THE UNIVERSITY of ADELAIDE

ELECTRIC VEHICLES FOR AUSTRALIA

A major component in moving to a more sustainable future is a transition to cleaner and greener transportation – from households to fleet vehicles and heavy industry such as agriculture, mining and defence.

Electric vehicles (EV) are a clear pathway to achieving this goal, with the opportunity to combine electricity generated from renewable sources, and with the ultimate aim to achieve fully autonomous vehicles.

To make this transition, the Electric Vehicle Industry will need to overcome some key technological challenges if it is to provide consumers with the confidence needed to adopt them.

Moreover, the priority should be given to address Australian specific problems while providing new job opportunities in EV-associated industry and offering training for the future workforce.

The Electric Vehicle Industry

The global EV market is growing exponentially and it is likely to reach over 60% worldwide by 2050. Bloomberg's 2019 Electric Vehicle Outlook report predicts that electric vehicles will overtake conventional vehicles by 2040. This prediction includes EVs taking up 57% of the global passenger car sales and electric buses set to hold 81% of municipal bus sales by the same date.

Furthermore, EV manufacturers are planning to invest at least 300 billion dollars within the next decade with a focus on the development and procurement of batteries and vehicles. The combination of environmental concerns, government policy and targets coupled with advances in battery technology has seen considerable increase in research and development spending globally.

The sales figures, investments and future projections all point to a globally competitive and technologically driven EV market which is underpinned by social, economic and environmental motivation.

The EV industry is faced with both challenges and opportunities in moving forward. The following discussion highlights some of these challenges and opportunities that we in Australia face and how our researchers are looking to shape the future of the EV industry in Australia.

EVs in Australia

The Electric Vehicle Council's report on the State of Electric Vehicles identifies Australia as being well positioned to participate in the electric vehicle supply chain.

The EV car market has seen a 203% jump in Australian electric vehicles sales 6,718 EVs were sold in Australia in 2019, up from 2,216 in 2018. In the same period, combustion engine vehicle sales dropped by 7.8%.

The EV market size and consumer choice in Australia is also increasing with the number of EV models available, which is expected to jump from 22 as of August 2019 to 31 by the end of 2020.

This increase in EV uptake is occurring despite the lack of government policies on EV adoption or incentives to support purchase and ownership.

Supporting the EV Industry

It is important to note that Australia is already indirectly supporting the critical components of EV industry. This is predominantly in the form of exporting rich mineral concentrates to be used in battery technologies and electric motor components (such as copper for windings and rare-earth material for permanent magnets).

Moreover, Australia has already demonstrated novel technologies and case studies to provide support for the EV charging infrastructure, including microgrid platforms for remote areas and the development of commercial charging systems.

Moving Forward

The Industry is at a point in its development where it needs to identify and address both the potential setbacks of an EV future as well as capitalise on the potential opportunities it can bring.

One potential setback is the effect of large-scale adaptation of EVs to the power network. This is due to Australia's unique electricity grid which is long and thin, with aging conventional generation sources and infrastructure. This is made more complex due to the large-scale integration of renewable energy sources and sparsely populated landscape located at the fringe of grid in remote towns or mining sites. This has potential impacts on factors such as charging security which is fundamental to the operation of EVs.

When considering the opportunities, the most compelling is the utilisation of renewable energy to power transportation. This begins with household but rapidly expands through neighbourhoods, regions and across the country. It offers energy and transport solutions for remote operations such as mine sites and farms as well as settlements that are independent of the electricity grid.

Most importantly, outcomes play a key role in reducing society's reliance on fossil fuels and paving the way for a greener energy and transport future.

What is an Electric Vehicle?

An electric vehicle or "EV" is a vehicle which uses one (or multiple) electric motors and motor controllers for propulsion. An EV is considered an alternative fuel vehicle as it uses these electric motors in place of more common ones such as the internal combustion engine (using petrol or diesel).

More common electric vehicles include cars, bikes, scooters, buses and trains and as technology develops, trucks and heavy vehicles, boats, airplanes and spacecraft will also be realised (Fig. 1).

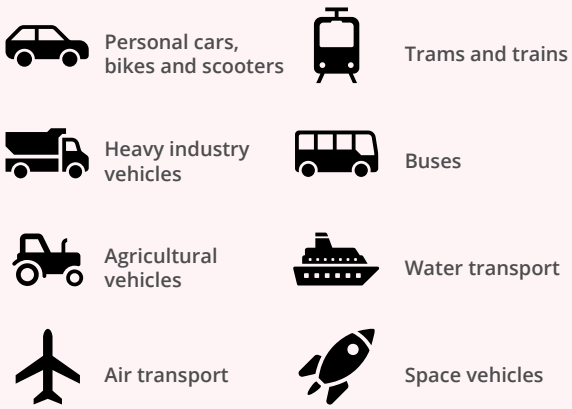

Figure 1. The future of electric vehicles will revolutionise a wide range of transportation methods and have applications in homes, communities and many commercial and industrial sectors.

Key components of an electric vehicle include the battery (or fuel cell); charge port and onboard charger; DC/DC converter; power electronics controller; traction motor; electric transmission, and a thermal cooling system.

Electricity is used to power electric vehicles with the electricity held in an energy storage device, such as a battery or hydrogen fuel cell. Being battery or fuel cell-based, EVs have limited energy storage capacity and must be replenished once drained of power.

Research towards an EV future

The complete structure of the EV research has been summarised in Figure 2. This figure highlights some of the critical research areas at the vehicle level as well as highlight the broader dependencies and influences that affect the overall EV ecosystem.

It is important to note that these areas will progress at different time frames, developing as there are new technology advances, policy developments and changes in overall uptake.

In the short-term, the primary focus of EV development will be centred on energy storage technologies, vehicle systems and optimisation and the standardisation of charging solutions.

Moreover, as efficiency, capacity and longevity of EV batteries increase, and when they are charged faster and less frequently, the major barrier to adoption of EVs will be removed.

Critical challenges

As we move to adopt EVs in Australia, there is need to address few critical challenges (see Figure 3). These are primarily the ability to travel long distances, operate in regional and remote areas, the provision of low-cost charging and the availability/ accessibility of long-lasting charging infrastructure.

Furthermore, an EV's dependency on the electricity grid – at least initially –will require new processes, systems and technologies to help manage the electricity grid.

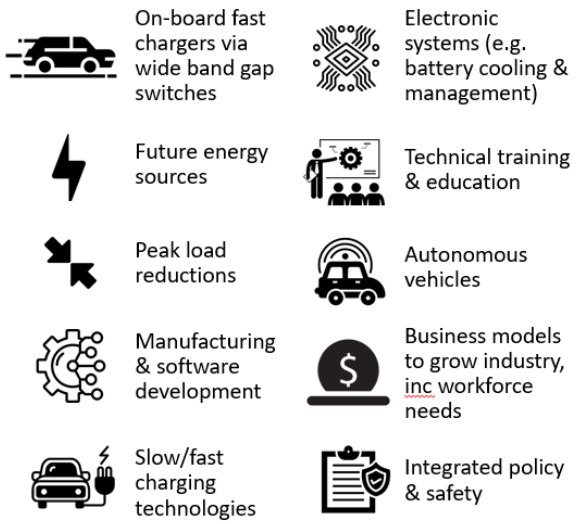

Figure 3. Examples of the critical challenges that need to be overcome to promote the adoption of EVs in Australia.

As the number of EVs increase, so too will the demand for charging infrastructure in households, cities and towns, commercial properties and locations such as farms, mine sites.

This increase is likely to be a significant impact on the Australian electricity grid which has unique characteristics.

It is envisaged that "training, public acceptance, testing and safety, legal and ethical issues" need to be addressed in conjunction with these developments.

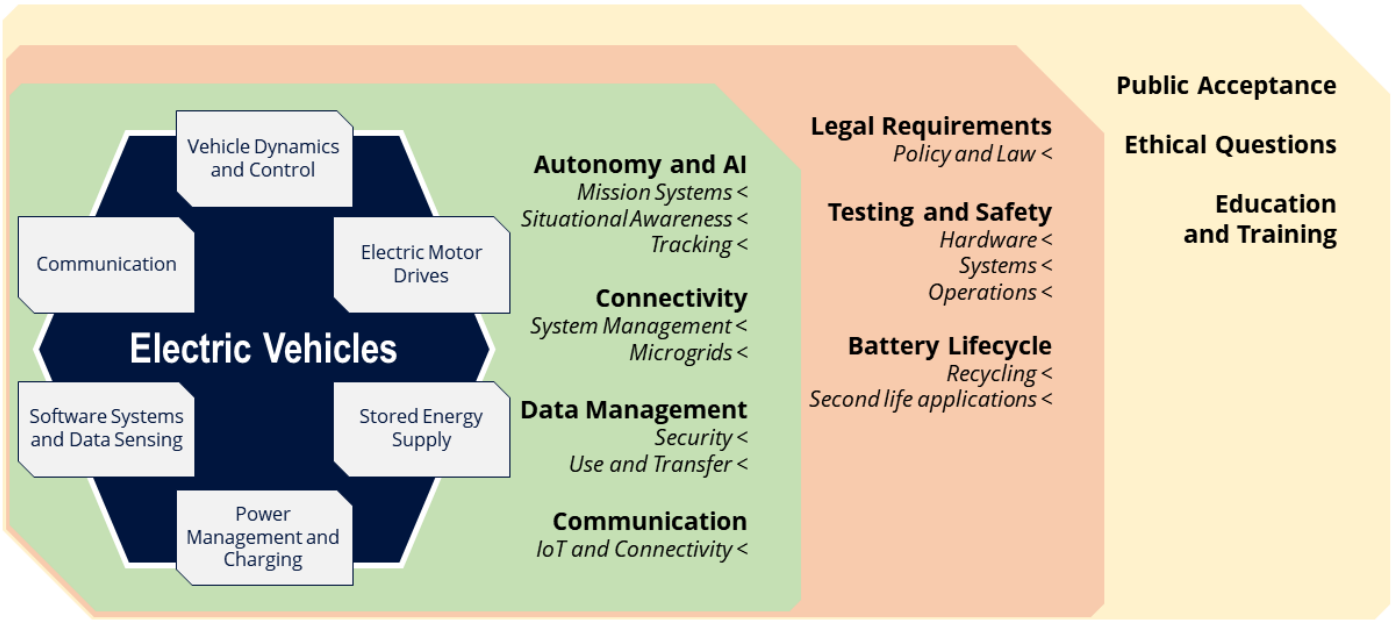

Figure 2: Overview of functional structure of Electric Vehicle Research and its broader relationship with other key components of the Electric Vehicle Ecosystem.

EV Research at the University of Adelaide

The University of Adelaide has world leading research capability in electrical engineering, power systems, battery management and optimisation, autonomous vehicles, cyber security, artificial intelligence and machine learning.

The University of Adelaide is involved in several local and national research initiatives such as the Future Battery Industry Cooperative Research Centre (FBI CRC), Australian Energy Storage Knowledge Bank, and has well established links with battery technology companies in Australia and Internationally.

The School of Electrical and Electronic Engineering

The School of Electrical and Electronic Engineering has strong ties to the local utility industry, both commercially and through research and education.

The school has involved in several activities addressing the backbone of the EV systems. We are keen to apply our cutting-edge research to support our community to adopt EVs in Australia and in doing so achieve a sustainable future for Australia.

Figure 4. An example of the research areas that are currently being undertaken or have the potential to be investigated at the University of Adelaide.

Vehicle Dynamics and Control; Electric Motor Drives; Stored Energy Supply; Management Charging Systems and Energy Supply

Projects Undertaken

- Electric motor designs (such as drivetrain and cooling motors) with varying in cost and performance and with emerging magnetic materials; using efficiency-mapping techniques to improve EV system efficiency.
- Reduction and elimination of sensors/feedback devices in the motor-control to improve performance hence to reduce system cost and increase reliability.
- Development of battery modelling for faster detection of State of Charge.
- Coordinated EV charging to reduce peak demand
- Vehicle-to-grid algorithm development to provide services to the grid using EVs
- Battery charging systems for Photo Voltaic systems using wide band gap devices for high power density (high temperature environment and high efficiency)
- Steering by braking to obtain safe-state in Autonomous Vehicles under fault.
- Light Hybrid Electric Vehicles for Defence Industry.
- A mobile and flexible microgrid test system for community level and remote area applications.

Potential Future Projects

- Electric vehicles as a source of mobile storage to uptake of renewable energy and to offer grid support.
- Vehicle to Grid, Grid to Vehicle power/energy transfer and grid impacts of EV on electricity grid
- Development of on-board fast/intelligent charging systems for EVs using wide band gap devices for high power density (volumetric and weight)
- Autonomous Electric Vehicles for mining, farming and defence applications
- Remote communities and integration with renewable energy sources and battery infrastructure, and autonomous microgrids for fast charging E-Buses from renewable sources.
- Modelling of overall grid stability and interactions with EVs and future electricity demands
- 2nd and 3rd Life in EV batteries, and investigation for Australian applications and environment.
- End of Life in EV batteries and EV components, and recycling opportunities.
- Battery efficiency, communication systems and low power electronics for UAVs
- Battery system design, testing, management and optimisation.

Communications, Sensors and Data Fusion

Projects Undertaken

- Condition Monitoring in electric motors and power quality monitoring in power systems.
- Utility scale battery storage mobile test system: environmental monitoring, power quality monitoring linked to the adverse impact of renewable energy integration.
- The actual position detection and data fusion in autonomous electric vehicles.

Potential Future Projects

- Vehicle to Vehicle and Vehicle to Grid communication and cyber security

Environment

Topological Map, Intelligent Roads, Electronic Horizon, Traffic Rules, Monitoring, Tracking, Object Detection

Projects Undertaken

- Lane detection in electric vehicles

Potential Future Projects

- Commercial charging stations – data transfer and analysis
- External communication interfaces - smart roads and traffic infrastructure

Mission Coordination and Trajectory Planning

Projects Undertaken

- Trajectory planning in autonomous electric vehicles.

Potential Future Projects

- Fleet management – operational data collection, transfer and analysis
- EV data security and management (personal/ consumer data and transfer, manufacturers data

Artificial Intelligence (AI)

Potential Future Projects

- Intelligent charging using on-board charges and widely distributed stationary power points.
- AI and Machine Learning (ML) managing on- board systems and increasing safety.
- AI and ML to understand user behaviours, optimisation car management (e.g. charging)
- ML for EV fleet management, analysis of consumer behaviour; industry optimisation.
- Autonomy and AI for "whole of vehicle" management – sensing, communications, vehicle operation.

Public Acceptance; Legal Requirements; Ethical Questions; Testing and Safety; Education and Training

Projects Undertaken

- Expert Witness Statements for the Senate Committee on EVs and The Future Power Systems, and for SA Government's EV Initiative.
- The Centre for Automotive Safety Research (CASR) regularly provides independent professional advice on road safety matters to government and non-government organisations in Australia and overseas.
- CASR offer advanced driver-assistance (ADA) systems (ADAS) testing here in Australia to ensure suitability for our conditions.
- The School of EEE has offered a number of courses which are related to EV systems including: Automotive Electric/Electronics Systems, Power Electronics, Distributed Generation Technologies, Power Systems, Control Systems and Autonomous Systems.

Potential Future Projects

- Urban planning and risk assessment EVs
- Opportunities to independently test the safety of EVs.
- Battery safety in EVs
- The emerging EV industry needs specialised engineers, not only for the electrical aspects of a vehicle but also for automation, artificial intelligence and machine learning, communication, safety and more.
- Specific training courses on EVs, industry-led training courses and postgraduate course.

The EV market and the development of autonomous vehicles are on similar trajectories in terms of penetration in the transport market with manufacturers exploring future

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