVS) project is a multidisciplinary, multi-industry project that aims to demonstrate vehicle-to-grid (V2G) as a key part of the future energy system. In this project 51 Nissan LEAF vehicles are connected to the energy system through bidirectional chargers. These vehicles provide contingency frequency control (FCAS) services. The vehicles, 50 of which are part of the ACT Government fleet, are used day-to-day for normal fleet duties.

This report documents the technical and business capabilities that have been developed and implemented as part of delivering REVS, as well as the additional capabilities required to implement V2G in a fully-fledged real world offering.

Delivering REVS is a complex undertaking. It required new relationships between transport and energy sectors, new tools, and new processes. Merging the transport and energy worlds was challenging due to the interactions between how vehicles are used, the hardware design of the chargers, and the software that drives them.

The REVS project was scoped to minimise impact on the vehicles' primary transport role. Even with this design, many of the largest issues in the project related to conflict between the transport and V2G functions. The diverse use cases of the vehicles and the hardware design of the charger resulted in usability and business process challenges.

Systems implemented during the REVS project were “proof of concept”. The exclusive focus on contingency FCAS, for example, was adopted to simplify the system. Energy impacts on the vehicle's battery are minimal when providing contingency FCAS, meaning that there was no need to collect the drivers' charging preferences. The service is always enabled which removes the need for enablement signals from the market systems, and the booking system did not need to be aware of the energy system's needs.

Due to the relatively low number of vehicles, lack of active participation in the energy market, and trial framework, there was little need to prescriptively define revenue and risk sharing arrangements. In the future, these will need deeper consideration. Transparency will be important so that all value chain participants understand the revenues, costs, and risks they are taking on.

Dynamic connection agreements will be important enablers of V2G. Current static connection agreements limit the amount of value V2G can provide. REVS prototyped a dynamic connection agreement, leveraging work done by ANU in their *evolve* project. There is work underway already (such as *evolve* [1], and work done by SA Power Networks [2]) that can be further leveraged to deliver this capability.

Nearly every issue raised in this report affects fleet managers in some way as they will need to manage new information and implement new processes. They are also interested in more than just the operational details [3]. Fleet managers need to be engaged as part of implementing V2G.

The REVS project has not been without challenges, but overall has successfully built a framework to enable V2G-equipped electric vehicles to deliver grid services. As the project enters its demonstration phase there will be more knowledge sharing opportunities. These will be communicated in future reports.

Section 1 Introduction

Vehicle-to-grid (V2G) is a new technology that is proposed to create additional value from electric vehicles by leveraging their idle periods to provide services to the grid. This value can be shared with vehicle owners, supporting and accelerating both transport electrification and grid decarbonisation.

The REVS project tests V2G. It adds V2G capabilities to 51 vehicles in the ACT government fleet. These vehicles provide contingency frequency control services – a service that is used rarely, has limited impact on the vehicle's battery, but is currently valuable. The project is described further in the inset at the end of this section.

V2G couples energy and transport in ways it hasn't been before. Delivering REVS has required forging new processes, roles, and relationships. This report details the “mechanics” of delivering REVS. It describes the actions and processes that were used to deliver REVS. It also describes how these processes could be refined as V2G is scaled beyond trial.

Nearly every issue raised in this report affects fleet managers in some way as they will need to manage new information and implement new processes. They are also interested in more than just the operational details [3]. Fleet managers need to be engaged as part of implementing V2G.

Introducing the Realising Electric Vehicle-to-grid Services (REVS) trial

This report has been developed as part of the REVS trial. In an Australian first, the Realising Electric Vehicles-to-grid Services (REVS) project demonstrates how commercially available electric vehicles (EVs) and chargers can contribute to energy stability by transferring power back and forth into the grid, as required.

EVs will inject power back into the grid during rare events (to avoid possibility of blackouts) and EV owners will be paid when their vehicles are used for this service.

Employing 51 Nissan LEAF EVs across the ACT as part of the ACT government and ActewAGL fleet, the REVS project seeks to support the reliability and resilience of the electricity grid, unlocking economic benefits making electric vehicles a more viable and appealing transport option for fleet operators.

The REVS consortium covers the whole electricity and transport supply chains including ActewAGL, Evoenergy, Nissan, SG Fleet, JET Charge, ACT Government and the Australian National University. Together the consortium will produce a roadmap with recommendations that will accelerate the deployment of V2G nationally.

The project has been endorsed by the Australian Renewable Energy Agency (ARENA) and has received funding as part of ARENA's Advancing Renewables Program.

REVS is underway and will publish a final report in late 2022.

<https://secs.accenture.com/accenturems/revs/>

1.1 Purpose, approach and structure

The purpose of this report is to consolidate findings and learnings generated delivering REVS. It provides detail of how we have dealt with the technical, social, legal, taxation and business process issues of V2G in fleets and identifies other emerging issues. It is based on a series of workshops and interviews of members of the REVS consortium.

The scope of the report is limited to V2G. There are many issues to consider when transitioning a fleet to EVs, and there are many good resources available to guide those undertaking the transition¹. We have provided links to other pertinent information where relevant, however the report does not deal with issues not directly relevant to V2G.

The report is structured in three sections: The current status of the trial (Section 2), delivering the REVS project (Section 3) and V2G in practice (Section 4).

Section 2 summarises the status of the trial. It describes the trial's performance so far and the way the project goals have evolved through the project.

Section 3 deals with capabilities developed and learning that has occurred in delivering the REVS trial, including enabling V2G response in vehicles spanning the chargers, vehicles, controls and grid integration, followed by management of energy and vehicles in terms of participation in the energy market and integrating into fleet booking systems.

REVS is a trial, which necessarily involves some workarounds. Section 4 examines the gap between the trial and fully-fledged V2G to identify further capabilities. Firstly, this covers technical components, including the intricacies of grid integration and installation, and then the business processes including assessing the business case, financial and contractual concerns, taxation, and end user issues. Some of these aspects are (or will be) covered in separate project reports dealing with social and economic issues and lessons learned.

This report is intended to meet the requirements of two separate deliverables for the REVS project: the capability developments report and the progress of demonstration report. This has occurred due to project delays. Originally the capability development report was intended to be published earlier, however it was delayed because the capabilities the report aimed to analyse had not been completely developed yet. The progress of demonstration report was intended to analyse early findings from the operation of V2G in the energy market. This is yet to occur and will not occur far enough in advance of the final milestone to make publishing an early findings report worthwhile. The intent of this report has been integrated into this report (specifically Section 2) to reduce duplication.

¹ Such as Evenergi's [Charge Together Fleets](#) program

Section 2 Progress of demonstration

The REVS project has been active for around two years so far. In that time many activities have been accomplished and much has been learned. This section summarises the status of its project and how learning has influenced expected outcomes.

2.1 The REVS delivery journey so far

The REVS project is yet to install and activate V2G in participating fleet EVs. This means much of the learning required to assess performance is yet to happen. This section will focus on how the project has evolved throughout its delivery.

There were several key events throughout the trial that impacted on its delivery. They are summarised in Table 1. Many of these learnings are discussed in this report and other project publications (such as our previous lessons learned report [4] and another one to be published in concert with this report).

It is important to take these events in context. With the benefit of hindsight, it is easy to see they may have been foreseen with additional planning. But this is not a given. The learnings from REVS can help future projects not make the same mistakes, but this likely means that these future projects will make other mistakes instead. Trials necessarily forge into the unknown. For REVS, these issues have been managed through the way the consortium has managed issues in a positive and resourceful way. All consortium members have expended considerably more effort than expected because that was what was required to deliver the project, and the project goals have had to flex through its delivery. But largely the project will still deliver on its primary aims: to demonstrate V2G's capability in providing grid services.

Table 1 Trial events

What happened	How it altered the trial
COVID delayed the project by making resourcing and equipment delivery more complex.	COVID was a significant contributor to the project delay due to the challenges. <ul style="list-style-type: none">• COVID and work from home delayed the charger manufacturer building and certifying chargers• Australian lockdowns - especially the extended lockdown in the ACT at the end of 2021 delayed installation and made processes more complex• ACT lockdowns also delayed lab testing of chargers due to the inability to access the lab
Vehicle allocation and delivery amongst ACT government fleets and sites was more complex than anticipated. The overlay of vehicle use case, site, and fleet manager expectations was complex to manage. More detail is in [4].	This negotiation process was a cause of early project delays. This process delayed delivery of the vehicles and site selection for charger installation. Fleets were reluctant to accept vehicles without chargers installed. This caused a dependency between installation and vehicle delivery

What happened	How it altered the trial
The installation process took much longer than expected. Sites had unique installation and process requirements which dramatically increased the effort required to deliver.	Installation delays extended the timeline of the project. There were several overlaying processes that needed to be navigated including: <ul style="list-style-type: none"> • Fleet and parking allocation to identify where chargers need to be installed • Internal ACT government installation, electrical, and IT approvals • Evoenergy connection processes, including a required exemption from CEC compliance for the charger
AS/NZS 4777 certification for the V2G charger was more complex than expected, requiring three testing events with work by the charger manufacturer in between to rectify deficiencies. This issue is described further in a knowledge sharing report published in tandem with this report.	This delayed the delivery of the trial significantly as each certification and rectification step added time delays to the project. As an interim measure non-AS/NZS 4777 compliant chargers were installed in a single-directional (charge only) configuration. This process itself was challenged by installation delays. Interpretation of AS/NZS 4777 has caused the chargers to have a slow raise response for some types of frequency events. This issue is still in discussion by may reduce the FCAS raise response achievable.
Originally it was intended to bid the REVS V2G chargers in the live FCAS market by combining them with other existing resources to form the 1 MW capacity requirement. It later became apparent this additional capacity would not be available, preventing registration in the market.	The chargers will not provide FCAS in the live market. Systems are still being developed as if they were. This means FCAS bid and response data are being collected, but no revenue is being generated.

2.2 Project status




Delivering the REVS project has been far more complex than expected. 2 years in and the V2G capable chargers are yet to be installed. Currently the project is in the install and demonstration phase as shown in Figure 1 (correct as of 05/2022).



Figure 1 Project status

The installation and vehicle delivery status are shown in Table 2. V2G and FCAS is not yet active although the framework in which it will be delivered is developed.

Table 2 Trial installation and delivery status

 Chargers		
Total: 51	Installed (V1G): 50	Installed (V2G): 50
 Sites		
Total: 10	Network connected: 5	
 Vehicles		
Total: 51	Delivered: 48	

2.3 Significant changes to trial assumptions

The REVS project is yet to deliver active FCAS response. This means the performance is yet to be validated in the real world. An analysis of the “as built” performance of REVS will be delivered in the final milestone report. This section summarises key assumptions made in the trial that were reassessed throughout its course so far.

The technical performance of the chargers has been validated in the lab. More detail on the tests themselves and the results can be found in the AS/NZS 4777 lessons learned report and technical report published in concert with this report.

There have been several issues that have impacted the initially expected technical performance of the trial. These are described below.

Assumption: FCAS could be delivered without altering existing vehicle usage processes

Initially it was expected that grid services should be delivered without drivers having to alter their usage patterns.

To deliver FCAS, the charger must keep a charge session always active. This has an inadvertent impact on usage processes. For safety reasons, the vehicle locks the charge connector into the vehicle when a charge session is active. This prevents drivers from simply unplugging the vehicle and driving it as they would using existing processes. Resolving this issue resulted in a minor change to process where the driver needs to tap an RFID card on the charger to terminate a charge session. The impact of this change is minor, but still a departure from expectations

Assumption: Chargers respond quickly to FCAS raise events

V2G chargers are inverters, therefore it was expected that their response to FCAS events would be fast. This turned out not to be the case. The issue was caused by how AS/NZS 4777 manages changes in power setpoint issued from external controllers (such as JET Charge’s external control box). There is more detail on this issue in the AS/NZS 4777 lessons learned report issued at the same time as this report.

This issue is still under discussion and a resolution may yet be found. If it is unable to be resolved the FCAS raise capability of the charger will be constrained.

Assumption: Chargers would connect under existing standard processes

The initial hope was that chargers could comply with all relevant standards and see use in Australia outside of trial settings. The AS/NZS 4777 compliance process was challenging but was ultimately navigated successfully. Most networks require inverters connected to their system to be approved by the Clean Energy Council under their guidelines. Due to how the

CEC classifies inverters, CEC approval would require the EV/charger system to comply additionally with AS/NZS 5139. It is not possible for a vehicle-mounted battery to comply with this standard. This is discussed further in the AS/NZS 4777 lessons learned report published at in concert with this report.

For the trial to proceed, evoenergy provided an exemption to the requirement for CEC approval. This exemption may not be accessible for other use cases.

Section 3 Delivering the REVS project

V2G has many possible use cases, many of which are described in our “A to Z of V2G” report [5]. The REVS trial is about demonstrating one of these use cases: contingency frequency control. This service was chosen because of its technical complexity and commercial simplicity – the logic being that establishing this service will have maximal impact in paving the way for others. This chapter details how REVS delivered this use case. It describes the key building block tools, systems, and processes that were developed, how they interact, and how they were built.

REVS aims to be a “working model” of a future where V2G is a key part of the energy ecosystem. This requires the project to be a microcosm of this future. There are seven project partners, six of these involved in the operational delivery. The REVS ecosystem including these partners is shown in Figure 2, and described further in Table 3.

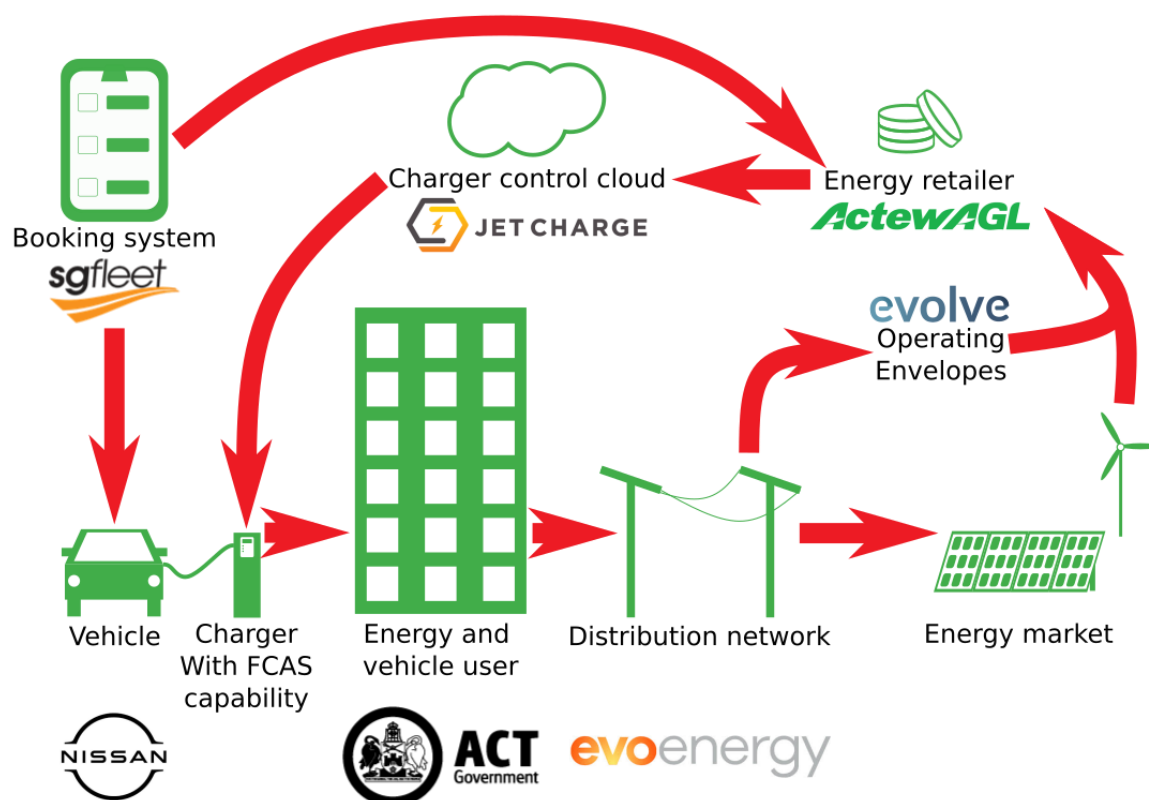


Figure 2 The flow of control signals in the REVS ecosystem

Table 3 REVS partners and roles

Organisation	Role
Nissan	Nissan provides vehicles, warranty support, and worldwide V2G know how. While not involved day-to-day in the project, the Nissan LEAF's explicit warranty support for V2G is critical to enable the project and V2G in general.

Organisation	Role
ACT Government	ACT government are the fleet owner and energy customer. They own the vehicles and receive a share of the revenue from the vehicles.
Evoenergy	EVO energy are the distribution network. They provide the technical connection between the chargers and the energy market. They are responsible for managing their network capacity by issuing operating envelopes to the chargers.
ActewAGL	ActewAGL are the energy retailer. They interface the chargers to the energy market, collect and distribute the revenue, and implement operating envelopes.
JET Charge	JET Charge are responsible for ensuring the chargers comply with local standards and respond to frequency control events. JET Charge built the charger control cloud and control box that enables FCAS response.
SG Fleet	SGFleet operate vehicle fleets. They manage vehicles and their booking day-to-day. The booking system integrates with the charger control scheme to ensure that vehicles have sufficient charge while still providing frequency control services.
The Australian National University	The ANU are the knowledge sharing partner. They collect and disseminate learnings from the project with the wider industry. They are also responsible for mapping the future path to wider V2G uptake. ANU also provides the dynamic operating envelope platform, evolve, for managing network constraints and connection agreements.

There were many components required to implement REVS. These span physical, technical, and commercial domains. This chapter describes these components and the actions we took to implement them.

3.1 Enabling V2G response

Maintaining power system frequency requires actively balancing generation and demand continuously. Frequency Control Ancillary Services (FCAS) is how these balancing services are delivered. Contingency FCAS corrects generation or demand imbalance following major contingency events. Contingency FCAS is controlled locally, autonomously triggered by frequency events. Regulation FCAS balances the power system in normal conditions. This project delivers contingency FCAS but not regulation FCAS.

FCAS services require vehicles to respond to local frequency. They must autonomously discharge when frequency drops and charge when frequency increases. The V2G services are provided by a bidirectional EV charger which, meaning it must be AS4777 compliant. Many chargers, including the one used in this trial, does not have built-in capability to respond to frequency events. The EV charger needs an additional controller that collects data from the chargers and enable its frequency response capabilities to autonomously support FCAS. This landscape is shown in Figure 2.

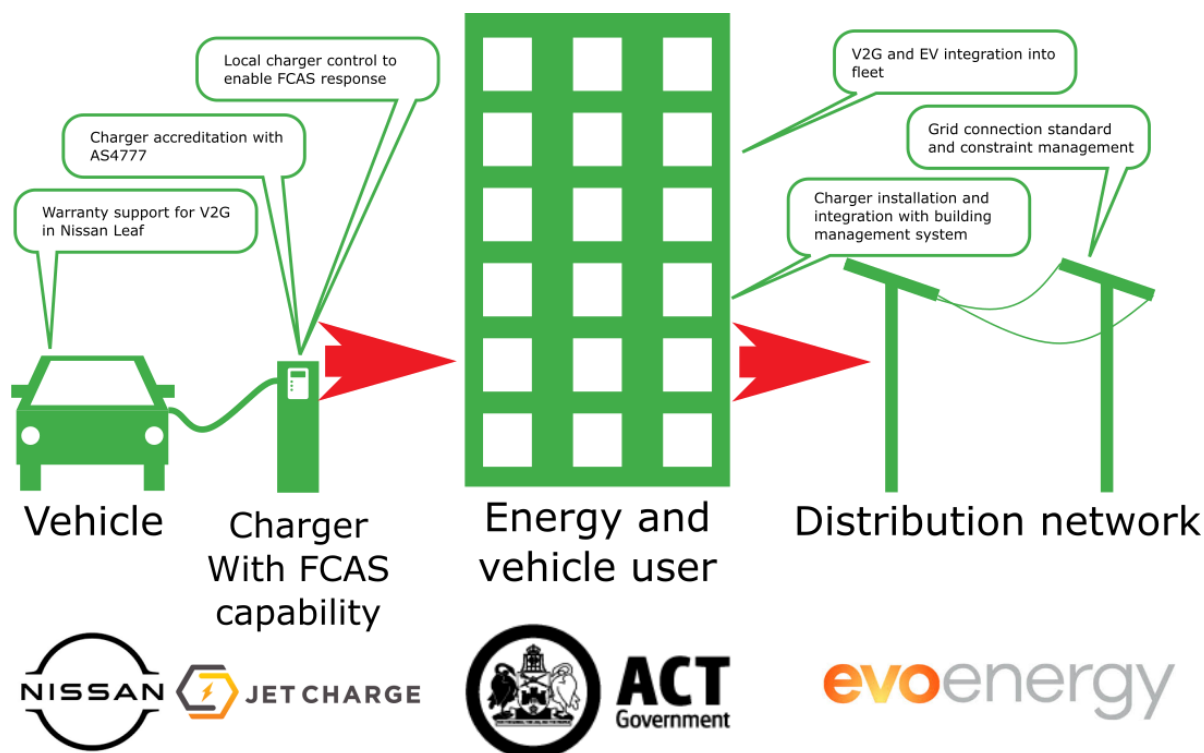


Figure 3 Enabling physical response: Components

3.1.1 Warranty support for V2G

For fleets to be comfortable providing FCAS from their vehicles, they require warranty support from vehicle manufacturers. The warranty terms help fleets better understand the compatible devices, compatible use cases and approved programs, thus enables them to make informed decisions before participating in V2G services.

Specifics

Inputs	General instructions set by Nissan and simulation files of driving behaviour
Outputs	Warranty documentation and agreements that outline compatible devices, compatible use cases and approved programs
Partners involved	Nissan, ActewAGL, JET Charge

What the process involved

Nissan's warranty stipulates that only Nissan approved chargers can be used. For V2G projects where charging and discharging patterns are managed by a 3rd party, and where Nissan are actively involved or promoting to their customers, Nissan also request a use case simulation to assess the overall impact on the vehicle to prevent any negative vehicle or customer outcomes. This is generally for mutual benefit as the party responsible for program management typically wants to ensure they are not impacting or damaging a participant's vehicle.

This approval process is not strictly a warranty requirement. If an approved device is used to implement V2G and usage doesn't exceed one cycle a day end users will be covered by their vehicle warranty. But Nissan may not endorse the service provider and steer their customers away from the program.

In order to support the development of a project, Nissan suggest the follow general guidelines as a starting point;

- 11 kW power rate limit for charging and discharging
- A maximum of 1 cycle/day inclusive of driving

For the REVS project, the specific approvals process included:

- Nissan required expected vehicle and grid services usage patterns so they could simulate battery wear.
- The agreements and contracts between the respective partners (i.e. customers, energy retailers and Nissan) explicitly encode the provided charging and discharging profile.

Approval of the charger by all appropriate standards bodies (such as the CHAdeMO association and Australian standards) and Nissan.

Issues and Learnings

- There may be specific approval requirements for both the charger and its expected usage profiles. Projects should ensure that the vehicle manufacturer is involved early enough in the process to allow for necessary studies to be completed.
- Co-optimizing several services from the same vehicle may be challenging when considering general guideline parameters, particularly when other usage for driving or grid services is unknown.

Recommendations

- In the short term, unidirectional and V2H use cases are easier to implement with a simpler structure.
- The warranty process should be better documented and general guidelines or advice should be publicly available through webpages, user's manual and warranty booklet.
- In the longer term, once Nissan has built sufficient experience, warranties should be updated based on the actual impact of V2G on vehicle batteries.

3.1.2 Charger accreditation against Australian standards

For any inverter based embedded distributed generator to connect to an Australian grid, it must comply with the current AS/NZS 4777 standard. Prior to REVS there were no V2G capable chargers with AS/NZS 4777 compliance, therefore the decision was made to certify the Wallbox Quasar charger. This issue will also be discussed in a REVS Lessons Learned report which will be published in concert with this report.

Specifics

Inputs	Chargers and Australian standard requirements
Outputs	Accredited chargers
Partners involved	JET Charge

What the process involved

This process involved testing the charger in a certification lab against the AS/NZS 4777 requirements. These tests are specific for Australia and are different to other international grid codes.

Issues and Learnings

This process was significantly more difficult than expected. The AS/NZS 4777 standard's requirements are much more onerous for a V2G charger to comply with than equivalent EU and UK standards for which the charger was originally designed.

The Australian standard is focused on Battery/Inverter/Solar systems and does not consider operational differences with an EV. The standard calls for an earthed load whereas an EV is a portable battery supply and is not directly tied to earth. This creates a ground loop in the connected circuit, causing noise to exceed the amount specified in the standard.

Resolving this issue required electrical and mechanical changes to the Quasar charger. These changes and retesting caused significant delays in the certification of the charger.

Recommendations

There are several different mitigations that could be considered for this risk including:

- Select hardware that already has all the required certifications
- Build certification times into project timelines
- If none exist, avoid AS/NZS 4777 certification and aim for specific trial approval
- Spread the risk by using multiple chargers
- Involve charger manufacturers deeper and earlier in the project
- Involve standards bodies deeper and earlier in the project

3.1.3 Local charger control

Current generation chargers cannot natively respond to frequency in a way that complies with FCAS requirements. The REVS project involved developing and implementing a specialised control box that collects data from the chargers and enables frequency response. This box also manages operating envelopes and orchestrates chargers to maintain them. It is installed with the chargers and connects to the JET Charge cloud.

This control box is also required to manage operating envelopes issued from the JET Charge cloud.

Specifics

Inputs	Charger specifications, FCAS specification
Outputs	Charger control
Partners involved	JET Charge, ActewAGL, ANU

What the process involved

This process involved developing a local control box connected directly to the charger that enables it to respond to frequency disturbances. This response is also measured by the box and its associated power meter to validate the level of FCAS services provided. The control box and its connections are shown in Figure 4

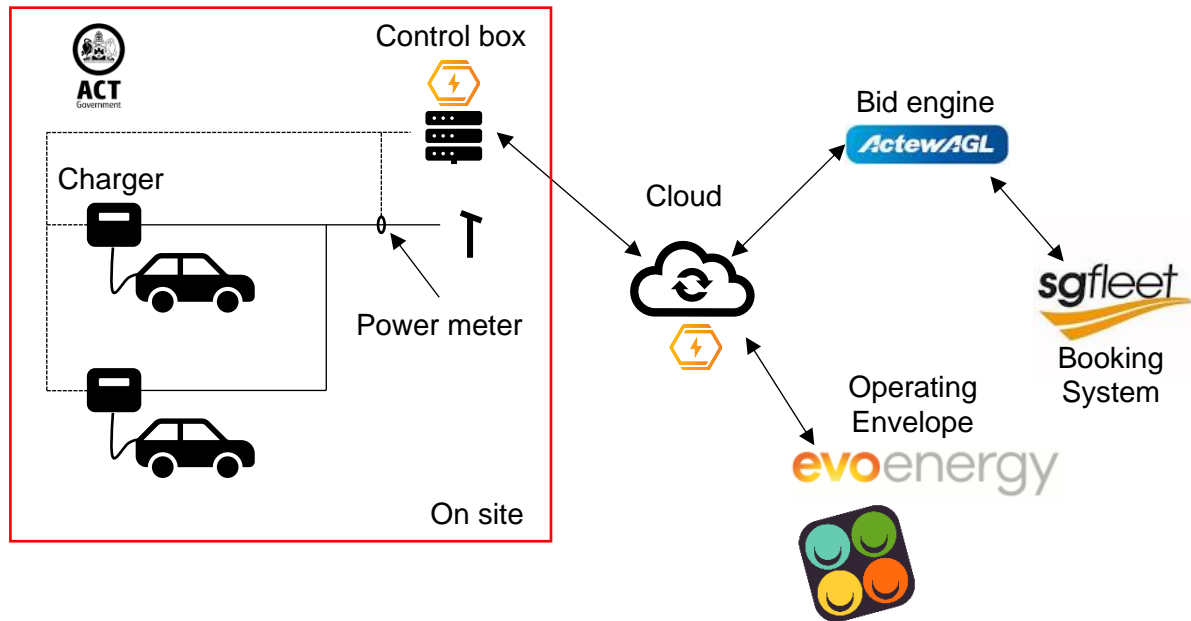


Figure 4 Charger control framework

Issues and Learnings

- Satisfying the FCAS requirement for recording frequency responses at 50 ms is challenging. There was only one commercially available 3-phase power meter for metering at the main switch board that could respond that fast. Most meters only cater for 1-second interval data
- In earlier tests performed in JET Charge facilities, the response time of the charger was 13 seconds for some testing scenarios. This was because of the CHAdeMO communication and handshakes between the charger and the car. This was improved by maintaining an active charge session for the whole time the vehicle is plugged in but reducing the power to zero when charging is not required. This enabled the charger to respond to FCAS events within 4 seconds but caused other vehicle usability issues (see 3.1.6).
- A stable network connection between all parts (charger – control box and control box – cloud) is critical to stability of the system. Stability can only be determined by running the charger for a long time.

Recommendations

The local control box added flexibility to the charger control stack. It allowed issues to be resolved quickly by JET Charge. This demonstrates the benefit of in-project development capabilities.

3.1.4 Charger installation and integration

In the REVS trial, one V2G charger was installed per participating vehicle. This requires work to install and integrate these chargers

Specifics

Inputs	Chargers, install locations
Outputs	Installed chargers integrated with platforms

Partners involved	ACT government, JET Charge
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What the process involved

This process involved installing 51 V2G-capable EV chargers across several sites in the ACT. Most of these sites were in ACT government facilities.

Issues and Learnings

Charger installation took far longer and was more complex than expected. There were several factors that led to this:

- ICT integration required co-ordination and installation of additional hardware (such as cabling). Similarly, the network needed to be configured to allow the control box to access the chargers and the JET Charge cloud. Similar effort would be required for single-direction chargers where cloud control is required.
- Cabling was expensive and complex to install. The car parks where chargers were to be installed are not built for EV charging. This effort is similar for similarly sized single and bidirectional chargers.
- Canberra Health Services (CHS) sites required specific contractor approvals before installation could commence.
- Installation approval across the multiple sites was complex to obtain with multiple stakeholders and processes.
- This additional complexity was encountered during the project due to insufficient technical detail and scoping at the beginning of the project. This has contributed to delays and increased in the overall costs of carrying out the installation and integration of the V2G chargers. The detailed commentaries on this issue in the REVS lessons learned report [4] on the ARENA knowledge base.

Recommendations

Should this type of project be undertaken again, we recommend that:

- The full technical detail and specific integration requirements be determined and scoped from the outset.
- Consultation with key stakeholders such as ICT, technical teams, building owners, fleet managers etc be undertaken from the very outset so that feedback can be integrated into the overall project plan.
- Set a realistic timeline and budget based upon this advice.

3.1.5 Grid connection and constraint management

As an embedded generator, V2G chargers must undergo a connection process. This process defines the technical envelope the chargers must abide by. This outcome of this process is a connection agreement. The connection agreement defines how much energy V2G chargers can exchange with the grid and thus the maximum benefit they can attain from grid services. A restrictive connection agreement will reduce the amount of capacity the chargers can provide and the associated revenue.

Specifics

Inputs	Connection configuration, Charger specifications, distribution network model
Outputs	Connection agreement, operating envelope

Partners involved	evoenergy, ACT government, JET Charge, ANU
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What the process involved

This process involved evoenergy assessing the proposed connection against their connection requirements. Connecting the charger required three changes to evoenergy's existing rules:

- The total capacity of the chargers exceeded the maximum static limit of 5kW/phase
- The current connection standard was not designed to allow V2G
- V2G chargers cannot currently meet the requirements to enter the Clen Energy Council (CEC)'s approved list of inverters (detailed in a "lessons learned" report published in concert with this report)

This was managed through exemptions to existing rules and new rules applied under trial conditions. In particular, the 5kW static limit was partially relaxed using dynamic operating envelopes. This capability leveraged the technology developed by the ANU as part of the [evolve DER](#) project. They allowed the chargers to generate more than 5kW most of the time when the grid was not constrained. An example of the operating envelope for one site is shown in Figure 5. The envelopes used in this project were calculated offline rather than online like they are in the evolve DER project. Their implementation serves as a proof of concept of the technology.

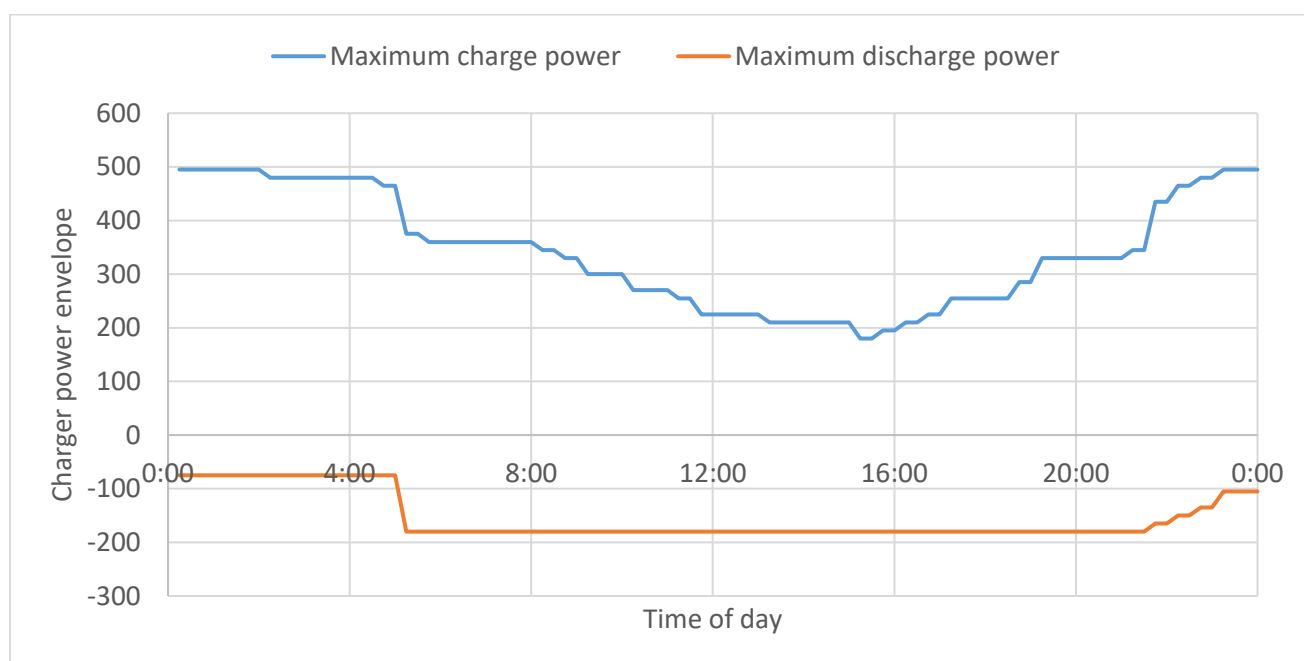


Figure 5 Example operating envelope used in REVS

Issues and Learnings

Operating envelopes directly influence the potential of a V2G system. They define how fast and at what times vehicles can charge and discharge. In the REVS trial, operating envelopes are an input to the bid engine and charger control cloud.

The REVS project was the first time that operating envelopes had been applied to electric vehicles. The system built on existing technology developed by ANU and was extended to also define a demand side envelope.

Using the extant evolve operating envelope platform reduced risk significantly. Partners needed to build their systems for transport and implementation of the signal.

Communication between partners was important. Particularly for edge cases such as when envelopes change during an event. It is important to clearly define behaviour in all cases.

Recommendations

Particularly as most EV chargers exceed 5kW alone, operational tools and systems such as evolve will be important to enable V2G. Organizations should consider implementing dynamic capacity management systems as EV uptake increases. These can also be used to manage charge profiles and avoid associated network reinforcement.

3.1.6 Integration of V2G and EVs into fleets

The electric vehicles deployed in this trial replaced traditional internal combustion engine vehicles. The vehicle's fuel type (electricity) and V2G capability were both new for fleet managers. ACT government fleet managers are perhaps some of Australia's most experienced in integrating EVs, but V2G was new to them and came with significant uncertainty.

Specifics

Inputs	Current fleet vehicles, specifications of EVs and chargers, potential charger locations
Outputs	Locations and fleets of V2G electric vehicles
Partners involved	ACT government, SGFleet, Nissan, JET Charge

What the process involved

The original intent of the trial was that vehicle users did not need to be aware of vehicles' V2G capability or the services it was providing. They would use existing electric vehicle processes and procedures to use the vehicle. Early on the project took steps to ensure this. For example, the FCAS service was chosen because it could be delivered without requiring the vehicles regularly discharge their batteries. The project was scoped and specified on this basis.

Several technical issues challenged the simple driver interface envisaged in the trial. There is a diverse array of vehicles included in the trial. The diversity of use cases leads to many different vehicle usage patterns and driver expectations. For example, some vehicles are pool vehicles and booked for a variety of uses by a variety of people while others have more specific use cases and have few users. Pool vehicles are generally booked through a platform ("booking intelligence") provided by SGFleet. Single use vehicles generally aren't booked and have their usage managed by the corresponding people/teams. Some may be "on call" and used at any time.

This impacts the way vehicles can be used for FCAS (or transport). In line with 3.1.3, the JET Charge controller always keeps a charge session active to enable fast response to FCAS events. This however locks the charge connector into the car, preventing the user from driving it. Two strategies were used to resolve this issue:

- Vehicles which are booked before use are automatically unlocked using a connection between JET Charge and SGFleet's booking system
- Vehicles which are not booked will terminate a charge session using an RFID card tapped on the charger

This minor change to process was judged to be acceptable to drivers however still represents a departure from the original intent of the trial to not change process.

Issues and Learnings

The Nissan LEAF vehicle is designed to lock the charging connector to the vehicle while it is charging to prevent inadvertent disconnection. For DC chargers (such as those used during the trial) this charge session must be terminated by the charger. The FCAS service requires fast response. To minimise response time, the system is designed to always hold a charge session open and hence the connector is usually locked. The original intent was that SGFleet's booking intelligence platform would be used to unlock the connector on the vehicle just before it was to be used.

During the project it became apparent that this was not suitable for many of the trial vehicles. These vehicles were used for special purposes (e.g. on-call or assigned directly to small teams) and did not use SGFleet's booking system. The intent of the project that it would be transparent to the end user. Adding the vehicles to the booking system would have required vehicle users change their normal usage patterns which was undesirable. The ultimate solution for these vehicles involved Wallbox updating the charger to allow use of a RFID swipe card to unlock the connector during a session.

Recommendations

It is critical to understand the implications of the solution. The challenge in this project was a combination of people, process, and technology. The technology introduced limitations that impacted on process and people. Involving the vehicle's users and fleet managers earlier in the prototyping stage may have revealed these issues earlier.

3.2 Energy and vehicle management

The physical installation and control of the vehicles must be backed by software controls and contracts. These manage data, revenue, and control flow between the vehicles, their chargers, the market, and the project participants. This landscape is shown in Figure 6.

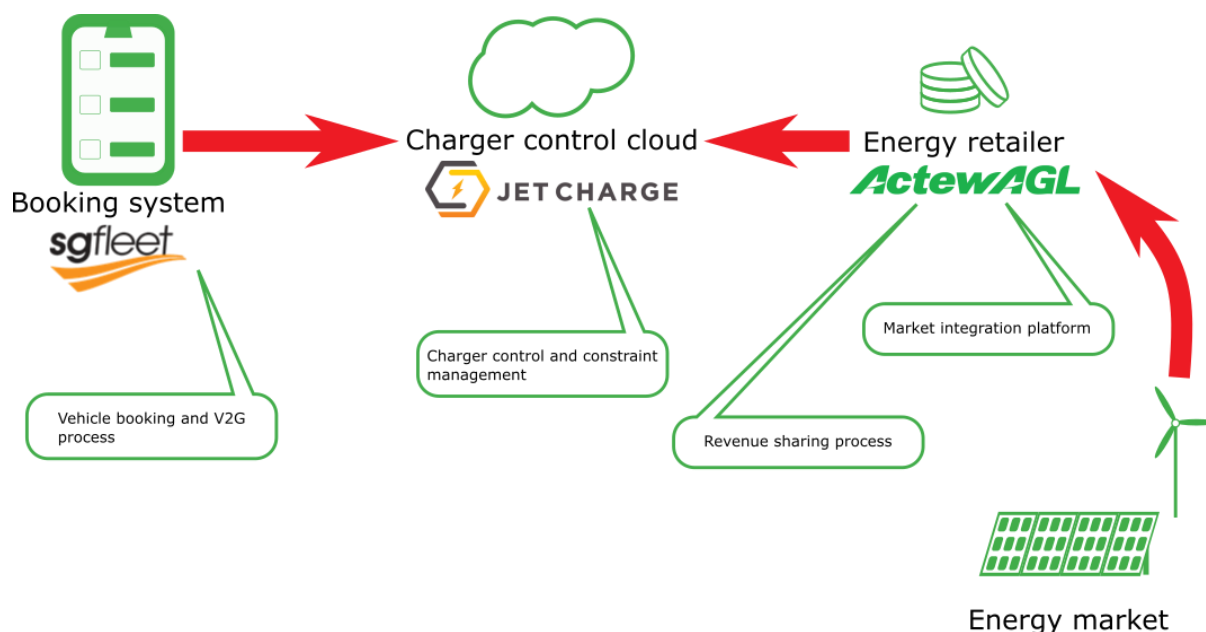


Figure 6 Energy and vehicle management: Components

3.2.1 Market integration and constraint management platform

In the REVS trial, ActewAGL is responsible for bidding EV chargers into the market. There were three key functions of this system:

- Generate bids based on vehicle availability
- Manage distribution network constraint signals from evoenergy
- Issue commands to charger management cloud to enact response

Specifics

Inputs	The ActewAGL bid system ingests data from the charger control cloud (plug in status), booking system (future availability), evonergy constraint management system (operating envelopes), and the energy market (market prices). Of these only booking system, charger control cloud, and energy market data are real time.
Outputs	Bids to AEMO
Partners involved	ActewAGL, evonergy, JET Charge, SGfleet

What the process involved

The market operates on a 24 hour ahead time horizon. This means that ActewAGL must have visibility of the available resource from the participating vehicles in the trial, both current and future. The system to generate these bids required connections to most of the other project participants. The configuration of this system is shown in Figure 7.

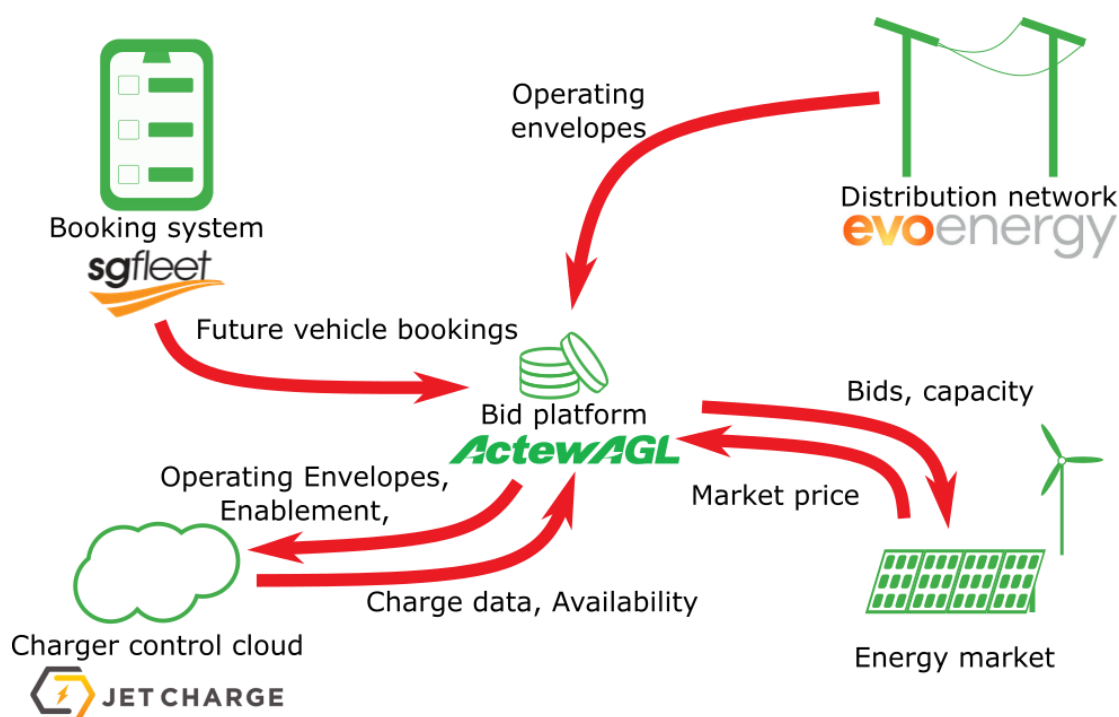


Figure 7 Bid platform data flows

For the REVS trial the focus was on simplicity. The bid platform had several simplifying assumptions:

- Vehicles are always enabled for FCAS (regardless of price) to their maximum capability.
- Vehicles were price takers, so market price was not used in bid algorithm.

As the total capacity of the participating vehicles is less than 1 MW, vehicles were not actually bid into the market.

Issues and Learnings

The bid platform is central to the delivery of REVS. It acts as a central data warehouse: collecting, storing, and sharing the data needed for the delivery of the trial.

The bid engine changed over the course of the trial. These changes were:

- Managing vehicles which aren't booked through SGFleet's booking intelligence software
- Implementing dynamic operating envelopes.

At the beginning of the trial, we expected that vehicles would be booked through SGFleet's "booking intelligence" platform. This platform enables users to book shared vehicles as needed. During the trial it became apparent that most vehicles in the ACT government fleet aren't booked. Instead, they are assigned to teams who manage use of the vehicles through other processes. This adds complexity to the bid engine. It needs a high accuracy picture of vehicle availability to ensure that the capacity bid into the market can be delivered.

The bid engine decision process is shown in Figure 8. Vehicles that are plugged in in the preceding dispatch interval can be bid with either high or low confidence.

- If the vehicle is not expected to be used in the immediate future, it is bid in less conservatively.
- If the vehicle is likely to be used in the immediate future, it is bid in conservatively.

The conservativeness of the bids will be learned through experience in the trial.

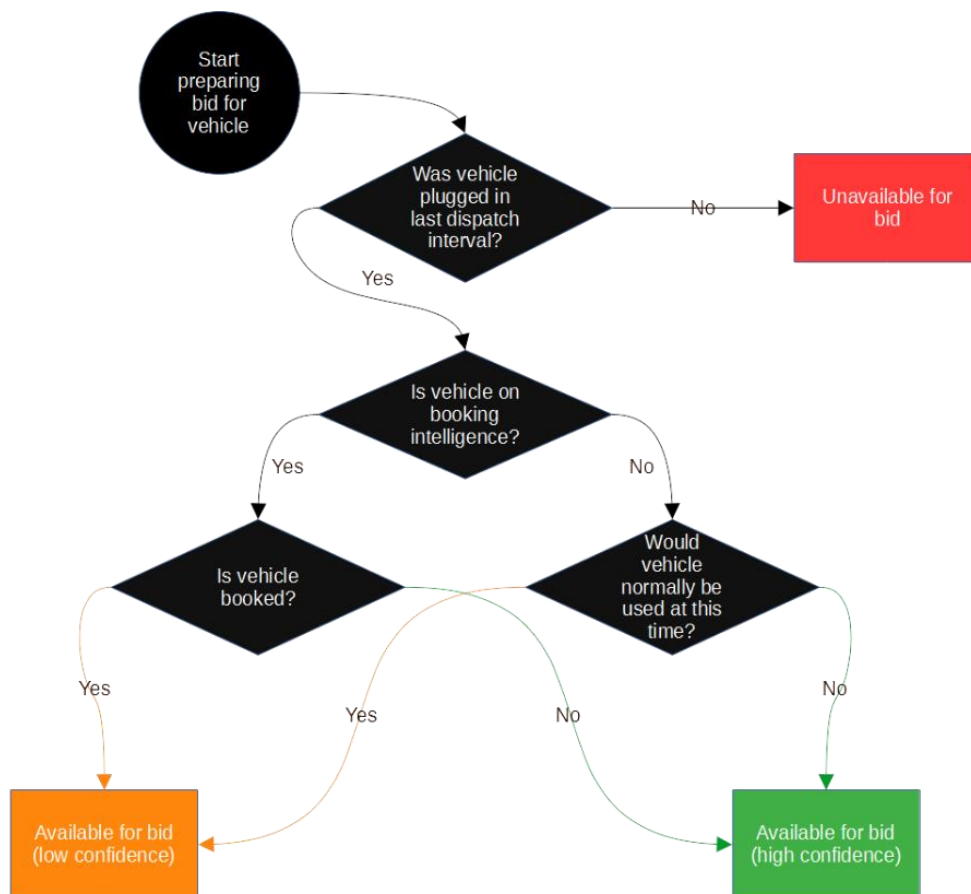


Figure 8 REVS bid process

Originally dynamic operating envelopes (see 3.1.5) were expected to be static and provided once only at the start of the trial.

To increase demonstration value of the trial, the operating envelope framework developed as part of the *evolve* project was implemented. This framework can generate dynamic, real time operating envelopes, although in this case is configured to provide static envelopes instead.

The deeper operating envelope integration was undertaken as a future-proofing measure. Currently the system implemented in the trial does not calculate envelopes in real time but simulates data flows as if it did.

Recommendations

A more detailed investigation of the booking platform needs, input data quality, and development/operation effort including platform developers would lead to a more accurate allowance in the project budget.

3.2.2 Revenue sharing process

REVS would have generated revenue from providing contingency frequency control services as part of its operation if it were to bid into the market. For 51 vehicles the total amount of revenue would have been small. However, in the future grid services revenue will be the primary driver of initiatives such as REVS.

Specifics

Inputs	Market participation revenue
Outputs	Revenue split between participants
Partners involved	ActewAGL, JET Charge, ACT government

What the process involved

Originally, the vehicles in REVS were intended to bid frequency control services into the National Energy Market (NEM) as part of a larger Virtual Power Plant (VPP).

During the trial it became apparent that this was not possible. This removed the need to share revenue, as there was no revenue to share.

As originally scoped, the REVS project intended to use a simple approach of splitting revenue evenly between ActewAGL, ACT government, and JET Charge. Other project partners would not have received revenue from grid services.

3.2.3 Charger control cloud

The chargers installed as part of the REVS trial connect to the JET Charge cloud. This cloud is responsible for managing charge/discharge sessions and transmitting data and control between JET Charge and other project participants.

Specifics

Inputs	Charger data (from chargers), booking data (from SGFleet), Operating envelopes (from evoenergy)
Outputs	Charger controls (to the chargers via the onsite control system), Charge session data (to ActewAGL)
Partners involved	JET Charge, SG Fleet, ACT government, evoenergy, ANU

What the process involved

The JET Charge control cloud's critical function was managing charge sessions. This involves selecting the optimal charge patterns to reduce cost and manage operating envelopes. JET Charge also provides charge session data, charger availability, and status to ActewAGL for use in their bid platform (see 3.2.1).

For this trial the system was relatively simple. It did not optimise charging based on energy costs and vehicles were always enabled for FCAS. This simplified implementation and reduced risk.

The charger management cloud was responsible for ensuring that the chargers honoured the operating envelopes. These apply both in normal system conditions and during FCAS events.

As the charger control cloud was responsible for unlocking the vehicle connectors when vehicles are booked it was important that it had a high reliability. System outages would have rendered it impossible to unplug vehicles without power cycling the charger.

The charger management system was implemented on cloud infrastructure and communicated to the local control box (described in 3.1.3) over the internet.

Issues and Learnings

The charger management system needed to integrate a diverse array of data. Significant work was required to integrate these diverse data sources.

The vehicle integration issues described in 3.1.6 impacted the control system. Although the ultimate solution was implemented locally in the charger several initial proposed solutions would have required the charger control cloud to implement the charger release functionality.

Recommendations

It was important that the charger control cloud was developed by project partners. This enabled it to be flexible and change to meet the requirements of the project. The nature of trials is that not all needs can be known at the start of the project. Flexibility is important to meet unexpected needs that arise during the project.

3.2.4 Booking system

Booking system data is required by V2G systems for two purposes:

- To better forecast when vehicles are available for participation in the FCAS market.
- To enable charge sessions to be halted prior to vehicles being needed.

Bookings are dynamic and can be made right up to the moment the vehicle is needed therefore the data retrieval process needs to be real-time.

Specifics

Inputs	Bookings
Outputs	Time series vehicle availability data
Partners involved	SG Fleet, ACT government, JET Charge, ActewAGL

What the process involved

The booking system existed prior to the trial and is used day-to-day to manage shared vehicles. The REVS project did not alter the booking system, it merely provided a link between it and the energy market and charge management systems. The data it provides is critical to ensure that bids are accurate (see 3.2.1) and chargers are unlocked (for booked vehicles) at the right time (see 3.1.6).

Importantly, because REVS is only providing FCAS services and charging is not being orchestrated, the quality of forward booking data only impacts the amount of FCAS that can be bid into the market and the automatic charger unlocking. This dramatically reduced the complexity and criticality of the system.

Issues and Learnings

The biggest learnings from the booking system were the cases where it is not used rather than when it was used. Only shared pool cars are booked using the booking platform. Other cars are not booked and are managed by their assigned teams or people. 27 out of 51 participating cars use the booking platform. This reduced the quality of data that the booking platform can provide. As described in 3.1.6 it is important to get a good understanding of the target fleet and how they use their vehicles.

Recommendations

As described in 3.1.6, a better understanding of vehicle usage would have made it easier to implement the trial.

Section 4 Scaling V2G

As a trial, delivery of REVS has necessarily involved a level of improvisation, working within the constraints of existing infrastructures. This chapter extends consideration of the technical and business capabilities required of a future, fully-fledged, V2G offering that were not included in REVS.

For the purposes of this report, a fully-fledged V2G offering is one that:

- Provides more types of grid services (particularly energy-based ones such as market price response and distribution network management)
- Is compatible with more vehicles, chargers, and use cases
- Generates more revenue for participants

This chapter will present issues relating to each of these components of V2G, and where possible provide guidance on solutions. Future reports from REVS will provide additional detail on some of these aspects.

4.1 Technical components

4.1.1 Operating envelopes / grid connection

Any new connection to the electricity network, including new export behind an existing connection, is subject to network limits. Currently, in Australia, this limit ranges between 0 and 10 kW per phase. A fleet of EVs (or even a single EV in some cases) simultaneously exporting power at a single connection can easily exceed that limit, especially if there is little load behind the meter. V2G in fleets can therefore be greatly constrained by fixed export limits. A solution to this is the adoption of operating envelopes.

Operating envelopes allow distribution networks to communicate their time-varying network capacity without being prescriptive about how the customer uses it. They are bidirectional in that they indicate both generation and demand limits, which is particularly important for V2G that can both charge and discharge. Operating envelopes can be static or dynamic. They are described in Figure 9

Less complexity, More capacity unlocked	Static limits: Same limit all the time, every day
	Static envelope: Limit varies through fixed schedule (e.g. daily)
More complexity, Less capacity unlocked	Dynamic Envelope: Limit varies in real time depending on prevailing network conditions

Figure 9 Types of export limits

REVS implemented a static envelope. However, they were communicated using the same framework as the dynamic envelopes generated and used in the *evolve* [1] project. This approach allowed REVS to prove that dynamic envelopes could work without the additional modelling effort involved in fully dynamic envelopes. An example static operating envelope used in REVS is shown in 3.1.5.

As the amount of V2G chargers, batteries, and PV increases it is likely dynamic envelopes will fully supplant static envelopes. The requirements to implement these envelopes are diverse though.

Solutions like those developed by the *evo/ve* [1] project and GridQube [6] enable dynamic operating envelopes to be generated and shared in real-time. This base level capability needs to be extended with commercial and legal models that enshrine the need to abide by and maximise the value of operating envelopes. REVS has built a first pass attempt at this which can be extended as this technology transitions put of trial into business-as-usual environments.

4.1.2 Orchestration platform

The orchestration of V2G involves software to provide an interface between the market operator, the chargers, and the intermediary. In a fully-developed scenario, the software would provide a range of functions including:

- Giving the end user a level of control over how their EV battery is used. For example, specifying the battery's minimum state of charge
- Aggregation of multiple batteries in order to meet the minimum capacity for participating in markets (e.g. for FCAS this is 1 MW)
- Perform optimisation to maximise revenue and manage operating envelopes
- Manage risks such as availability and pricing events
- Forecast future availability
- Allow bidding into the market

These are all functions that apply to any virtual power plant, except for optimising and accounting for vehicle availability. Of these requirements REVS has only implemented aggregation and bidding capability. The FCAS service was chosen because it has minimal impact on the battery, meaning that charge optimisation was not required. Similarly, only the availability of the vehicle impacts on its ability to provide grid services. These roles are split amongst ActewAGL and JET Charge. ActewAGL manages the market interaction while JET Charge manages charging and availability. The link between ActewAGL and JET Charge is only single directional as implemented because the energy market does not impact the way vehicles are charged and discharged in REVS.

As V2G exits its trial phase and becomes a mainstream service, more complex algorithms will be required. These algorithms are also likely to need more involvement from vehicle users as they need to state their charging preferences and trust algorithms to manage them.

4.1.3 Charging and integration into building services

For REVS, chargers were not deeply integrated into building management systems. There was no orchestration of charge power beyond implementation of operating envelopes (see 3.1.3). Although metering and control hardware is capable of this function, it was not implemented to reduce overall project complexity.

As V2G (or even single-directional charging) scales beyond trials, this strategy will no longer be adequate. The combined demand of charging will exceed the physical capacity of the building's network. Chargers will need to integrate with building services more deeply. This will require chargers to be active participants in demand response within the building.

4.2 Business components

4.2.1 Business case and flexibility

Business processes will need to account for the costs and benefits of V2G, both when estimating the feasibility of participating in V2G and later when it is in operation. The primary use of fleet vehicles, like most vehicles, is obviously transport. V2G could limit the availability of the participating vehicles when they are used for grid services. At a minimum this will be through a lower average battery state of charge but may extend to physical availability during high-price events. Ideally, V2G occurs at times such that there is minimal disruption, but reducing disruption requires the vehicle to be operated for grid services more conservatively, reducing revenue.

This flexibility/revenue trade off, shown in Figure 10 will be key in the fleet V2G uptake landscape. REVS opted for reduced risk through the selection of the services it implemented (contingency frequency control) and how it manages vehicle charging (convenience charging). From a vehicle utility point of view, the only change is that vehicles are only charged to 80% rather than 100% to reserve capacity to participate in FCAS lower events. Future V2G initiatives will need to explicitly define their own risk/flexibility profile. It will be critical that this is determined upfront and agreed between the vehicle owners and the organisation aggregating the vehicles.

The value of V2G is defined by several factors including:

- The markets that V2G can participate in and provide services for.
- The value of services provided to those markets.
- The regularity of response (e.g. continuous or just after events?).
- The power capacity of V2G, as defined by the physical circuitry connecting the vehicle with the grid (including the operating envelope), the energy available in the vehicle(s) and the maximum power capacity of the vehicle.
- How often the vehicle is plugged in.
- The cost of purchasing energy to charge the batteries.
- The cost of battery wear, over and above that incurred from driving.

A future output of the REVS project will be an estimate of the revenues that can be earned with V2G.

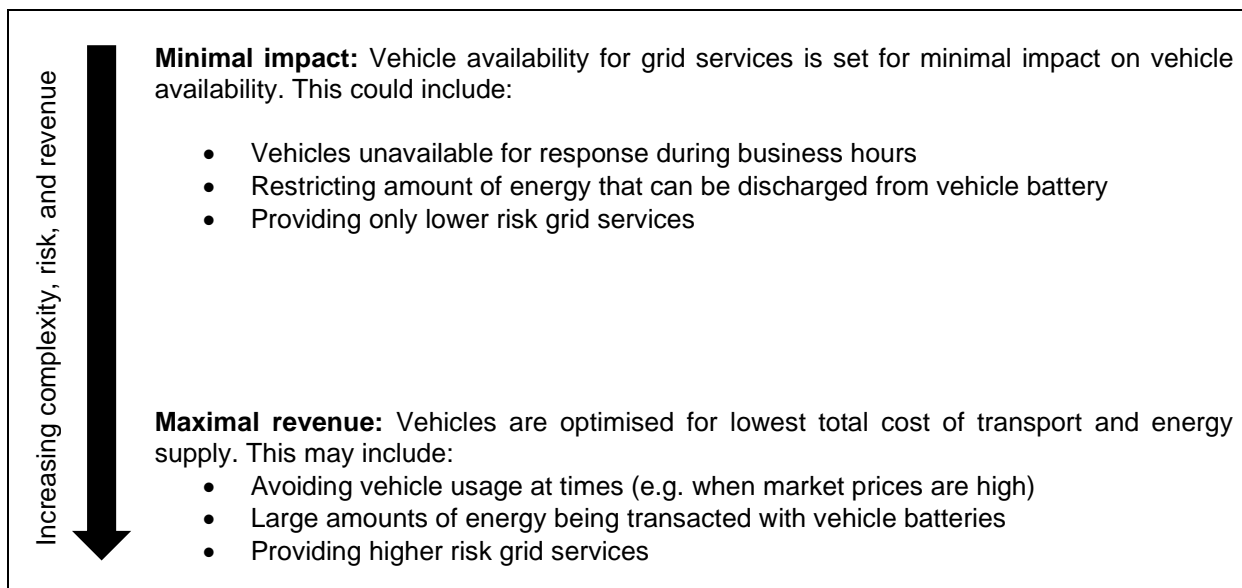


Figure 10 Impact of flexibility on value

REVS did not generate revenue. Charger subsidies and the value of participating in the trial was sufficient to encourage participation. Beyond trial though, the revenue generated by V2G must be sufficient and shared appropriately to encourage participation.

The original framework for REVS shared revenue evenly between the market participant (ActewAGL), orchestration platform provider (JET Charge) and vehicle owner (ACT Government). For the small amount of revenue originally expected to be generated a simple approach was warranted. Beyond trial though, this will require further thought. In other similar technologies (such as battery-based VPPs) there is little transparency of revenue sharing models. This may need to be considered by regulators as these technologies scale.

4.2.2 Vehicle leasing, contracting and warranties

There are several vehicle ownership models currently used in Australian fleets. The two most common are outright ownership (or finance) and leasing. While in all cases, the impact of V2G comes down to cost, different ownership models have different impacts on cost.

Use of V2G is, from a fleet point of view, a risk. It may cause battery degradation, increase maintenance, or reduce resale value of a vehicle. For example, using V2G on a vehicle that technically supports it but doesn't from a warranty perspective (such as a Mitsubishi Outlander) may cause battery degradation that is unsupported by the manufacturer. This means that the cost of any damage caused by V2G sits with the vehicle owner. If this vehicle is leased, this risk will be seen as higher lease costs (presuming the lessor allows this use of the vehicle). Even where the manufacturer supports V2G within their warranty, use of V2G may reduce resale value which increases lease costs. The centrality of resale value in leasing costs means that it is worthwhile considering these possibilities in the design of V2G schemes. Resale value increases if the seller can demonstrate stewardship over the condition of the battery. For example, this may be records of V2G events or battery condition.

Even given good records, the impact of V2G on resale value is currently unclear. It will be important for early adopters of V2G to share learnings to ease this knowledge deficit.

Currently only Nissan explicitly supports V2G in their warranty. As described in 3.1.1, even this support is not unconditional, and requires the use of approved devices. As V2G enters

mainstream it will be important to ensure warranty processes are clear. It is unlikely that many fleets would uptake V2G on vehicles where there is no warranty support.

4.2.3 Charging and accounting

Even without V2G, transitioning a fleet to EVs changes the processes of accessing and paying for fuelling. Whereas previously fleets would refuel at service stations using fuel cards, EV fleets might use charging at home, bases or depots, and public charging. These all involve different types of chargers (and sometimes just general purpose outlets) and paying for charging varies across these locations and can involve different charging networks. Charging can make vehicle analytics difficult as data from different networks needs to be integrated to build a complete picture of running costs. Payment data may be available, but energy data (as analogue to litres of fuel) might not be, particularly when charging is paid for through time, parking fees, or another method. Furthermore, grey fleets² may use different accounting and reimbursement methods, such as per-km reimbursement for work-related vehicle expenses.

V2G adds extra layers of complexity, for example:

- Reconciling V2G earnings with fleet running costs
- V2G capable home chargers creating new flows of benefits to vehicle users
- V2G capable public chargers enabling new flows of costs and benefits (e.g. allowing parking providers to make V2G income from fleet vehicles as a way to pay for parking)
- Warranty impacts of V2G, particularly when used in multiple contexts from the same vehicle (e.g. workplace and home)

These are issues that are likely to require solutions from fleet and charger management platforms. These platforms may be shared with those that deliver other EV services such as fuel card replacements or building management systems.

Charging will increase energy costs and discharging will provide revenue. There are many ways in which energy is priced, ranging from fixed fees to fully dynamic pricing. This makes it far more challenging to determine the value V2G has provided or the cost it has incurred in each situation.

4.2.4 Tax implications

Vehicles come with tax implications for employees and employers, particularly those vehicles which are used for both private and workplace purposes. Vehicle-related benefits are managed via Fringe Benefits Tax (FBT). Fringe benefits occur when employees receive payment through goods and services rather than salaries or wages. Employers must assess their FBT liability and lodge a return with the tax office.

Fleet electrification creates several new potential scenarios which incur an FBT liability. Some example scenarios are detailed below. These scenarios must be taken in context. Many scenarios may be exempt from FBT if they are minor. This is defined as less than \$300 and if treating them as a fringe benefit is unreasonable according to the ATO's guidance (e.g. infrequent and irregular) [7]. Many energy services are relatively small benefits individually. For example, \$300 would be around 1,400 kWh of energy at prevailing energy rates in the ACT or around 9,000 km of driving for a Nissan LEAF. This is unlikely to be met in almost all circumstances, particularly for V2G which is ancillary to the transport purpose of the vehicle. However, if the benefit is routine (e.g. happens every day) it may still incur FBT as it is no

² Privately owned vehicles that are used for business travel.

longer infrequent or irregular. In the longer term these use cases may require an explicit ruling from the ATO to provide clarity.

Some tax scenarios are described in Table 4, Table 5, and Table 6.

Table 4 Tax implications of charging private vehicles at work

Charging private vehicles at work	
Scenario	An employer offers workplace charging to their employees. This could be single-directional or bidirectional charging. This involves employees charging personal vehicles during the workday at the workplace. The employer receives benefit from energy services from the vehicle while it is plugged in, particularly if the charger and vehicle are bidirectional.
What's the benefit	For employees: Employee receives energy for their vehicle. For employers: Employer receives energy services from the vehicle while it is plugged in.
Tax implications	Energy is a fringe benefit and would be taxable. Revenue gained from grid services while plugged in would be dealt with separately to the fringe benefit calculation.

Table 5 Tax implications of employer provided home charger

Employer-provided home charger	
Scenario	An employer provides employees with a charger to charge work vehicles at the employee's home. The employer might also allow employees to charge their personal vehicles on the work-provided charger. If the charger and vehicle (employer or employee owned) is V2G capable it may provide benefit to the employee or employer: <ul style="list-style-type: none"> • It can fit in the employee's home energy system, providing bill reduction, grid services, or reliability. • It can be part of an employer controlled VPP, providing grid services revenue to the employer, and potentially some gains or additional cost to the employee.
What's the benefit	For employees: Employees may receive several benefits: <ul style="list-style-type: none"> • Charging facilities for personal vehicles and energy (depending on meter and billing configuration) • Home energy management from V2G capable chargers For employers: Employers may receive grid services revenue as part of a VPP.
Tax implications	The bill reduction is a fringe benefit and would be taxable provided it meets the ATO's guidelines.

Table 6 Tax implications of using EVs to transport energy

Energy transportation	
Scenario	V2G capable cars can transport energy by charging in one location and discharging in another. Some specific cases for this are: <ul style="list-style-type: none"> • Bringing energy from home or public charging facilities to a workplace • Taking energy from a workplace home • Transporting energy between two non-employer provided charging locations (e.g a public charger and home)
What's the benefit	For employees: Employees receive energy for use in their home. For employers: Employers receive energy for use in the workplace.
Tax implications	Energy used at home that was sourced from a work-paid source (at work or through public charging infrastructure that the employer pays for through something like a fuel card) would attract FBT.

4.2.5 End users and other stakeholders

The addition of V2G to an existing EV fleet probably means there will be V2G and non-V2G vehicles, and V2G and non-V2G chargers. They all look the same to drivers, but they aren't the same inside the box. V2G equipped vehicles have an extensive framework of agreements, processes, technologies, and expectations behind them. Connect a V2G equipped vehicle to a non-V2G enabled charger and it will likely charge and operate like a non-V2G equipped vehicle. But it will not provide the services expected and thus have a financial impact on those with expectations around its availability. Similarly, a non-V2G equipped vehicle can connect to a V2G charger. The vehicle may even discharge when requested by the charger, but that scenario may be unsupported by the manufacturer and cause vehicle damage or void the vehicle's warranty.

Within the REVS consortium it is generally expected that these issues will be managed by process and fleet management systems. On the hierarchy of control [8], administrative controls such as these are not preferred, however hardware limitations make better solutions challenging. Vehicles are not capable of identifying themselves to chargers, and the notion of "tapping on" to chargers for identification is error prone and dependant on process itself.

Even the process of assigning parking spots to vehicles can be contentious. If the most desirable parking spots are used for V2G, people displaced to less desirable spots are likely to resist. The inverse is similarly true.

These issues can be thought of as bugs in the fleet EV process which need to be resolved before V2G can see large penetration in fleets. A summary of some identified in the project are listed in Table 7.

Table 7 Bugs identified as part of trial

Bug	Potential future solutions
Use of non V2G vehicles for V2G voiding warranty or damaging vehicle	<ul style="list-style-type: none"> • Process and signage to identify which vehicles to use with which charger • A way of identifying plugged in vehicles to ensure the right vehicle is used for the right services
V2G vehicle used during events causing financial impacts	<ul style="list-style-type: none"> • Accept risk • Advanced booking systems that can dynamically assign vehicles

Bug	Potential future solutions
Public use of V2G chargers voiding warranty, damaging vehicle, or locking connector in vehicle so it cannot be removed	<ul style="list-style-type: none"> • Process or signage to identify non-public chargers • A way of identifying plugged in vehicles to ensure the vehicle is approved for use before locking connector
Use of workplace vehicles in VPPs which they are not approved in (e.g. at employee homes)	<ul style="list-style-type: none"> • Process or in-car signage to identify which public chargers can be used • In-car technology to disable bidirectional charging where not approved
Events causing vehicles to have insufficient charge to drive required distances	<ul style="list-style-type: none"> • Alternate transport (e.g. taxi vouchers) • Better or more conservative battery state of charge optimisation

Section 5 Conclusion

The REVS project is designed to test V2G. More than a technical test it has aimed to build a “working model” of a V2G future. This includes building the tools, relationships, systems, and processes to support V2G – at least in the use case tested in this project.

Delivering REVS is a complex undertaking. It required new relationships between transport and energy sectors, new tools, and new processes. Merging transport and energy worlds was challenging due to the interaction of how vehicles are used, the hardware design of the chargers, and the software that drives them.

This project built several tools and processes that underpinned its delivery. These are shown in Figure 11 and Table 8.

Building prototype systems during REVS has revealed how these would need to evolve to support V2G longer term. How V2G interacts with the transport world, capability expansion of systems, revenue, and risk sharing, and transitioning to dynamic connection agreements are areas of need. This report has discussed actions that could assist in wider uptake of V2G.

The REVS project was scoped to minimise impact on the vehicles primary transport role. Even with this design, many of the largest issues in the project related to this issue. The diverse use cases of the vehicles and the hardware design of the charger resulted in usability challenges.

Systems implemented during the REVS project were simplified and “proof of concept”. The focus on contingency FCAS was a simplification factor. Energy impacts on the vehicle’s battery are minimal meaning that there was no need to collect the driver’s charging preference. The service is always enabled which removes the need for enablement signals from the market systems. And the booking system did not need to be aware of the energy system’s needs. These simplifying assumptions will need to be reconsidered to expand the scope of V2G, but the overall framework built during REVS is fit for purpose.

Due to the few vehicles, small initially hoped for revenue, and trial framework there was little need to prescriptively define revenue and risk sharing arrangements. Into the future these will need deeper consideration. Transparency will be important so that all value chain participants understand the revenues, costs, and risks they are taking on.

Dynamic connection agreements will be important enablers of V2G. Current static connection agreements limit the amount of value V2G can provide. REVS prototyped a dynamic connection agreement, leveraging work done by ANU in their *evolve* project. There is work underway already (such as *evolve* [1], and work done by SA power networks[2]) that can be leveraged to deliver this capability.

Nearly every issue raised in this report affects fleet managers in some way as they will need to manage new information and implement new processes. They are also interested in more than just the operational details [3]. Fleet managers will be critical to uptake of V2G and this far have not been engaged to the level they expect or would be required for fleet based V2G to see widespread uptake.

The REVS project has not been without challenges, but overall has successfully built a framework to enable V2G-equipped electric vehicles to deliver grid services. As the project enters its demonstration phase there will be more knowledge sharing opportunities. These will be communicated in future reports.

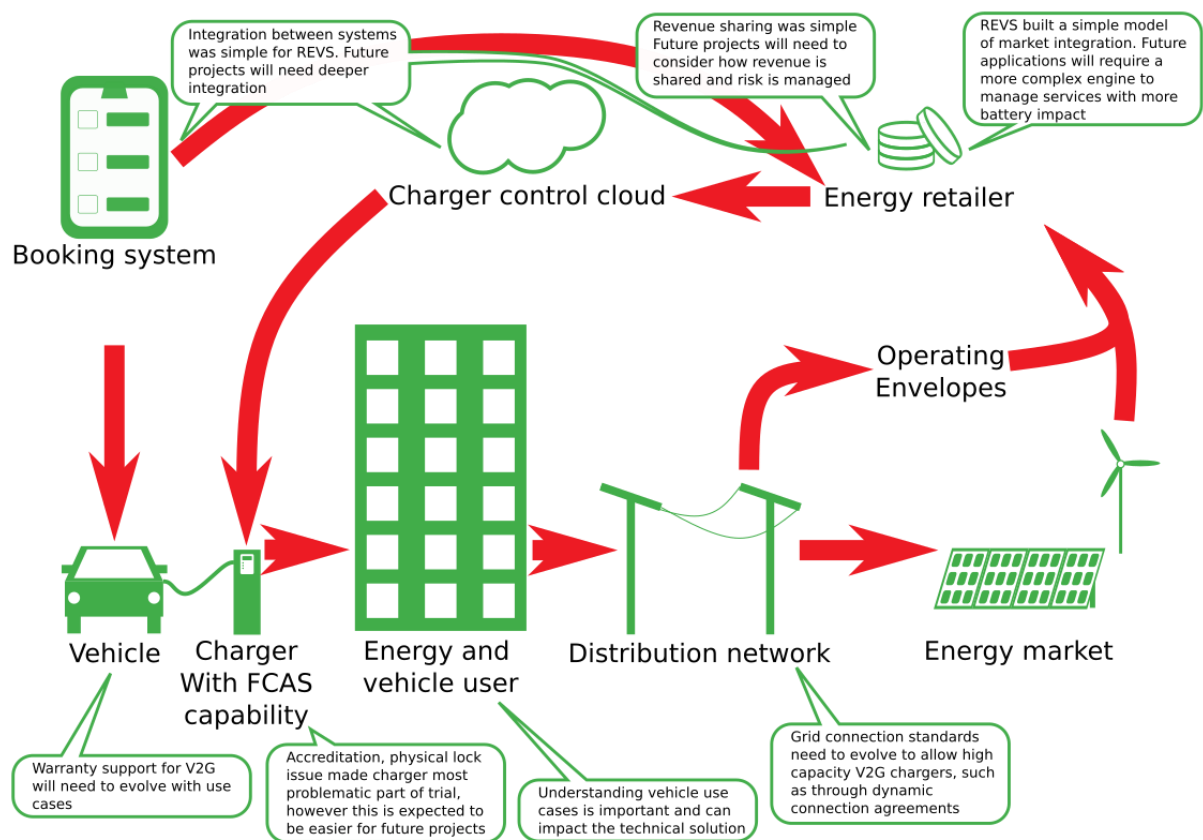


Figure 11 REVS process learnings

Table 8 REVS processes and learnings

Capability/process	Lead	Section	REVS experience
Warranty support for V2G	Nissan	3.1.1	Nissan's standard process will likely need to be altered as V2G enters BAU
Charger accreditation	JET Charge	3.1.2	This was a complex process, however future processes are expected to be simpler
Local charger control	JET Charge	3.1.3	Local control was implemented as part of REVS. Hardware currently has limited functionality but was designed to be modular and extensible.
Charger installation and integration	JET Charge	3.1.4	Charger installation was a much more complex process than expected. We recommend additional upfront effort for future projects.
Grid connection and constraint management	EVO energy and JET Charge	3.1.5	More charger capacity than normally allowable under connection agreements was connected through use of semi-dynamic operating envelopes. This validated the process for applying dynamic operating envelopes but stopped short of calculating them in real time.

Capability/process	Lead	Section	REVS experience
Fleet integration of V2G	ACT government	3.1.6	This process was more challenging than expected due to a combination of technical (charger lock) and process/people (car usage) factors. Resolution required a change to the software on the charger. There is an unknown impact on FCAS bidding.
Market integration	ActewAGL	3.2.1	The single service and intermittent nature of its usage allowed a simplified bidding engine to be used. There was no need for real time communication between the bid engine and the car. Similarly, market participation did not impact on the charge behaviour of the vehicles. Future implementation will require more complex bid engines. As vehicles are not yet actively being bid into the market there may still be learnings, to be communicated in future reports.
Revenue sharing process	ActewAGL, JET Charge, ACT government	3.2.2	Revenue was split three ways evenly for REVS. The total revenue is expected to be small, so this was not contentious. Future revenue sharing models will need to be developed as total revenue becomes larger. Particularly this will need to consider risk/revenue trade off, how the benefit is shared, and transparency of revenue flows. pr
Charger control cloud	JET Charge	3.2.3	The charger control cloud developed for REVS was simplified for trial purposes. It does not implement user control, or a bidirectional link to the bid engine. Both will be required if additional service revenue is to be procured.
Booking system	SGFleet	3.2.4	The booking system was not altered to accommodate REVS, other than to build a pathway to utilise its data in the charger control and bidding systems. Future application for other services with a bigger energy impact on the battery (e.g.

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