Review of Alternative Fuel Vehicle Policy Targets and Settings for Australia

Prepared by ENERGEIA for the Energy Supply Association of Australia

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Executive Summary

Developments in new technologies, concerns over long term fossil fuel security and the need to reduce greenhouse emissions from the transport sector have all contributed to discussion about the potential role of electric vehicles (EVs) and natural gas vehicles (NGVs) in Australia. The Energy Supply Association of Australia (esaa) commissioned Energeia to provide an independent, evidence based report identifying appropriate EV and natural gas vehicle (NGV) targets for Australia considering a range of costs and benefits and the mix of best practice policies for achieving the target.

The Net Benefits of Electric and Natural Gas Vehicles

Energeia's analysis of the net incremental benefits to Australia from increasing uptake in AFVs relative to petrol vehicles focused on economic growth, employment, fuel security, environmental costs (greenhouse gas reduction and local air pollution) and direct transportation costs.

Benefits

Electric vehicles and natural gas both delivered increased economic growth and employment in Australia by substituting away from imported energy supply towards domestic energy supply. The net result of this was to increase growth and domestic employment. This also increased Australian energy security by reducing reliance on imported fuel supplies.

The environmental performance of natural gas vehicles was better than petrol or diesel vehicles, while the performance of electric vehicles improved over time as the greenhouse intensity of electricity generation fell driven by carbon pricing and greater integration of renewable energy. Electric vehicles charged from 100% renewable energy were clearly the best environmental performers.

Costs

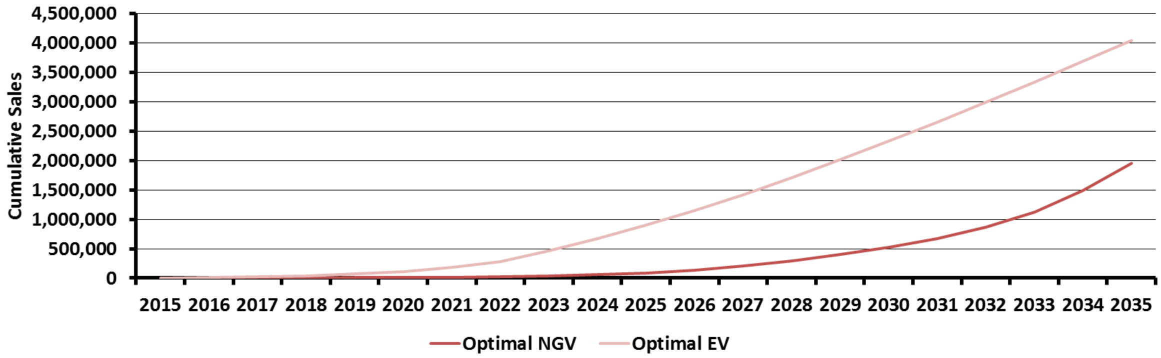
The net cost of AFVs compared to conventional petrol and diesel vehicles depends on the rate at which the costs of these vehicles fall over time. Energeia's modelling shows AFVs will deliver passenger transport more efficiently across the community than conventional petrol vehicles by 2025. This analysis includes all the direct costs faced by drivers including purchase, refuelling and maintenance costs.

Energeia's modelling therefore shows that policies that increase adoption of AFVs from 2025 will increase the overall economic efficiency of meeting Australia's private passenger transportation needs.

Alternative Fuel Vehicle Targets

Energeia's analysis of the net benefits of an efficient level of AFV adoption over the next twenty years and the cost of addressing market failures and government barriers has found that the economically efficient target for EVs is 4 million EVs by 2035, representing approximately 22% of Australia's light passenger vehicle fleet as shown in Figure 1.

Figure 1 – Optimal EV and NGV Uptake Targets for Australia to 2035

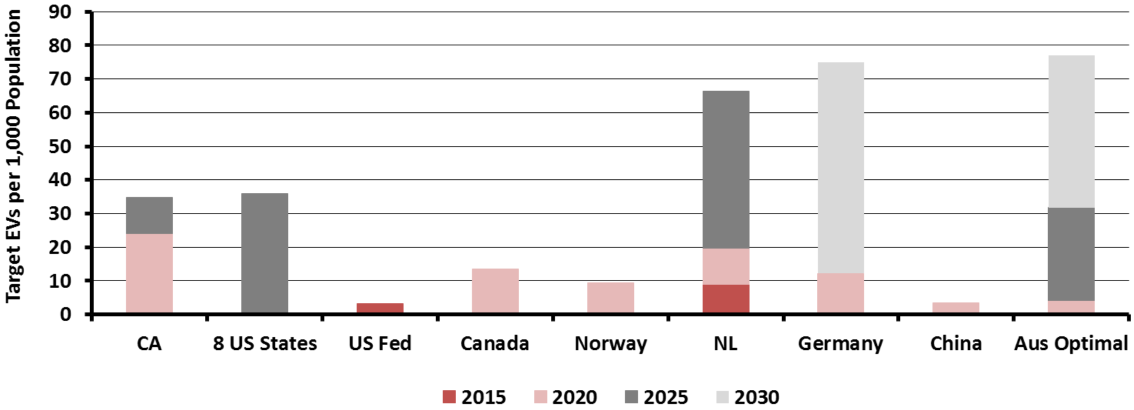


Source: Energeia

Interim targets to achieve this goal are 900,000 EVs by 2025 and 2.3 million EVs by 2030. Similarly, we estimate the economically efficient target for NGVs to be 2 million, or just over 11% of Australia's light passenger vehicle fleet, by 2035, with interim targets of 85,000 NGVs in 2025 and 525,000 NGVs in 2030.

Importantly, Energeia's targets do not incorporate any quantified benefits from greater economic growth, jobs or fuel security. Higher values placed on these community benefits could warrant greater policy intervention and a higher target, and are therefore an appropriate topic for discussion as part of the esaa's call for a national dialogue on AFV targets and supporting policies.

Figure 2 – EV Uptake Target Comparison[1,2]



Source: Energeia, various government EV programs

As shown in Figure 2, Energeia's estimate of an optimal EV target for Australia is consistent with other leading AFV jurisdictions across North America, Europe and Asia.

Cost of "Do-Nothing" Approach by Government

In Energeia's view, the analysis and modelling undertaken for this assignment has demonstrated the economic and policy case for targeted AFV policy interventions in the form of both demand and supply side incentives.

Over the 20 year study period, the 'do nothing' policy scenario for EVs would result in:

- A net economic cost of $368 million over 20 years to the Australian economy
- The loss of a potential additional $878 million Gross Value Added (GVA)
- An additional 17,407 TJ of imported fuel
- An additional 2,299 kt CO2e valued at $42 million
- An additional $16.3 million in health related costs as a result of local air pollution

Similarly, for NGVs it is estimated that a do nothing approach would result in:

- A net economic cost of $113 million over 20 years to the Australian economy
- The loss of a potential additional $202 million GVA
- An additional 14,541 TJ of imported fuel
- An additional 998 kt CO2e valued at $18 million
- An additional $4.6 million health related costs as a result of local air pollution.

[1] CA=California; 8 US States are California, Oregon, Connecticut, Maryland, Massachusetts, New York, Rhode Island, Vermont; NL=Netherlands.

[2] Canada and Norway's EV targets are both for 2018. To simplify the figure they were assumed to be 2020 targets.

Policy Options to Optimise Benefits of AFVs

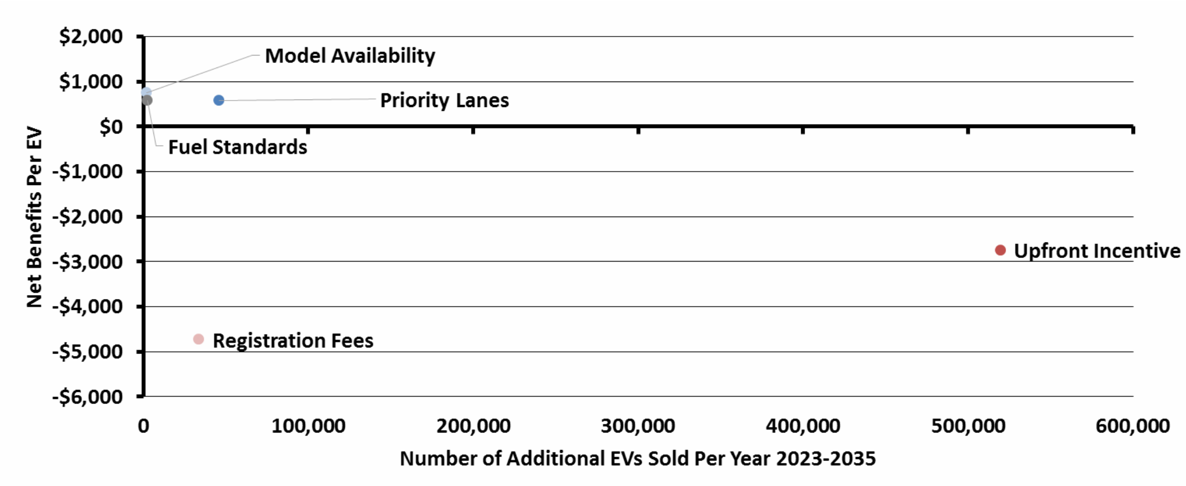
Australia does not have a comprehensive AFV policy framework at the Federal level and is lagging behind many international peers. Virtually all activity over the past four years has been at the state level. The key Australian Government development to date has been aligning vehicle emissions standards with Europe to improve fuel efficiency and lower emissions intensity.

Even when externalities are taken into account, upfront subsidies are unlikely to ever deliver a net benefit on their own. Non-financial rights like access to priority lanes provide a low cost/marginal benefit policy incentive. There is also a net benefit from increasing vehicle emissions or fuel efficiency standards to bring Australia into line with international fuel efficiency targets.

Electric Vehicles Policies

Increasing the number of vehicles manufacturers are required to sell into Australia would increase model availability to international levels and bring their availability into Australia forward by three years. The direct costs of such a policy would be close to zero, although there may be modest indirect costs to consumers as the increased sales requirement is subsidised across the fleet. Overall, this policy gives rise to a small net benefit.

Figure 3 – Comparison of Impact of EV Policies



Natural Gas Vehicles Policies

Availability of OEM passenger CNG vehicles is limited in Australia. Without its own vehicle manufacturing industry, Australia will need to rely on the US implementing an aggressive NGV policy as other traditional suppliers of vehicles to Australia such as Japan and Europe have limited drivers to develop a NGV manufacturing industry. A further option is the subsidisation of after-market conversions which has not been considered in this modelling, but has a precedent in the recently abolished subsidies for LPG conversions.

There may be a stronger case for policies supporting NGV deployment amongst the heavy vehicle fleet, which has gained prominence in countries such as the US. However, the scope of Energeia's study was limited to Australia's passenger vehicle fleet.

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Glossary

AEMO	Australian Energy Market Operator
AFV	Alternative Fuel Vehicle
BEV	Battery Electric Vehicle
CNG	Compressed Natural Gas
DNSP	Distribution Network Service Provider
ECGS	Energy Grants Credits Scheme
ERF	Emission Reduction Fund
EV	Electric Vehicle
GHG	Greenhouse Gas Emissions
GVA	Gross Value Added
HEV	Hybrid Electric Vehicle
HOV	High Occupancy Vehicle
ICE	Internal Combustion Engine
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NEM	National Electricity Market
NGV	Natural Gas Vehicle
OECD	Organisation of Economic Co-operation and Development
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle
PM10	Particulates < 10μm in diameter
T&D	Transmission & Distribution
ZEV	Zero Emission Vehicle
vkt	Vehicle Kilometres Travelled

Disclaimer

While all due care has been taken in the preparation of this report, in reaching its conclusions Energeia has relied upon information and guidance from the esaa, information provided by Australia fleet managers, retailers, Distribution Network Service Providers (DNSPs) and publically available information. To the extent these reliances have been made, Energeia does not guarantee nor warrant the accuracy of this report. Furthermore, neither Energeia nor its Directors or employees will accept liability for any losses related to this report arising from these reliances. While this report may be made available to the public, no third party should use or rely on the report for any purpose.

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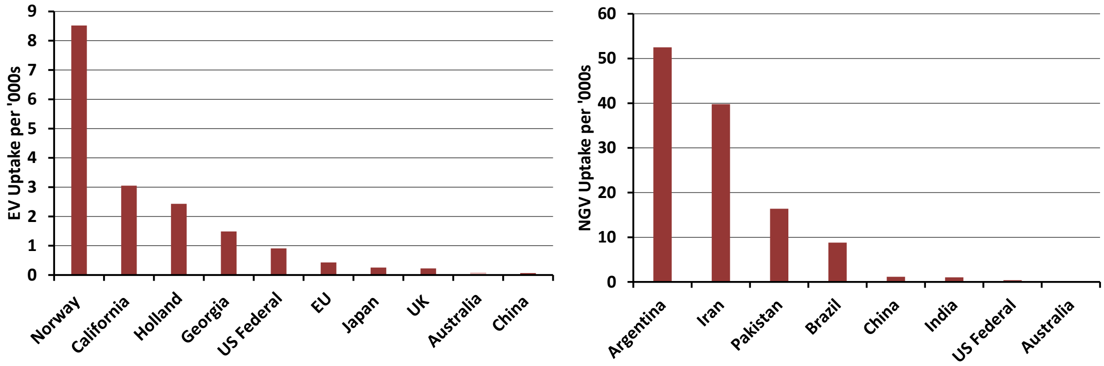
1 Introduction

Internal combustion engine (ICE) vehicles fuelled by petroleum have been the dominant vehicle technology in the global automotive sector for over a hundred years. In recent years, alternative fuel vehicles (AFVs) have grown in prominence especially in places where governments have implemented specific policies to increase the availability and relative attractiveness of AFVs. The drivers for these international policies vary depending on the geopolitical circumstances of individual countries and states, but for the most part tend to be driven by government policymaking targeting either greenhouse gas abatement, local air pollution and/or energy security.

Figure 4 – Comparison of Australian and International EV and NGV Uptake (per thousand people)



Source: Various government EV programs; Natural Gas Vehicle Knowledge Base

Australia has among the lowest shares of both Natural Gas Vehicles (NGV) and Electric Vehicles (EV) of all OECD countries. Battery electric vehicles (BEVs) accounted for only 0.03% of new passenger vehicle sales in 2014 and hybrid electric vehicles (HEVs) accounted for less than 2%. To date, NGVs have only been adopted on a small scale within Australia's commercial fleet[3], mainly in taxis, with no natural gas fuelled passenger vehicles from Original Equipment Manufacturers (OEMs) currently available in the Australian market.

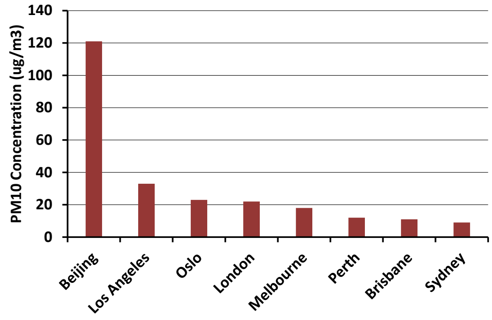
The specific policy drivers for AFVs in Australia are not the same as for other markets and vary by type. In Australia, EVs do not offer the same greenhouse gas abatement benefits by default at the present time as they do for other markets due to the relatively high greenhouse gas intensity of the grid in states other than Tasmania where the grid is largely powered by low carbon sources. They can, however, achieve zero emissions transportation where the driver chooses to purchase sufficient 100% green power certificates.

Additionally, air quality is relatively good compared to other jurisdictions such as California and China where air pollution has driven AFV policies[4], even though pollutant concentrations frequently exceed prescribed health based standards in some major Australian cities.

[3] Based on data provided by the Federal Chamber of Automotive Industries in a VFACTS Specialist Report on 22 May 2014. This only includes passenger vehicle sales, and does not include SUV and commercial vehicle sales. Petrol is considered to be petrol only vehicles and does not include petrol LPG or electric hybrids.

[4] The World Health Organization's Ambient (outdoor) Air Pollution In Cities Database (2014) ranks Australian cities between 1335 and 1570 of 1622 global cities

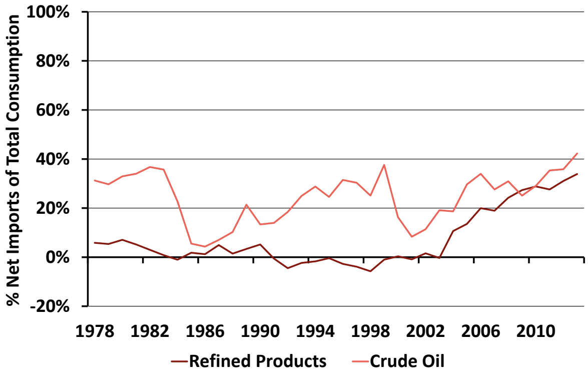
Figure 5 – Comparison of PM10 Pollution in Major Australian and International Capitals[5]



Source: WHO Organisation Air Pollution in Cities Database

There are, however, specific benefits offered by AFVs in Australia related to improved fuel security and economic growth. Currently more than 50% of Australia's transport fuel is imported from overseas markets, exposing it to global oil and refined product supply constraints and the associated price volatility.

Figure 6 – Trends in Net Imports of Oil and Refined Products into Australia



Source: BREE Energy in Australia 2014 Report

A shift to indigenous fuel sources and domestic supply chains not only increases fuel security, but also provides added economic growth.

Importantly, each of the above factors will be impacted by a range of likely changes to passenger vehicle technology and the energy value chain. For example:

- Changes to global oil prices due to non-conventional oil production and OPEC's reaction
- Changes to Pacific Liquefied Natural Gas (LNG) prices due to contract linkages with oil prices
- Changes to Australian natural gas prices due to the market's increasing LNG linkages
- Falling solar PV costs and the rise of decentralised energy in the electricity system
- The potential introduction of a price on carbon in the next ten to twenty years in Australia
- Changes to the carbon and PM10 intensity of electricity due to changes in the generation mix
- Increasingly efficient internal combustion engine technology due to tightening global standards
- Falling battery storage costs due to global electric vehicle uptake and stationary applications

A robust consideration of Australia's policy drivers for greater AFV uptake must therefore take these key changes explicitly into account.

[5] WHO Ambient Air Pollution Database 2014

1.1 esaa's Reports and Call for Dialogue

In November 2013, the esaa released its report *Sparking an Electric Vehicle Debate in Australia* highlighting the potential benefits of encouraging a local electric car market. The paper identified greenhouse gas abatement, local air pollution and fuel security as potential benefits of AFVs as well as improved utilisation of the current electricity grid. The paper also identified potential government barriers and market failures that could undermine the efficient realisation of these benefits, suggesting that policy interventions may be justified.

In June 2014, the esaa released a further discussion paper *Developing a market for Natural Gas Vehicles in Australia* on the potential future for NGVs, which summarised the current state of play with respect to NGV availability. This paper also identified a range of potential benefits, current government barriers and market failures, which could undermine efficient future deployment.

Both of these reports sought to stimulate discussion between the electricity and natural gas sectors, vehicle manufacturers, policy makers and other stakeholders with respect to the potential for AFVs to contribute to improving the country's overall economic welfare with respect to passenger transportation, but stopped short of calling for specific policy intervention.

As recognised by the esaa in both its reports, any determination of the case for policy intervention must be made on the basis of a net incremental improvement in community economic welfare from moving from one passenger vehicle technology to another one and only where the market alone will be not be able to deliver the improvement due to recognised market failures such as split incentives, incorrect or incomplete information and/or unpriced externalities.

Addressing these information requirements requires a comprehensive analysis of the direct and indirect impacts of AFVs, the impact of barriers on achieving efficient market adoption, and the costs and benefits of the main government policy interventions to address these barriers over a twenty year timeframe.

1.2 Limitations of Previous Quantitative Studies

In the last five years, there have been a number of quantitative studies commissioned or funded by state and federal governments to inform policy development as shown in Table 1. The key study objectives included identifying the environmental and electricity network impacts of electric vehicle uptake, and identifying the market and economic conditions under which EVs would provide a net benefit to society.

Table 1 – Major Quantitative Studies of Australian Electric Vehicle Uptake

Year	Author	Title
2009	AECOM	Economic Viability of Electric Vehicles
2010	CSIRO	Combining choice modelling and multi-criteria analysis for technology diffusion: An application to the uptake of electric vehicles
2011	Energeia	Electric Vehicles: Driving a Revolution
2011	AECOM	Forecast Uptake and Economic Evaluation of Electric Vehicles in Victoria
2011	CSIRO	Spatial Modelling of Electric Vehicle Charging Demand and Impacts on Peak Household Electrical Load in Victoria, Australia
2012	AECOM	Impact of Electric Vehicles and Natural Gas Vehicles on the Energy Markets
2012	CSIRO	Electric vehicles and the smart grid: spatial modelling of impacts and opportunities
2013	AECOM	Electric Vehicles Uptake and Behaviour Modelling
2013	Energeia	Jumpstart: The Australian Market for Electric Vehicle Products and Services to 2022

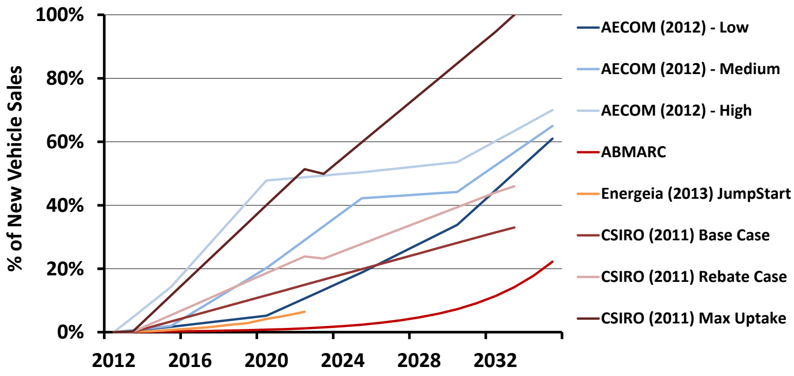
Source: Energeia, CSIRO and AECOM

The forecasting methodologies adopted vary but generally seek to model how key buyer considerations such as vehicle price, performance, running costs and environmental attitudes impact uptake. Many of the models are based on explicit relationships between socio-demographic factors (e.g. age, affluence, education level, dwelling size and location) and uptake.

Analysis undertaken by CSIRO as part of their Energy Transformed Project used choice modelling (stated preferences), multi-criteria analysis and technology diffusion theory to forecast uptake calibrated against a large scale survey in Victoria. Similarly, analysis undertaken by AECOM for the Victorian Government, AEMO and as part of the *Smart Grid, Smart City* project adopts choice modelling based on stated preference surveys.

The range of forecasts provided by various previous studies is shown in Figure 7.

Figure 7 – Previous Studies' Forecasts of BEV uptake



Source: AECOM, ABMARC, CSIRO and Energeia

Interestingly, more than two thirds of the forecasts show EVs representing more than 35% of total sales by 2035. Diesel technology was only able to reach 5% market penetration about a decade after diesel passenger vehicles became widely available in Australia, but has stagnated at this level for the last few years. While the reasons for this are likely to be complex, Energeia notes that new technologies including hybrid electric vehicles and battery electric vehicles have been periodically emerging and may be competing with diesel for the lower-cost-to-fuel segment of the passenger vehicle market.

The scope of each of the models with respect to the range of potential community wide costs and benefits outlined above is reported in Table 2.

Table 2 – Modelling of Key Costs and Benefits by Major Study

Stakeholder	Cost or Benefit Type	AECOM 2009	AECOM 2011	AECOM 2012	CSIRO 2012
Driver	Transportation Costs	✓	✓	✓	✓
	Infrastructure Costs (chargers)				
Community	Infrastructure Costs (chargers)				
	Carbon Emissions (CO2)	✓	✓	✓	
	Particulate Emissiosn (P10)	✓	✓	✓	
	Gross Value Add (GVA)				
	Energy Security				
	Australian Jobs				
Industry	Market Demand				
	Industry Costs	✓	✓	✓	

Source: Energeia

Most of the models have included estimations of the direct financial benefits to drivers, and the cost of key environmental externalities in terms of greenhouse gas emissions, local air pollution and industry externalities in terms of electricity and natural gas sector costs. None have to date attempted to model the change in energy security, economic growth or jobs.

The scope of each of the models in terms of assessing the costs and benefits of potential polices to address the key barriers to efficient uptake is listed in Table 3.

Table 3 – Modelling of Key Policy Options by Major Study

Target	Type	Sub-Type	AECOM 2009	AECOM 2011	AECOM 2012	CSIRO 2014
Demand Side	Subsidies	Upfront (rebates)				✓
		Ongoing (fuel, licensing)				
	Obligation	Controlled Charger				
		Renewable Energy				
	Rights	Parking				
		Commuter Lanes				
Supply Side	Subsidy	Charging Infrastructure				
		Vehicle Development				
	Obligation	Model Availability				
		Sales Targets				
		Charging Infrastructure				
		Fuel Efficiency				

Source: Energeia

This shows that really only one potential policy (subsidisation of the vehicle) has been modelled previously. There is therefore little quantitative modelling of the net benefits of key government policy options, including vehicle model availability and access to commuter lanes and premium parking.

1.3 Energeia's Scope and Approach

The esaa commissioned Energeia to undertake a study of efficient EV and NGV targets for Australia. The objective of the study is to determine:

- Whether an EV and NGV target is appropriate for Australia
- If so, at what level should the target be set?
- What the role of government policy is in achieving any target?

Given the significant potential benefits to the electricity and natural gas sectors, the esaa also seeks to identify steps that the sectors could take towards contributing to any target.

Energeia's approach to delivering a comprehensive analysis of the economy wide costs and benefits of AFVs, the impact of barriers on achieving efficient market adoption, and the costs and benefits of the main government policy interventions to address these barriers over a twenty year timeframe included the following key steps:

1. Identify potential drivers and benefits of AFVs and the case for a transition to AFVs over time
2. Identify the barriers to AFV uptake and the realisation of full benefits
3. Identify potential AFV policies for Australia from overseas experience to overcome the barriers identified
4. Model potential AFV policies in terms of potential net benefits
5. Identify the optimal policy mix including targets to deliver the greatest net economic benefits
6. Identify the role of the energy supply industry in enabling the transition and achievement of targets

It should be noted that the quantitative assessment excludes public transport and commercial vehicles, however these types of vehicles and the suitability of NGVs to this sector in particular is discussed in Section 3.2.

In addition, Energeia also undertook a series of stakeholder interviews with distribution network service providers and energy retailers to identify current and future actions and strategic intentions with respect to AFVs. A summary of the interview results is presented in Appendix 2.

2 Benefits of Alternative Fuel Vehicles

ICE vehicles have been the dominant technology in the passenger vehicle market because they have offered consumers a number of distinct benefits over competing technologies including range, towing power, total cost and acceleration. However, EVs and NGVs provide a number of their own direct consumer benefits including

- Superior acceleration and torque (EVs only)
- Lower fuel and maintenance costs
- Reduced or zero (EVs only) tailpipe emissions of PM10 and CO2
- Energy independence through using domestic or renewable energy sources to fuel an AFV, and
- Enhanced safety from increased front crumple zones.

There are also benefits to the wider community from a shift towards AFVs through:

- Reduced dependence on foreign energy sources
- Greater economic growth, and
- Lower emissions of GHG and air pollutants.

The key potential costs of NGVs and EVs are mainly associated with their impact on the natural gas and electricity sectors. However, AFVs can benefit these sectors through demand growth.

In this section Energeia analyses the potential benefits of a transition to AFVs to the vehicle owner, Australian society and the country's energy supply industry.

2.1 Benefits to the Vehicle Owner

Vehicle purchase decisions are traditionally linked to a customer's lifestyle or as a statement of their values. Depending on the individual, the vehicle's price, fuel efficiency, safety, power, carrying capacity and environmental impact may all be important decision criteria. The better AFVs compare against ICEs in each of these categories, the greater customer demand will be for them.

The relative benefits offered by AFVs to vehicle owners compared to conventional ICE technology are outlined in Table 4. Energeia notes that factors other than cost and emissions do not neatly integrate into our Welfare Economics framework. They do provide utility benefits to vehicle buyers, but they are just not readily comparable.

Table 4 – Comparison of AFVs Performance Against Key Buying Criteria[6]

	Cost							
Technology	**Upfront**	**Maintenance**	**Fuel**	**Range**	**Emissions**	**Power**	**Acceleration**	**Safety**
Petrol	✓		✗		✗			
Diesel		✗		✓		✓	✗	
Natural Gas Vehicle				✓	✓			
Electric Vehicle*	✗	✓	✓	✗		✓	✓	✓

✓ = Best; ✗ = Worst

Source: Energeia

Energeia notes that NGVs and EVs score differently across the traditional vehicle purchase criteria. It is also important to note that in the case of EVs at least, technology advances are expected to reduce their upfront cost relative to petrol vehicles, and make them increasingly competitive with petrol vehicle range capabilities.

Each of the key criteria listed above are discussed in the following sections.

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[6] *Energeia recognises that the GHG emissions benefits of EVs are dependent on the emission intensity of the electricity used for EV charging. Where renewable or low carbon electricity is the source of EV charging, then it is likely to outperform other vehicles with the lowest GHG emissions.

2.1.1 Acceleration

EVs are able to achieve higher acceleration than a comparable ICE vehicle due to the flat torque curve of an electric motor and the direct power delivery to the wheels. The Tesla Model S can reach 100km/h in 3.4s[7]. To put this in perspective, this performance is superior to a Ferrari F430 which claims to do 0-100km/h in 4s [8].

The acceleration performance potential of EVs may not be well known to the Australian passenger vehicle market, particularly because many of the first generation of EVs sold in Australia over the last 5 years had sluggish acceleration and relatively low top speeds.

The acceleration performance of NGVs is comparable to diesel vehicles, and slower than petrol or EVs.

2.1.2 Power

EVs have relatively high low-end torque, which is also the hall-mark of diesel engines. EVs, NGVs and diesels all have higher low-end torque than a comparably sized petrol engine. This is typically important for sport utility vehicles (SUVs), which are often used to tow other loads such as boats or for off-road driving.

The superior power of EVs is again not widely recognised by consumers due to the lack of larger, sport utility EVs on the market. This may change with the introduction of the Mitsubishi Outlander PHEV and Tesla's Model X in Australia, potentially increasing demand through greater vehicle choice.

One of the reasons BEV technology has not been widely used for SUVs to date is that they tend to be heavier, which plays against EV's current range limitations. Energeia expects advances in storage technology will increasingly lead to more electricity powered SUVs on the market.

2.1.3 Safety

Safety is a primary concern amongst vehicle buyers. OEMs often target their marketing and branding around safety. EVs have a number of safety advantages thanks to the absence of an ICE which takes a lot of space 'under the hood', allowing for the addition of impact absorbing reinforcement materials at the front of the car to improve safety during collisions. However, there are a number of safety risks specific to EVs related to potentially lethal power flows from fast charging and maintenance of EV propulsion systems which operate at high voltages.

NGVs largely rely on the same ICE as petrol and diesel engines, and while they use a compressed instead of a liquid fuel, there does not appear to be any additional reported safety issues.

2.1.4 Maintenance Costs

Electric motors generally require less maintenance than ICE, due to their relative simplicity and lack of moving parts, which also translates into relatively high levels of reliability[9]. Lower maintenance requirements save vehicle owners money over the lifetime of the vehicle, following the end of the manufacturer's warranty period.

As NGVs and EVs are both relatively rare, maintenance unit costs could be higher due to lower scale economies across the supply chain. This is expected to reduce over time with a growing share of the overall vehicle market.

2.1.5 Refuelling Costs

AFVs refuelling costs are a small fraction of the cost of petrol or diesel on a per km basis, shown in Figure 8. The actual cost for an EV depends on whether charging occurs on a flat or a discounted off-peak tariff.

The costs reported in Figure 8 exclude the cost of refuelling infrastructure, but this is a small fraction of the total cost of refuelling.

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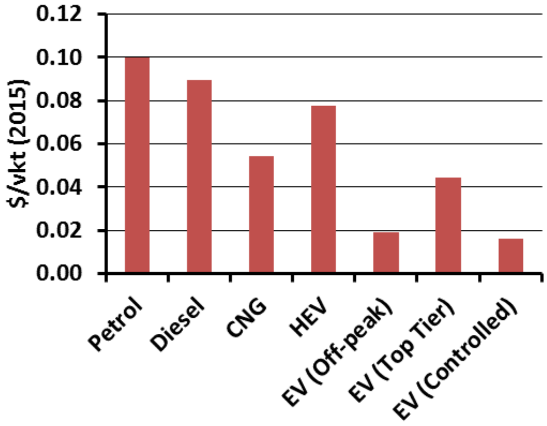
[7] *Tesla* website, accessed on 6th February 2015, http://www.teslamotors.com/en_AU/models/

[8] *Ferrari* website, accessed on 6th February 2015, http://auto.ferrari.com/en_EN/sports-cars-models/past-models/F430/

[9] US Department of Energy, *All-Electric Vehicles*, accessed on 6th February 2015, http://www.fueleconomy.gov/feg/evtech.shtml

Figure 8 – Refuelling Cost per Vehicle km Travelled (vkt) by Fuel Type



Source: Energeia, IHS, EIA

The cost of electric charging infrastructure is higher for public and fast chargers, but Energeia expects most EVs to charge at home most of the time.

Most NGVs are expected to refuel at petrol stations in Australia as home refuelling technology is less well established here compared to overseas jurisdictions including the US.

2.1.6 Emissions

Consumer benefits from lower emissions AFVs are qualitative in nature as consumers do not receive any financial incentives to reduce their vehicle emissions of CO2 or PM10 in Australia.

Section 2.2 quantifies the emissions benefits of AFVs for the community, who currently bear any associated externality costs related to CO2 and PM10 emissions.

2.1.7 Energy Independence

Some vehicle buyers have a desire to be energy self-sufficient – these people are likely to have a solar PV system and are looking to charge their EV through their own renewable energy storage system.

While this is understood to be a relatively small segment of customers at the moment, growing solar PV ownership, falling stationary energy costs and low feed-in tariffs could see this segment grow over time.

Others may be looking to reduce their own dependence on 'foreign oil', preferring to use domestically sourced grid electricity or natural gas to power their vehicles.

2.2 Community Benefits

Increasing uptake of AFVs in the passenger vehicle fleet has the potential to bring wider benefits to the community beyond those received directly by vehicle owners. Energeia has quantified the range of potential community benefits (economic, environmental and energy security) in an Australia-wide context for three types of AFVs (CNGVs, HEVs and EVs) and two types of ICE vehicles (petrol and diesel) in terms of the following:

- Economic growth ($ Gross Value Added per vehicle type/year);
- Jobs creation (jobs per vehicle type/year);
- Energy security in terms of the level of imported fuel consumption (GJ per vehicle type/year);
- Environmental externality costs ($ per vehicle type/year);
- Direct transportation costs ($ per vehicle type/year).

The following sections present the results of this analysis over a 20 year assessment period to 2035. All results are in annualised real value AUD discounted to the present (2015) using a 7% real discount factor. The analysis assumes an average 10 year vehicle lifetime to calculate annualised costs.

2.2.1 Economic Growth

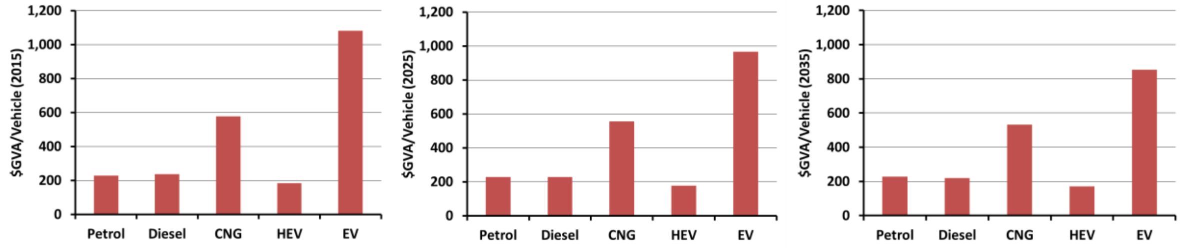
Energeia measures the contribution each vehicle type makes to the economy in terms of gross value added (GVA), a standard economic measure of the incremental value of goods and services produced in a sector. The net GVA contributions of AFVs are calculated relative to petrol for the purpose of estimating per AFV impacts.

As the value chains of petrol, gas and electricity are quite different due mainly to where the fuel comes from, increased uptake of AFVs will cause petrol supply sectors to contract, and the energy supply sector to expand.

Energeia's modelling in Figure 9 shows that EVs deliver the largest contribution to Australian economic growth from 2015 in terms of gross value added ($GVA). This is driven by increased electricity demand which in turn drives sales in domestic industries, particularly the energy supply sectors[10].

NGVs deliver the second highest $GVA impact owing to the almost 100% domestic fuel source.

Figure 9 – Gross Value Added per Vehicle by Type in 2015, 2025 and 2035 ($2015 real)



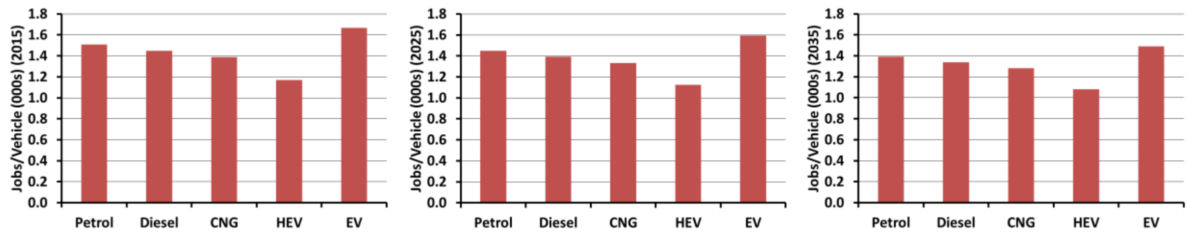
Source: Energeia

Energeia's modelling over the 20 year study period shows that EVs will more than triple economic growth relative to petrol vehicles, while NGVs will more than double economic growth relative to petrol vehicles[11].

2.2.2 Jobs Creation

Energeia's analysis has found that that AFVs have the highest direct jobs per vehicle due to greater domestic sector involvement over the 20 year period as shown in Figure 10[12]. Petrol vehicles, and to a lesser degree diesel, come next, with HEVs the lowest number of jobs due less refuelling required.

Figure 10 – Jobs per Vehicle by Type in 2015, 2025 and 2035



Source: Energeia

Energeia therefore conclude that increasing NGVs relative to petrol vehicles will slightly increase the number of jobs in directly impacted sectors in Australia, with EVs resulting in slightly less direct jobs. However, it is important to note that the direct and indirect cost savings reported below will increase jobs indirectly in other sectors where the savings are spent, further increasing Australian jobs relative to petrol vehicles.

[10] While EV electricity consumption may be largely accommodated within existing electricity assets, removing the $GVA does not change the ranking.

[11] Valuation of this benefit typically requires a General Equilibrium Model of the Australian economy and is beyond the scope of this report.

[12] Energeia assumes EV drivers will use public fast charging infrastructure around 40% less than petrol drivers based on our re-charging model.

2.2.3 Energy Security

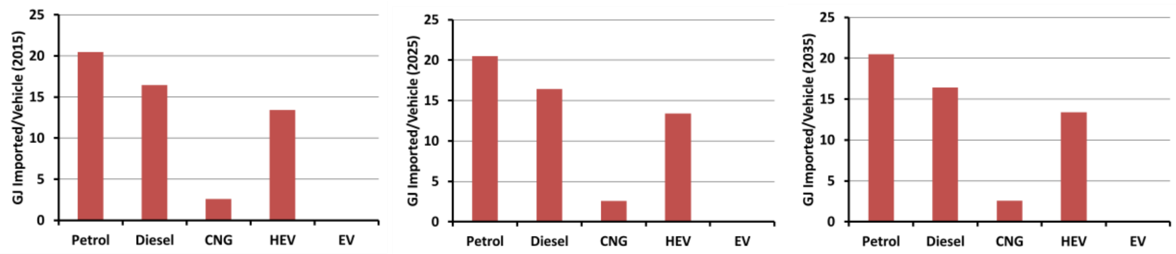
The cost of petrol and diesel stockpiles to cushion potential supply disruptions represents a real cost that is passed on to vehicle drivers in the form of higher prices at the bowser.

Community costs associated with energy security in terms of the cost of supply disruptions on the Australian economy. Both of these costs are difficult to estimate accurately and in any case out of scope for this report.

While the value of greater energy security is difficult to estimate, it may be measured and compared on the basis of energy imported. Analysis of Australia's level of refined product imports was reported in Figure 6, and shows that a growing share of energy used in non-AFVs is imported.

Energeia's modelling of fuel security impacts, the results of which are reported in Figure 11, shows that transitioning to AFVs, fuelled almost entirely by domestic supplies, will substantially reduce Australia's dependence on foreign oil and refined products for passenger transportation.[13] EVs and NGVs use almost 100% domestic fuel supplies, while petrol, diesel and HEVs have the highest level of imported fuel.[14]

Figure 11 – Fuel Imports (GJ) per Vehicle by Type in 2015, 2025 and 2035



Source: Energeia

Energeia's modelling shows that moving to AFVs will virtually eliminate imported fuel relied upon by varying degrees by petrol and diesel burning vehicles, including HEVs. [15]

2.2.4 Environmental Benefits

The main environmental impacts of private passenger vehicle travel are Greenhouse Gas (GHG) and Particulate Matter (PM10) emissions. The following sections quantify emissions from each vehicle technology over the next 20 years, the costs of which are borne by the community in the absence of a price on carbon or PM10 emissions.

GHG Emissions

Energeia estimated the GHG emissions from fuel use for each vehicle technology based on the Department of Environment's fuel emission factors and previous carbon price projections[16,17].

Energeia's modelling of indirect environmental costs shows that petrol vehicles, followed by diesel, have the highest GHG emissions with natural gas vehicles performing the best, as shown in Figure 12. The increase in GHG emissions costs over time is due to the assumption of rising carbon prices. There is also a relative reduction in EV emissions costs due to changes related in the NEM generation mix over time. EVs which are charged from a renewable source (such as rooftop solar PV) would have zero GHG emissions.

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[13] Natural gas imports tend to be from offshore locations in close proximity to Australia's maritime borders.

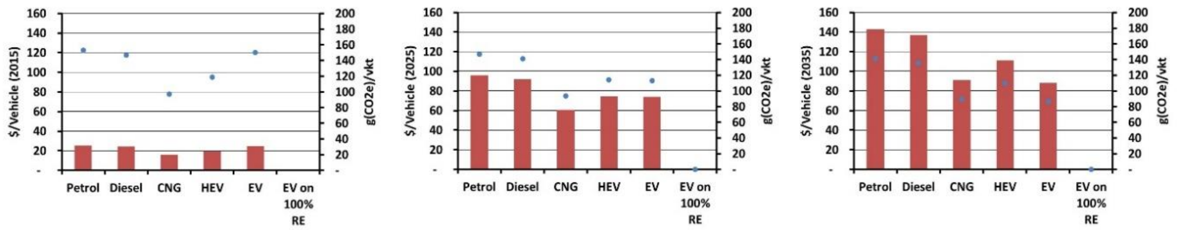
[14] Energeia's analysis of energy security benefits assumes no change in the current level of energy imports.

[15] Valuation of this benefit typically requires quantifying the cost of wars fought to protect fuel supply channels and is beyond the scope of this report.

[16] Australian Government Department of Environment, *National Greenhouse Accounts Factors*, December 2014

[17] Department of Innovation, Industry, Climate Change, Science, Research and Tertiary Education, *Electricity Sector Emissions: Modelling of the Australia Electricity Generation Sector*, September 2013

Figure 12 – GHG Emissions and Associated Cost per Vehicle by Type in 2015, 2025 and 2035



Source: Energeia

The increase in the value of GHG emissions is due to the assumption of rising carbon prices. There is also a relative reduction in BEV costs due to changes related in the NEM generation mix over time.

Energeia recognises that the GHG emissions benefits of EVs are dependent on the emission intensity of the electricity used for EV charging. Where renewable or low carbon electricity is the source of EV charging, then it is likely to outperform other vehicles with the lowest GHG emissions.

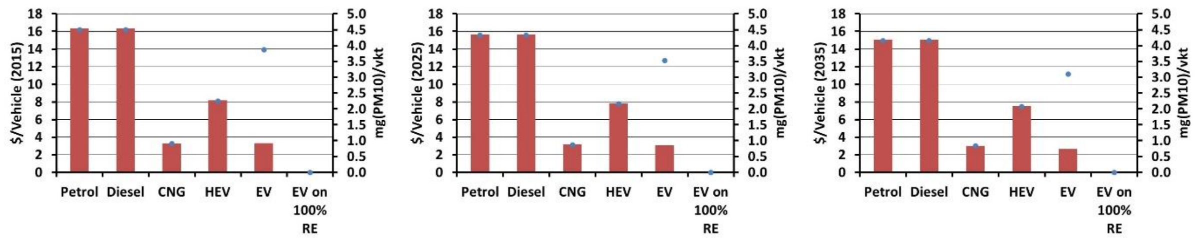
Particulate Matter (PM) Emissions

Air pollutants[18] from fuel combustion have a detrimental effect on air quality, particularly in urban areas, and on human health. Particulate matter, and specifically PM10, is one of the six key air pollutants in Australia with significant health and environmental impacts[19,20]. Australia has legally binding standards requiring PM10 concentrations to be below a maximum threshold and only allows exceedances for five days a year[21].

Energeia assessed the air pollutant impacts of the vehicle technologies in terms of PM10 emissions, and the associated cost to the community based on historical estimates of health damage impacts associated with PM10 in Australian state capital cities[22].

Figure 13 shows petrol and diesel have the highest impact on local air quality in terms of PM10 across the 20 year period. EVs also have relatively high PM10 emissions, but at a relatively low cost to society given that the source of the emissions come from coal and natural gas power plants which are located outside of urban centres. Again, EVs which are charged from a renewable source (such as rooftop solar PV) have zero PM10 emissions.

Figure 13 – PM10 emissions and associated cost per vehicle type in 2015, 2025 and 2035



Source: Energeia

Although Energeia's modelling assumes an ongoing improvement in vehicle efficiency and therefore a reduction in PM10 emissions over the next 20 years, it is only very slight. BEV PM10 costs are also slightly reduced relative to the other vehicle technologies due to changes in the generation mix by 2035.

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[18] The key air pollutants include carbon monoxide, nitrogen oxides, particulate matter, volatile organic compounds, benzene.

[19] Department of Environment, *Air Quality Standards*, accessed on 6th February 2015, http://www.environment.gov.au/topics/environment-protection/air-quality/air-quality-standards

[20] Department of Environment, *National Pollution Inventory - Particulate matter*, accessed on 6th February 2015, http://www.npi.gov.au/resource/particulate-matter-pm10-and-pm25

[21] Department of Environment, *Air Quality Standards*, accessed on 6th February 2015, http://www.environment.gov.au/topics/environment-protection/air-quality/air-quality-standards

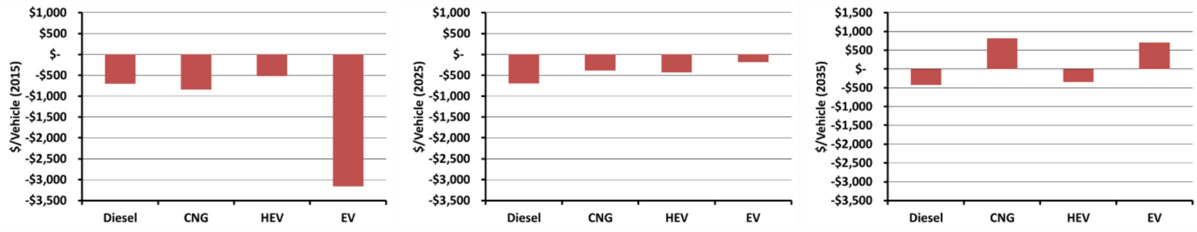
[22] NSW Environment Protection Authority, Methodology For Valuing the Health Impacts of Changes in Particle Emissions – Final Report, February 2013, pg. 12

2.2.5 Transportation Costs

Figure 14 shows that from a levelised cost perspective, AFVs will deliver passenger transport more efficiently across the community than conventional petrol vehicles by 2025. This analysis includes all the direct costs faced by drivers including purchase, refuelling and maintenance costs.

By 2025, the net cost of an EV is expected to be on par with a petrol vehicle. By 2035 Energeia estimates that EVs will cost around $600 less per vehicle per year than a petrol car. NGVs bring the highest net savings relative to petrol and diesel vehicles by 2035 as the cost of these vehicles and their refuelling infrastructure comes down.

Figure 14 – Net Econmic Savings per Vehicle Type in 2015, 2025 and 2035 ($2015 real)



Source: Energeia

Energeia's modelling therefore shows that policies that increase adoption of AFVs from 2025 will increase the overall economic efficiency of meeting Australia's private passenger transportation needs.

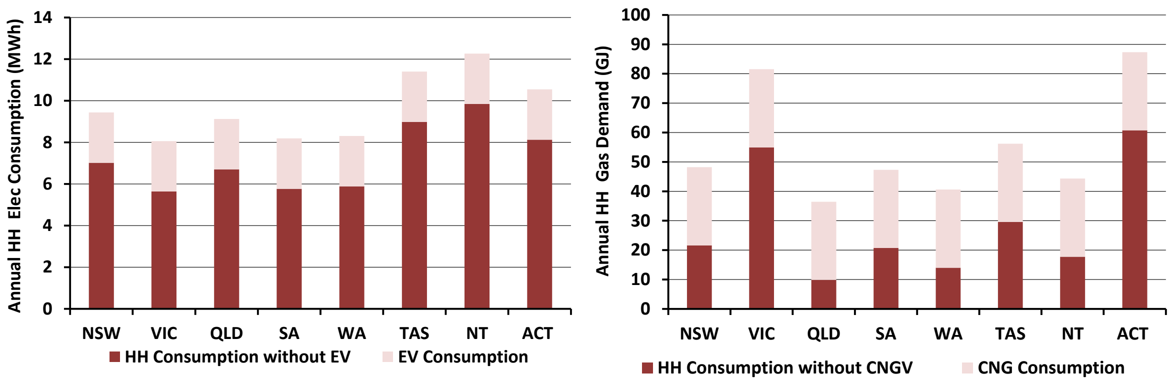
2.3 Industry Benefits

The key industry benefit of AFVs is increased utilisation, which Energeia's modelling shows could partially offset recent declines in consumption due to rising rooftop solar PV adoption and energy efficiency trends.

2.3.1 Market Growth

Figure 15 shows the estimated impact that BEVs and NGVs have on household level energy consumption by state. This analysis assumes that one vehicle per household is replaced by an EV or CNGV[23]. The analysis was conducted separately for EVs and CNGVs, so that it was assumed that there was no competition between these two technologies and customers did not have to choose between them.

Figure 15 – Impacts of EVs and CNGVs on Household Electricity and Gas Consumption by State



Source: ABS Household Energy Consumption Survey, Core Energy Group[24]

[23] ABS, *Australian Social Trends – Car Nation*, accessed on 6th February 2015, http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Main+Features40July+2013

[24] The baseline average household gas demand figure for WA was based on Core Energy Group's Gas Demand Forecast. *Gas Demand Forecast, Mid-West and South-West Distribution System Core Energy Group November 2014, Appendix 4.1,* Pg. 68, 27 November 2014, Response to the ERA's Draft Decision on required amendments to the Access Arrangement for the Mid-West and South-West Gas Distribution System.

Energeia's analysis shows that BEVs could increase annual household electricity consumption by 25% in NT to 43% in VIC. In VIC, the increase in demand is highest due to low base electricity consumption. Energeia notes that these increases would more than offset the decline in annual consumption due to uptake of rooftop solar PV.

The impact of this potential increase in consumption on network revenue depends on the tariff and regulatory regime. For example, under a consumption based pricing and a revenue cap, the increased throughput from EVs will lead to a growth in network tariff revenue. Assuming that no network augmentation is required to accommodate the EV load, fixed costs would become a proportionally lower part of network bills, putting downward pressure on network prices.

In the case of a typical household in QLD on Ergon's residential flat rate tariff (Tariff 11), the increased consumption from EV charging would result in their annual bill increasing from $2,295 to $2,970 p.a.

However as electricity prices increasingly move to cost reflective levels, and given the highly flexible nature of BEV charging, there may be little additional revenue contributed to the electricity networks from BEV uptake for the next 20 years. That being said, BEVs would still be charged for the incremental cost of generation under cost reflective retail tariff structures. There are similar dynamics at play in the natural gas sector for NGVs.

Figure 15 shows NGVs could increase annual household gas consumption by 44% for ACT and up to 370% in QLD[25], followed by WA, see the largest additions in gas consumption, primarily due to their low current levels of gas use. VIC and ACT show the lowest increases, as households are generally already large gas users.

[25] This analysis assumes a household was able to refuel their CNGV through their 'mains' connection

3 Barriers to Efficient Adoption

Identification and assessment of the barriers to efficient market uptake of AFVs is essential for developing an optimal policy response. In assessing barriers within a Welfare Economics framework, it is important to determine whether they are due to the government or a market failure. The default assumption is that it is the role of private enterprise to address barriers to their sales, which is also likely to be more efficient and dynamic.

This section reports on Energeia's review of the major economic, institutional and technical barriers to efficient market uptake of AFVs in Australia.

3.1 Economic

The main economic barriers include higher vehicle costs, the lack of cost reflective electricity tariffs, the bounded rationality of vehicle buyers, and unpriced externality costs.

3.1.1 Purchase Price

The relatively high price tag of EVs is the biggest barrier to efficient BEV adoption in Australia. As reported in Section 2.2, higher purchase prices, driven mainly by the high cost of battery storage, makes BEVs thousands of dollars more costly for transportation than petrol vehicles.

The Nissan Leaf, currently the top selling EV in Australia, retails at about $40,000 almost double that of a comparable performing ICE vehicle[26]. This is also the case with NGVs. While there are no OEM NGV passenger models sold in Australia, in the US the Honda Civic NGV costs 40% more than the equivalent petrol model[27,28].

Policies to reduce the price of BEVs and NGVs in Australia would help address this barrier. However, they must not add costs, at least not until there is a net benefit of BEV or NGV adoption, which only occurs post 2025.

One potential policy that is already being implemented is the removal of import barriers on vehicles from overseas. This could help reduce the significant premium paid by Australians for the same BEV. For example, the same Nissan Leaf in the U.K. costs about 20 percent less than Australia.

3.1.2 Cost Reflective Electricity Prices

Most electricity tariffs in Australia charge based on total consumption, regardless of cost of supply, which varies significantly by season, month, day of week and hour of day. As BEVs have significant flexibility around when they are able to recharge, they could see significantly lower refuelling costs from more cost reflective charges.

Energeia notes that the Australian Energy Market Commission (AEMC) recently tightened the National Electricity Rules (NER) around cost reflective network pricing. Energeia therefore expects more cost reflective pricing to be made progressively available across Australia for those with a smart meter.

While accessing a cost reflective tariff will cost around $250 per vehicle for a smart meter, and around $30 per year for remote reading and processing of the data, this is more than compensated for by lower electricity costs. However Energeia notes that Victoria has already had a mass-market smart meter roll out and expects there to be a full deployment of smart meters in most states over the next ten years [29], so the cost of a smart meter is not likely to be additional.

3.1.3 Bounded Rationality

Bounded rationality is a concept whereby individuals are restricted in their ability to make a rational decision by limited information, finite time, and cognitive limitations. Bounded rationality is relevant to AFVs because the limited market presence and information on these technologies means vehicle buyers do not have access to all information required to make a rational purchase decision. Bounded rationality becomes even more relevant when some of the barriers discussed in this section are removed.

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[26] *Nissan Leaf*, Accessed on 6th February, http://www.nissan.com.au/Cars-Vehicles/LEAF/Offers

[27] *Honda Civic CNG*, Accessed on 6th February, http://automobiles.honda.com/civic-natural-gas/price.aspx

[28] *Honda Civic*, Accessed on 6th February, http://automobiles.honda.com/civic-sedan/

[29] Energeia, *The Awakening: Smart Meter Market Insights*, 2014

3.1.4 Unpriced Externalities

As discussed in Section 2, motor vehicles produce GHG emissions and air pollutants which impact society in terms of health and environmental costs. However the cost of these negative externalities are generally not factored into the vehicle or fuel price. Environmental economists consider this to be a market failure.

Governments can address this market failure through a polluter pays scheme that establishes a price for these externalities. For example, the California Government includes GHG emissions from transport fuel distributors in its Cap and Trade Scheme thereby putting a market price on GHG emissions from transport fuel[30].

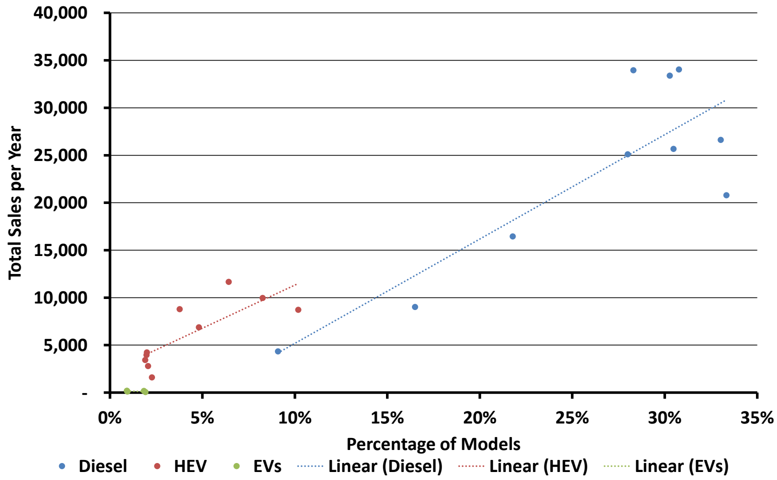
3.2 Institutional

The main institutional or supply side barriers to the efficient adoption of AFVs are the lack of vehicle choice and recharging infrastructure.

3.2.1 Vehicle Availability

Energeia's pioneering analysis of the relationship between model availability and market uptake described in Appendix 1 suggests that policies that drive greater availability of BEV model choice may increase AFV uptake. This is probably due to the lack of vehicle model choice being a major non-financial barrier.

Figure 16 – Relationship between Total Annual Passenger Vehicle Sales and Availability of Models



Source: Federal Chamber of Automotive Industries

In the last five years the four models of BEVs – Nissan Leaf, Renault Fluence, Mitsubishi i-MiEV and BMW i3 – sold in Australia have combined sales of around 700 vehicles, accounting for less than 0.5 percent of new sales[31]. In addition, the Tesla Model S became available in Australia last year. In the case of HEVs, there are currently 20 models sold through six manufacturers in Australia accounting for less than 2 percent of overall new passenger vehicle sales[32]. About 10 percent of passenger petrol vehicles have a HEV equivalent model[33]. This includes the Holden Volt which was modified by Australian-based design teams to better adapt the original model to Australian roads. There are no passenger CNGVs currently sold in Australia.

The limited selection of EVs and HEVs available in Australia is in contrast to United States, Norway and Netherlands where there is a wider variety of EV models sold. The US Department of Energy lists 29 models of EVs that have been released in the US over the last two years[34].

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[30] Centre for Climate and Energy Solutions, *California Cap and Trade*, http://www.c2es.org/us-states-regions/key-legislation/california-cap-trade

[31] Based on data provided by the Federal Chamber of Automotive Industries in a VFACTS Specialist Report on 22 May 2014. This only includes passenger vehicle sales. Petrol is considered to be petrol only vehicles and does not include petrol LPG or electric hybrids.

[32] Ibid

[33] Ibid

[34] US Department of Energy Fuel Economy website Web link: www.fueleconomy.gov. Accessed on 2 February 2015.

A low cost policy option might be to require manufacturers to offer all right hand drive BEVs offered overseas.

3.2.2 Public Refuelling Infrastructure Availability

The lack of availability of public charging infrastructure has been almost universally cited as a barrier to BEV and potentially therefore NGV uptake. Energeia notes that these claims have been based on surveys rather than empirical data, and that larger batteries over time will reduce the need for long-distance recharging.

For example, in a survey conducted by the Federal Government's *Smart Grid, Smart City* EV Trial 80 percent of respondents agreed that availability of a 'comprehensive' charging infrastructure is essential for the future of EVs[35]. However, by the end of the trial, 65 percent of respondents stated that they would be happy to continue using their EV even without a comprehensive charging infrastructure system[36].

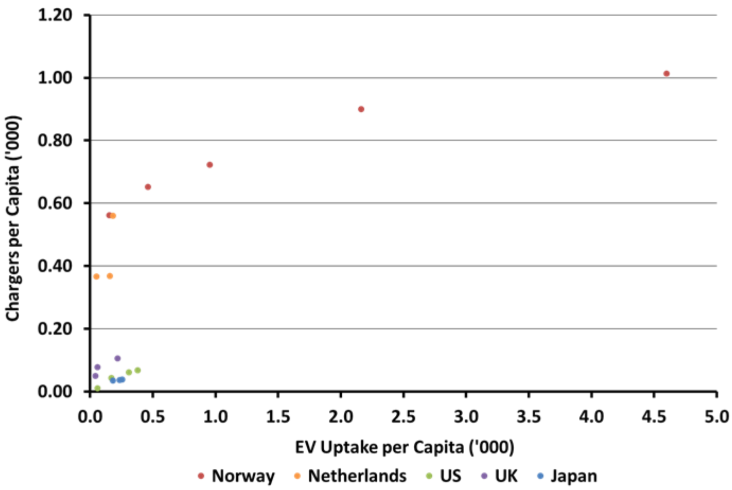
It is also important to distinguish between BEVs, which can easily be recharged at home using a standard plug, and NGVs, which require specialised equipment to refuel, which is not widely available in Australia. Energeia's view is that public refuelling infrastructure availability is therefore a much greater barrier for NGVs than BEVs.

Another key question is whether there is or is likely to be a market failure in the provision of efficient levels of public refuelling infrastructure.

Better Place planned on deploying a network of fast charging networks to support sales of their charging service concept, but this never materialised as the company went into liquidation. ChargePoint currently has the most developed public charging network in Australia with 95 charging stations operating in cities in Australia and New Zealand, including three DC fast chargers. Tesla announced plans last year to develop a fast charging network between Melbourne and Sydney in 2015, with the first couple of fast chargers already installed in Sydney[37]. Tritium, are an example of an Australian company that has brought to market its own fast charging system.

Energeia's analysis of the relationship of vehicle uptake and public charging infrastructure has found the empirical evidence is mixed with respect to the relationship between BEV uptake and charging infrastructure. Figure 17 maps per capita EV uptake in major international markets against charger availability. While the relationship is stronger in some markets than others, there is no clear pattern around a minimum threshold.

Figure 17 – Public Charging Stations and EV Uptake per Capita in Leading Countries



Source: Energeia

One area where there may be a market failure is around BEV and NGV refuelling arrangements in new buildings, where the cost of a conduit and access point during construction may be ten times lower than after. There is the potential in this case for there to be split incentives between the developers and consumers. As long as the

[35] Ausgrid, Smart Grid, Smart City: Electric Vehicle Technical Compendium, 2013, Pg. 111

[36] Ausgrid, Smart Grid, Smart City: Electric Vehicle Technical Compendium, 2013, Pg. 112

[37] McCowne, David, *Tesla unveils Australian supercharger network*, accessed on 24th February 2015, http://www.drive.com.au/motor-news/tesla-unveils-australian-supercharger-network-20141209-123ob4.html

incremental cost of the conduit and access point is low, there may be a case for mandating it in planning standards to improve net benefits. NGV refuelling technology may also be able use the parking area conduit.

3.3 Technical

Driving range and recharging limitations of AFVs are among the key technical barriers to the efficient uptake of BEVs in Australia.

3.3.1 Driving Range Limitations

Driving 'range anxiety' is a BEV related concern that has been identified in a number of surveys in Australia. This concern may be exacerbated by the lack of public charging infrastructure discussed earlier, particularly considering that drivers are accustomed to being able to easily access fuel stations and to refuel infrequently.

Vehicle manufacturers have responded to this primarily through development of Plug-in Hybrid Electric Vehicles (PHEVs) and Range Extended Vehicles (REVs), and increasing battery capacities to achieve longer driving ranges. OEMs are also looking to providing their own charging solutions to assist vehicle buyers in overcoming driving 'range anxiety'. For example, BMW in Australia offers i3 and i8 drivers access to ChargePoint's network of public charging stations. As shown in Table 5, while most of the vehicles fall short of the range of a petrol vehicle, Tesla's two models are comparable.

Table 5 – Driving Range and Battery Capacity for a Sample of BEVs

Make	Model	Elec Range (km)	Battery Capacity (kWh)
Ford	Focus	130	23
Mini	E	240	35
Mitsubishi	iMiEV	125	16
Toyota	RAV-4	165	42
Tesla	Model S	500	85
Tesla	Roadster	395	53
Renault	Zoe	210	31
Nissan	Leaf	118	24
Average		235	39

Source: Energeia

Based on our analysis of trends in vehicle ranges, Energeia concludes that the market appears to be responding to the perceived or actual barrier to BEV adoption.

As NGVs are able to travel a comparable range as petrol vehicles, it is not considered to be an issue.

3.3.2 Charge Time Limitations

Vehicle owners are accustomed to being able to completely refuel their ICE vehicles in less than 5 mins. Current EV owners can expect 4 to 8 hour recharging times using Level 1 or 2 chargers. The lack of available fast charging infrastructure has therefore been mentioned by some as a barrier to efficient BEV uptake in Australia[38].

Energeia's analysis of this potential barrier has found that it would mainly apply to drivers travelling long distances on a regular basis and therefore needing to charge within the day and not just overnight. This is more likely to be an issue for light duty commercial vehicles used for local transportation, which are on the road much of the day and need to refuel frequently. Energeia also notes that for some vehicle owners that the charging and driving range limitations may result in current models of EVs not being a suitable solution for their driving needs.

Faster Level 3 DC chargers have been developed to reduce recharging times dramatically. A level 3 charger is reported to be able to refuel a BEV to 80% of capacity in around 15-20 minutes. This is still 3-4 times longer than a petrol vehicle, but within the realms of the duration of a rest stop when travelling longer distances or suitable for everyday drivers whilst shopping or during sports or recreational activities.

[38] AECOM, *Forecast Uptake and Economic Evaluation of Electric Vehicles in Victoria*, 2011, Pg. 53,

While there is a lack of level 3 chargers in Australia, Energeia's analysis has found no barriers to a market led deployment of level 3 chargers in Australia. Nor have Energeia been able to determine from our research that the lack of fast charging is likely to represent a material barrier to the efficient adoption of BEVs beyond 2025.

As NGVs are able to refuel in a comparable timeframe as petrol vehicles, it is not considered to be an issue.

4 Review of Policy Options and Settings

Leading international jurisdictions have implemented a range of policies to address one or more of the barriers discussed in Section 3, typically in response to a perceived market failure. Energeia has undertaken a wide review of these policies to help identify the optimal mechanisms and settings for addressing Australia's barriers.

The results of Energeia's review of key international and Australian policy and regulatory settings is summarised in Table 6 below. Our review focused on a spectrum of countries including those that are recognised leaders in AFV markets (Norway, Netherlands and California); leading OEM manufacturers (US, Germany, Japan); major vehicle markets (US, China, Japan, EU, India) and emerging leaders (US states of Georgia and Oregon, UK).

Table 6 – EV Policy Support Measures in Leading Countries

	Policy Type	CA	OR	GA	US	CAN	EU	DE	NL	NO	UK	JP	CH	IN	AU	Score
Supply side	Vehicle Target	✓	✓	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓	✗	10
	Infrastructure Target	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	2
	Transport GHG Target	✓	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	2
	R&D Funding	✓	✗	✗	✓	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	3
	Career Training	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	4
	Manufacturer Incentives	✓	✓	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	3
	Emissions Standards	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	14
Demand side	Tax Credit/Exemptions	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✗	✓	12
	Fuel Tax Exemption	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	1
	Direct Vehicle Incentive	✓	✗	✗	✗	✓	✗	✗	✓	✗	✓	✓	✓	✓	✗	7
	Infrastructure Incentive	✗	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	3
	Registration Incentives	✓	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✓	3
	Government Fleet Incentives	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	4
	Vehicle Lane Privileges	✓	✗	✓	✗	✓	✗	✗	✗	✓	✓	✗	✗	✗	✗	5
	Indirect Vehicle Incentives	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	1
	Parking Incentives	✓	✗	✓	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	3
	Charging Incentives	✓	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	2
	Score	15	7	8	9	6	2	3	4	5	5	5	4	3	4	75

CA=California; OR=Oregon; GA=Georgia; CN=Canada; EU=Europe; DE= Germany; NL=Netherlands; NO=Norway; UK=United Kingdom; Japan=JP; CH=China; IN=India; AU=Australia

Legend
Highest Policy Activity
High Policy Activity
Medium Policy Activity
Low Policy Activity

Our research and analysis shows that a wide variety of policies have been implemented around the world to date. However, only a handful of them have been implemented by more than a few counties. Most of the leading jurisdictions in terms of BEV uptake have implemented five or more policies.

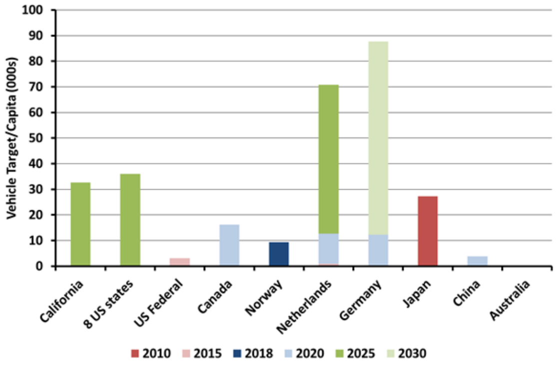
The following sections detail how international jurisdictions have implemented BEV and NGV policies to date.

4.1 International Policy Measures

The establishment of national targets for vehicle uptake is often the centre piece of most international government policy support frameworks for EVs. The range of government measures and their relative settings are then crafted to achieve the target, including the overall level of government investment. Alternatively, governments may choose a level of funding and determine the potential uptake target that may be achieved.

Figure 18 compares targets on a per capita basis implemented by leading national and regional governments. Germany with its target of 5 million EVs on the road by 2030 represent the most ambitious target to date, followed by the Netherlands, California, eight US states and then Japan.

Figure 18 – EV Uptake Targets by Time



Source: Energeia

Progress towards AFV uptake targets is reported in Table 7 as either ahead (green), on (orange) or behind (red) schedule assuming a linear progression. Interestingly, the only countries on track to reach their targets are also the two countries with the highest demand side incentive, as shown in Table7 below.

Table 7 – Progress Against EV Deployment Targets in Leading Jurisdictions

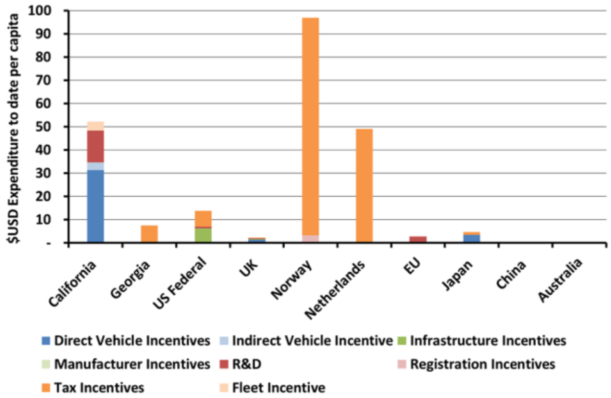
Jurisdiction	Program	Target	Progress
Germany	*National Electromobility Development Plan*	1 million EVs by 2020, and up to 5 million by 2030[39]	24,000[40] plug-in electric vehicles as of December 2014
Netherlands	*Cijfers Elektrisch Vervoer*	15,000-20,000 EVs by 2015; 200,000 EVs by 2020; and 1 million EVs by 2025[41]	43,060 plug-in vehicles sold to date
California	*Zero Emission Vehicles Plan*	1 million ZEVs by 2020 and 1.5 million ZEVs by 2025[42]	118,352 plug-in EVs to date[43]
Japan	*Clean Energy Vehicles Introduction Project*	3.5 million clean vehicles by 2010 incl. 110,000 EVs; 2.1m hybrid and fuel cells; and 1m CNG vehicles[44]	2010 target was missed, only achieving 40% of the target[45]
8 US States[46]	*State Zero-Emission Vehicle Programs*	3.3 million ZEVs by 2025[47]	Progress not available
Canada	*EV Technology Roadmap for Canada*	600,000 plug-in EVs by 2020[48]	8,500[49] registered electric vehicles as of September 2014
Norway	*EV Norway*	50,000 BEVs by 2018	To date have achieved almost 90% of rollout[50]
US Federal	*One Million Electric Vehicles By 2015*	1 million by 2015	300,000 BEVs and PHEVs sold to date in US[51]
China	*Twelfth Five-Year Plan*	500,000 EVs by 2015, 5 million by 2020[52]	By 2014, 90,000 EVs sold in China

Source: Various Government EV Program websites

[39] Germany Trade and Invest, Electromobility in Germany: Vision 2020 and Beyond, 2014, pg. 21
[40] *REneweconomy* website, accessed 6th February 2015, http://reneweconomy.com.au/2014/million-evs-germany-2020-merkel-says-yes-16488
[41] Dutch Government, *Cijfers Elektrisch Vervoer*, 2013, pg. 2
[42] Governor Edmund G. Brown Jr, *2013 Zero Emission Vehicle Action Plan*, February 2013
[43] *PEV Collaborative* website, accessed 6th February 2015, http://www.pevcollaborative.org/
[44] JARI, For the next generation: EV, HEV and FCV, 2003, pg. 1
[45] International Energy Agency, *Global EV Outlook 2013*, 2013, pg. 4
[46] These states are California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island and Vermont
[47] California Environmental Protection Agency – Air Resources Board, *News Release #13-70*, 24th October 2013
[48] *Market Wired* website, accessed 6th February 2015, http://www.marketwired.com/press-release/electric-vehicles-canada-surprising-gains-missed-opportunity-new-wwf-report-shows-both-1848540.htm
[49] *WWF* website, accessed 6th February 2015, http://www.wwf.ca/conservation/global_warming/transportation/electric_vehicles__where_are_we_now_/
[50] *EV Norway* website, accessed on 3rd February 2015, http://www.evnorway.no/#/now
[51] Electric Drive Transport Association, *Electric Drive Sales*, accessed on 4th February 2015, http://electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952
[52] Marquis, C, Zhang, H and Zhou, L, *China's Quest to Adopt Electric Vehicles*, Stanford Social Innovation Review, 2013, Pg 52

Figure 19 shows the AFV policy expenditure per capita in leading jurisdictions, illustrates that Norway, followed by California and Netherlands, have the highest per capita policy spend.

Figure 19 – EV Policy Expenditure per Capita to Date for Leading Jurisdictions



Source: Various Government EV Program websites

Also of interest is that over 80% of international government expenditure on EV policy supports has been focused on the demand side as either direct or tax incentives. Only the EU and California are reported to have made major investments in supply side measures.

4.1.1 Supply Side Measures

Leading international jurisdictions are introducing a range of supply side measures to support the deployment of AFVs including:

- Skills training to enable the workforce to support the design, development and diffusion of technologies
- Research & Development (R&D) programs which aim to achieve AFV technology breakthroughs
- Incentives for manufacturers to increase the supply and reduce production costs of AFV technology
- Standards which drive down the allowed emission intensity of vehicles, indirectly supporting AFVs

This section provides an overview of current supply side measures being implemented by leading jurisdictions.

4.1.1.1 Skills Training

While AFVs have many of the same vehicle components as ICE vehicles, they also have specific drivetrain components, such as lithium-ion batteries for EVs or fuel cells for hydrogen powered vehicles. As a result specialist skills are required to be employed in AFV manufacturing, maintenance and repair.

The US has a number of Federal funded training and education programs to provide the workforce with the required specialist skills and knowledge[53,54]. California also funds its own training programmes[55,56].

4.1.1.2 R&D Funding

Governments typically invest in AFV R&D to gain a long-term competitive advantage in the automotive industry. The majority of funding listed in Table 8 is focused on EV battery, alternative fuels and refuelling infrastructure technologies. The relative spend on R&D subsidies for AFVs is relatively low.

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[53] Training programs and centres include Clean Vehicle Education Foundation; National Alternative Fuels Training Consortium; National Institute for Automotive Service Excellence; Advanced Electric Drive Vehicle Education Program; and Natural Gas Vehicle Institute

[54] US Department of Energy – Alternative Fuels Data Center website, *Technician Training for Alternative Fuel*s, accessed on 4th February 2015, http://www.afdc.energy.gov/vehicles/technician_training.html

[55] Clean Technology and Renewable Energy Job Training, Career Technical Education, and Dropout Prevention Program provides grant funding to school districts for occupational training programs that focus on employment in clean technology businesses, such as AFV technologies

[56] US Department of Energy – Alternative Fuels Data Center website, *Alternative Fuel and Advanced Vehicle Career Training,* accessed on 4th February 2015, http://www.afdc.energy.gov/laws/11162

Table 8 – Key R&D Funding Initiatives

Jurisdiction	Program	Funding	Description
California	*Alternative and Renewable Fuel and Vehicle Technology Program*	US$100m p.a.	California Energy Commission's program supports a broad scope of fuel, drivetrain and refuelling infrastructure technologies through grants/ loans[57]
US Federal	*Low and Zero Emission Vehicle Research, Demonstration, and Deployment Funding*	US$70m in FY14	US DOE program providing funding for up to 80% of project costs supporting R&D and deployment of low/zero emission public transportation vehicles[58]
EU	*European Green Vehicles Initiative*	Funding through *Horizon 2020*[59] and EIB loans	Public-private partnership backed by the European Commission supporting R&D of technologies focusing on improving efficiency of alternative vehicles
UK	*Low Carbon Vehicles Innovation Platform*	Funding through *Innovate UK*[60]	Public-private partnership backed by *Innovate UK* includes a university research program and support for production of low carbon demonstration vehicles
Australia*	*Green Car Innovation Fund* *closed in 2011	$1 of funding for every $3 invested	Planned to support projects enhancing R&D and commercialisation of Australian technologies reducing fuel use/GHG emissions of passenger vehicles[61]

4.1.1.3 Manufacturer Incentives

Governments in the US, Germany, UK, Japan and South Korea have recognised the opportunity for supporting jobs and economic growth through offering incentives to the domestic automotive manufacturing industry to invest in the development of AFVs. They are providing strong incentives to manufacturers with a view on achieving production economies of scale and price parity with ICE vehicles.

The most prominent example of manufacturer incentives for AFVs is the California's *Zero Emission Vehicle (ZEV) Plan.* This policy includes a requirement for all OEMs with new vehicle sales in California over a certain volume threshold to sell a proportional quota of ZEVs or clean vehicles[62]. An OEM's ZEV requirement is based on a calculated percentage of all passenger cars and light-duty trucks that are delivered for sale in California.

OEMs that do not meet the ZEV requirement (reflected as a credit balance[63]) in a given year will have a credit deficit, and can purchase credits from other manufacturers with a positive balance in order to fulfil their credit requirements. This has provided an opportunity for smaller volume OEMs, such as Tesla, who specialise in manufacturing EVs to earn revenue through sale of ZEV credits.

ZEV revenue in effect acts as a subsidy on AFVs. The market price of ZEV credits has a ceiling of $5,000, which is the penalty value per credit paid by an OEM for not meeting their compliance requirements. This has been a significant source of revenue for Tesla, and the likes of Nissan who have had an 'over-compliance'[64].

The US Federal Government also recognised the opportunity during the recent global financial crisis (GFC) for stimulating growth and jobs through supporting the development of AFV manufacturing. For example, the US, through the 2011 Recovery Act, committed to investments in AFV manufacturing industry by providing:

[57] California Energy Commission website, *Alternative and Renewable Fuel and Vehicle Technology Program*, accessed on 4th February 2015, http://www.energy.ca.gov/altfuels/

[58] US Department of Energy – Alternative Fuels Data Center, *Low- and Zero-Emission Vehicle Research, Demonstration, and Deployment Funding,* accessed on 4th February 2015, http://www.afdc.energy.gov/laws/11552

[59] *Horizon 2020* is the EU's Research and Innovation program with $80 billion funding up to 2020, accessed on 4th February 2015, http://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020

[60] *Innovate UK* is the Government's Technology Strategy Board with £536 million in funding for 2014-15, accessed on 4th February 2015, https://www.gov.uk/government/organisations/innovate-uk/about

[61] Australian Government Department of Business, *Green Car Innovation Fund*, accessed on 4th February 2015, http://www.business.gov.au/grants-and-assistance/closed-programs/gcif/Pages/default.aspx

[62] Applicable vehicle types include ZEVs (such as battery EVs, fuel cells) and clean vehicles (such as clean plug-in hybrids, clean hybrids and clean gasoline vehicles with near-zero tail pipe emissions).

[63] Credits are in units of grams per mile Non-Methane Organic Gases (g/mi NMOG). Clean vehicles are assigned a credit multiple value based on their g/mi NMOG, whereby EVs or fuel cell vehicles have the highest credit value because they have the lowest g/mi NMOG.

[64] Ohnsman, A, BloombergBusiness, *Nissan Joins Tesla Selling California Green-Car Credits*, 30th Aug 2013, http://www.bloomberg.com/news/articles/2013-08-29/nissan-joins-tesla-selling-california-green-car-credits

- US$2.4 billion in loans to three EV factories in Tennessee, Delaware and California;
- US$2 billion in grants to support 30 factories that produce EV batteries, motors and components[65].

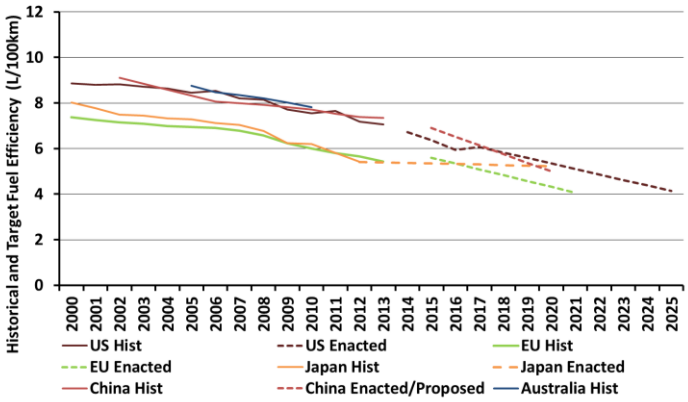
Another common form of manufacturer incentives are tax breaks or credits. For example, in Georgia, manufacturers of products for use in battery, biofuel, and EV businesses may claim an annual tax credit for five years. The amount of the tax credit is based on the number of eligible new full-time employee jobs.

4.1.1.4 Vehicle Emissions and Fuel Efficiency Standards

Vehicle emissions standards can support the AFV market. Emission standards impose limits on emissions of carbon monoxide, particulates and nitrogen oxide (NOx) for different types of vehicles. In order to comply with emission standards, some OEMs subsidise and market AFVs as a low cost approach to improving the average fuel efficiency of their fleets.

The major international vehicle markets of the US, Japan, China, the EU and Japan continue to raise the bar on minimum emissions and fuel efficiency standards for new vehicles. As a result of tightening standards these jurisdictions, as well as Australia, have achieved significant improvements in the average fuel efficiency of their vehicle fleets over the last fifteen years, as shown by the solid chart lines in Figure 20.

Figure 20 – Historical Fuel Efficiency and Future Targets for Passenger Vehicles



Source: International Council of Clean Transportation

In addition, these jurisdictions are introducing more stringent GHG emissions intensity targets out to 2020 and 2025, which also drive improvements in fuel efficiency. Figure 20 also shows (dashed lines) that the EU is leading the way with the most ambitious targets, followed by the US and China. Japan's vehicle fleet is currently amongst the most fuel efficient, however its targets are less ambitious than US, EU and China.

These targets will continue to put significant pressure on vehicle OEMs to reduce the average emissions intensity of their products over the next five to ten years. AFVs could play a significant role in meeting these targets.

4.1.2 Demand Side Measures

Figure 21 below shows that leading jurisdictions are introducing a range of incentives to assist buyers in overcoming the barriers of relatively high costs of AFVs including:

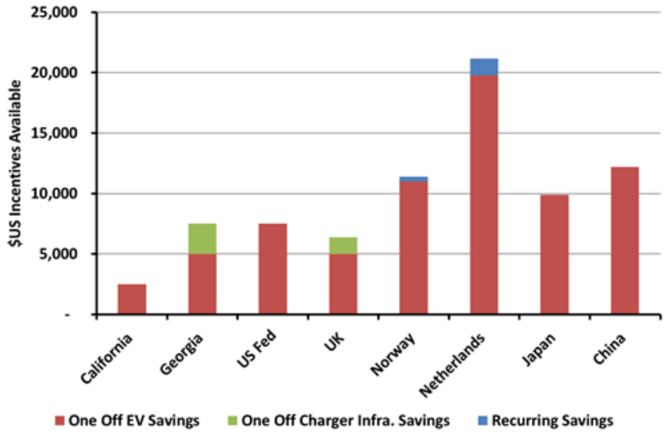
- Tax incentives
- Direct vehicle subsidies
- Charging infrastructure incentives
- Vehicle lane and parking privileges
- Indirect vehicle subsidies

[65] US Department of Energy, One Million Electric Vehicles by 2015: February 2011 Status Report, 2011, accessed on 4th February 2015, http://www1.eere.energy.gov/vehiclesandfuels/pdfs/1_million_electric_vehicles_rpt.pdf

- Charging incentives

As seen in Figure 21, Netherlands currently offers the highest level of incentives per EV, primarily through motor vehicle duty exemptions. Followed by Norway, which grants a full GST exemption on BEVs, and China, which offers high vehicle subsidies for BEVs and PHEVs.

Figure 21 – Demand Side Incentives Available per Vehicle for Leading Jurisdictions



Source: Various Government EV Program websites

The following sections detail the range of international demand side policy measures to support AFV uptake.

4.1.2.1 Tax Incentives

Tax breaks for AFVs, which are widely implemented in international jurisdictions, come in a variety of different forms. These tax incentives can be grouped into four main categories:

- Goods and Services Tax (GST) breaks;
- Motor vehicle duty or stamp duty fee discounts;
- Annual registration fee discounts;
- Company car tax breaks.

GST or VAT Breaks

GST or Value Added Tax (VAT) is generally applied in all countries considered in this analysis when purchasing a new vehicle. Due to the relatively higher purchase price of EVs, they pay a higher level of tax. Norway is the only government which offers a full VAT exemption on BEVs in Norway.

Motor Vehicle Duty Breaks

Motor vehicle duty (also known as stamp duty or purchase tax) is an additional up-front cost when buying a vehicle. In Australia, state transport authorities typically charge according to the price tag and weight of the vehicle. However in countries, such as UK, Netherlands and Norway, factors like the CO_2 emissions rating of the vehicle are considered. Norway, UK and Japan offer full stamp duty exemption for BEVs. In Japan this extends to PHEVs. Table 9 below provides a cross-country comparison of motor vehicle duty incentives.

Annual Registration Fee Discounts

Most jurisdictions considered in this review charge an annual licensing fee. Discounts or exemptions on these fees for AFVs provide vehicle owners with a recurring benefit. As per Table 9 below, Japan and China exempts EVs from its annual registration fee[66]. Netherlands and Germany charge registration fees according to the emissions intensity of the vehicle.

[66] Exemption applies to Japan's annual tonnage tax. Also a 50% exemption for EVs on automobile tax

Company Car Tax Breaks and Rebates

Company cars are widely used in Europe, particularly in countries such as Germany where over 60% of all passenger vehicles registered in 2013 were company cars[67]. Table 9 below shows that Germany, Netherlands and UK offer incentives on private use of a company car that is an AFV. In Germany for example, the Government offers a rebate of €500/kWh[68] of battery size for EVs, up to a max of €10,000. This was introduced to offset the 1% monthly tax of the vehicle's gross sales price associated with private use of a company car.

Table 9 –Tax and Subsidy Schemes in Leading Jurisdictions

Jurisdiction	Tax		Subsidy
	One-off	Annual recurring	One-off
Norway	• 100% GST exemption for BEVs, 25% for PHEVs • Motor vehicle duty based on vehicle weight, engine power, nitrogen oxide emissions, and CO_2 emissions. BEVs are exempted.	Registration fee about $515	
Netherlands	Motor vehicle duty based on the CO_2 emission level of the vehicle. BEVs and most PHEVs are exempted.	Registration fee based on the vehicle weight, fuel type, and CO_2 emission. BEVs and most PHEVs are exempted. • [Company car] Income tax for cars emitting more than 50 g/km CO_2 of 25% of the vehicle's catalogue value in 2013. BEVs and some PHEVs are exempted.	
UK	Motor vehicle duty based on the CO_2 emission and vehicle price. BEVs and some PHEVs are exempted	[Company car] Income tax based on CO_2 emission and price. BEVs are exempted.	Up to $9,800 for BEVs and some PHEVs
Germany		• Registration fee based on engine displacement and CO_2 emission. EVs are exempted for 10 years. • [Company car] Income tax based on price. EVs have deductions.	
China	• Acquisition tax (10%) • Excise tax based on vehicle engine displacement and price.	Registration fee based on engine displacement and price. EVs are exempted.	Up to $11,300 for BEVs, and $6,170 for PHEVs
US (incl. California)	• Registration fee around $50 • Gas-guzzler tax for very fuel-inefficient vehicles		• Up to about $9,600 based on battery capacity (federal); • About $3,200 for BEVs and $1,900 for PHEVs (Calif.).
Japan	Acquisition tax based on engine displacement and vehicle price. EVs are exempted.	• Tonnage tax based on vehicle weight. EVs are exempted; • Automobile tax based on engine displacement. EVs are exempted 50%	Up to about $9,500 based on price difference for EVs

Source: International Council of Clean Transportation

4.1.2.2 Direct Vehicle Subsidies

In absolute terms, China currently offers the highest one-off direct (non-tax incentive) subsidy of up to $11,300 on purchases of new BEVs. Vehicle buyers in California can receive up to $11,000 if they receive both the State and Federal subsidies. The US Federal subsidy program depends on the battery capacity of the vehicle. Japan's subsidy program for EVs and certain fuel-efficient vehicles, provides a bonus based on the price differential with a comparable petrol car as published by the government. UK vehicle buyers can receive a one-off bonus up to 25% of the car's value.

[67] Mock, P and Yang, Z, Driving electrification: a global comparison of fiscal incentive policy for electric vehicles, International Council of Clean Transportation, 2014, pg. 9

[68] Total amount offset declines at €50/kWh per year

4.1.2.3 Charging and Refuelling Infrastructure Incentives

Governments are providing incentives to support development of AFV refuelling and charging infrastructure, in order to overcome the perceived barriers associated with lack of refuelling infrastructure and drive range limitations discussed in Section 3. Policy support has contributed to expansion of public charging networks and growth of fast charging transport corridors as seen in Norway and the West Coast Electric Highway in the US.

The US has a Federal program providing tax credits to businesses investing in natural gas refuelling and EV charging equipment. In addition, Oregon and Georgia have introduced their own state based tax credit incentives for qualified alternative fuel infrastructure projects. Oregon and California also have leasing and subsidy programs which reduce the costs of natural gas vehicle refuelling systems for the home.

EU countries have also been actively supporting development of charging networks. The UK has a grant programme offering funding for plug-in charging stations located at home and in public. Belgium provides tax deductions of up to 40% for investments in public charging stations.

4.1.2.4 Vehicle Lane and Parking Privileges

Governments are also introducing 'soft' privileges to AFV owners to encourage a switch from ICE vehicles. These measures include parking privileges such as free parking as well as access to preferential parking for AFVs. California has introduced designated parking bays for AFVs in government operated public parking facilities. In Denmark, EV owners can access free parking in downtown Copenhagen.

Vehicle lane privileges for AFVs are another policy measure being used by governments in high traffic congestion areas to incentivise buyers to purchase an AFV. In California, CNG, hydrogen fuel cell vehicles, BEVs and PHEVs can gain access to High Occupancy Vehicle (HOV) lanes regardless of the number of occupants. Ontario and the US state of Georgia offer similar privileges.

In a recent survey of California AFV owners receiving the state's monthly subsidy, 15% of respondents noted HOV lane access as the primary motivation for purchasing an EV[69]. This indicates that these types of privileges can act as a strong incentive to purchase AFVs.

In the UK, vehicles that emit less than 75g CO_2/km – which applies to all BEVs and PHEVs – are exempt from congestion charges in central London.

4.1.2.5 Indirect Vehicle Subsidies

Alternative Fuel Tax Incentives

In many countries, taxes on fuel contribute to a significant proportion of the prices paid at the pump. In Australia, for example, 38c in fuel excise duty is charged for every litre[70]. Lower tax rates on alternative fuels reduce the price gap with petrol and diesel. As examples of this, US Federal Government offers a tax credit of up to US50c per gallon for alternative fuels (such as CNG, LPG, biodiesel). Austrian government offers a tax exemption on fuel consumed by AFVs up to €800 per annum.

Insurance Rebate Incentives

Motor vehicle insurance, to protect vehicle owners against the financial costs associated with vehicle damage and bodily resulting from road accidents, can be a significant annually recurring cost. Discounts and rebates on insurance premiums for vehicle owners can reduce the lifetime costs of AFVs. The Saskatchewan Government in Canada offers a 20% rebate on insurance premiums for hybrids and fuel efficient vehicles.

4.1.2.6 Charging Incentives

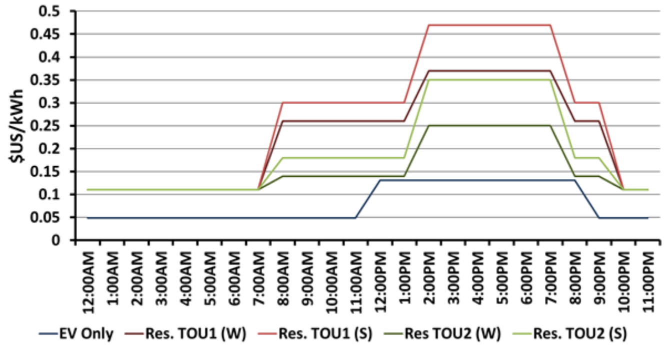
Electricity utilities are being required in some jurisdictions to offer cheaper off-peak rates for EV charging. A number of California based utilities, such as Southern California Edison (SCE), Sacramento Municipal Utility

[69] Centre for Sustainable Energy, *EV Consumer Survey Dashboard*, accessed on 6th Feb 2015, http://energycenter.org/clean-vehicle-rebate-project/survey-dashboard

[70] Australian Institute for Petroleum website, *Facts about petrol prices and the Australian market*, accessed on 6th Feb 2015, http://www.aip.com.au/pricing/facts/Facts_about_Petrol_Prices_and_the_Australian_Fuel_Market.htm

District (SMUD) and Pacific Gas & Electricity Company (PGE) have introduced Time-of-Use (ToU) product offerings with discounted tariff rates for EV charging during off peak periods through dedicated meters.

Figure 22 – Southern California Edison Residential Time of Use Tariffs for EV and non-EV customers



Source: Southern California Edison Schedule ToU-EV-1

Figure 22 shows electricity rates for SCE EV charging under a number of tariff options.

4.2 Australian Policy Measures

As shown in Table 6, Australia continues to lack a comprehensive AFV policy framework at the Federal level and is lagging behind its international peers in terms of the overall level of support. Virtually all activity over the past four years has been at the state level. The key Australian Government development to date has been aligning vehicle emissions standards with Europe to improve fuel efficiency and lower emissions intensity.

The following sections review key Federal and state policy measures relevant to AFVs in Australia.

4.2.1 Supply Side Measures

4.2.1.1 R&D Funding

Green Car Innovation Fund

In April 2009 the Australian government opened the Green Car Innovation Fund to provide assistance to Australian companies for projects that enhance the research, development and commercialisation of Australian technologies that significantly reduce fuel consumption and/or greenhouse gas emissions of passenger vehicles.

Grants were provided at a ratio of $1 of government funding for every $3 of eligible expenditure, contributed by the grantee. However, the Green Car Innovation Fund was closed in 2011 due to “Government's saving measures to support the rebuilding of infrastructure damaged by the floods over large areas of eastern Australia”. Although the program is closed to new applications, as of 30 June 2012, the GCIF had committed funding of $411.26 million to Australian companies under the program with the largest single grant of $149 million to GM Holden to develop its Cruze low emissions car[71].

4.2.1.2 Skills Training

Australian Government’s National Register on Vocational Education and Training currently recognises three qualifications specific to the repair of electric vehicles and/or CNG and LNG vehicles.

The Certificate III in Automotive Alternative Fuel Technology was introduced in 2013 and is currently offered by five training providers in NSW and Victoria[72,73].

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[71] Australian Government Department of Innovation, Science, Research and Tertiary Education, *Innovation Australia Annual Report 2011–12*, Accessed on 3rd Feb 2015, <http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22publications%2Ftabledpapers%2F67798%22>

[72] training.gov.au website, *Certificate III in Automotive Alternative Fuel Technology (AUR32012)*, accessed on 4th February 2015, http://training.gov.au/Training/Details/AUR32012

[73] myskills.gov.au website, Certificate III in Automotive Alternative Fuel Technology (AUR32012), accessed on 4th February 2015, http://www.myskills.gov.au/courses/details?Code=AUR32012

A range of other qualifications under the Automotive Industry Retail, Service and Repair Training Package, including the Diploma in Automotive Technology, include electives related to the manufacture and repair of EVs.

4.2.1.3 Vehicle Emissions Standards

Current vehicle emission standards impose limits on emissions of carbon monoxide, particulates and nitrogen oxide (NOx) for different types of vehicles.

Australia is currently converging its vehicle emissions standards with progressive EU standards, albeit on a lagged basis. The Euro 5 emission standards started being introduced in November 2013 for new model vehicles and from November 2016 will apply to existing models. In addition, Euro 6 emissions standards will commence for new model vehicles from July 2017 and for existing models in Australia from July 2018.

4.2.2 Demand Side Measures

4.2.2.1 Tax Incentives

Federal Luxury Car Tax Break for Fuel Efficient Vehicles (1999)

The Luxury Car Tax has been in place in Australia for over fifteen years. Under this law cars that are purchased or imported that are above a threshold value are subject to a higher tax rate (33%) for the proportion that exceeds the threshold. Fuel efficient vehicles are allowed a higher threshold value of $75,375 in 2014-5 compared to $60,136 for other vehicles. This is a financial benefit for premium priced EVs or NGVs.

If we consider the 60kWh Tesla Model S which currently retails at $98,500 before tax, a buyer would currently save about $3,500 due to the higher threshold under the Luxury Car Tax. Given the limited number of AFV models sold in Australia above this threshold, it is not likely to have a significant impact on EV uptake in the short term. For comparison, if Australia adopted a policy of full GST exemption for AFVs as Norway have for BEVs, there would be an additional saving of $15,170 for a Tesla Model S at current retail prices.

Federal Alternative Fuel Tax Breaks

Australian Government previously offered a fuel grant for alternative fuels through its energy grants credits scheme (EGCS). Fuel grants could be claimed by businesses for the purchasing LPG, LNG, CNG, ethanol and biodiesel. However the EGCS was repealed in July 2012 and claims are no longer accepted[74].

The ACT government's Green Vehicles Duty Scheme provides a stamp duty discount based on a vehicle's GHG and air pollution ratings to influence customers at the time of purchasing new light vehicles. Vehicles with A-rating are exempt from stamp duty. The scheme then charges a progressively higher stamp duty rate as a vehicle's emissions and air pollution ratings decrease, thereby providing an indirect incentive to AFVs. For example, buyers of a Mitsubishi iMiEV will save about $2,000 compared to the worst ranked category, which while relatively modest, remains the most generous in Australia.

ACT also offers a vehicle registration discount, whereby gas and electric powered vehicles are entitled to a 20% reduction on registration fees[75].

Victoria

Victorian hybrid passenger vehicle drivers currently receive a $100 discount on their annual registration fees[76].

[74] Australian Taxation Office, *Energy grants credit scheme – alternative fuels*, accessed on 6th Feb 2015, https://www.ato.gov.au/Business/Fuel-schemes/In-detail/Energy-grants-credits-scheme---reduced-to-zero/About/Energy-grants-credits-scheme---alternative-fuels/

[75] ACT Government Road Transport Authority, *Registration – Concessions* website, Accessed on 3rd Feb 2015, http://www.rego.act.gov.au/registration/concessions#d

[76] VicRoads website, *Vehicle registration fees*, Accessed on 4th Feb 2015, https://www.vicroads.vic.gov.au/registration/registration-fees/vehicle-registration-fees

4.2.2.2 Emissions Reduction Incentives

Emission Reduction Fund

The Emission Reduction Fund (ERF) was introduced in 2014 as the Coalition Government's central policy for reducing GHG emissions, replacing the Labour-backed Clean Energy Act (2011) which was repealed in July 2014. The ERF will offer incentives to reduce emissions from Australia's transport sector, which represents 15% of Australia's annual emissions[77].

Previously, the Clean Energy Act's carbon tax and subsequent cap-and-trade emissions trading scheme excluded transport liquid fuels but included electricity, effectively penalising EVs over ICE vehicles.

The ERF approved a transport methodology in February 2015, which credits GHG emission reductions achieved through a decrease in the emission intensity of transportation, rather than absolute emissions reductions. The methodology recognises abatement from a range of activities that reduce emissions intensity, including:

- replacing or modifying existing vehicles,
- fuel switching, or
- changes to operational practices.

The methodology targets large vehicle fleets such as hire car companies or public bus fleets, and therefore does not promote AFV uptake within the privately owned passenger vehicle fleet in its current form.

Based on Energeia's analysis using the fuel emission factors in this methodology, Section 2.2 showed that there is limited potential for crediting emission reductions from EVs in cases where electricity is sourced from the grid in all states excepting for Tasmania where the grid is largely powered by low carbon sources.

CNGVs could also offer a strong incentive for funding through the ERF as they have a significantly lower emissions intensity than petrol and diesel vehicles.

[77] Australian Government Department of the Environment, *Carbon Credit (carbon Farming Initiative) Methodology (Transport) Determination 2015 – Explanatory Statement*, February 2015, Pg. 2

5 Optimal Targets and Policy Measures

The following sections report on the results of Energeia's modelling of the net benefits of policy intervention for both passenger BEVs and NGVs compared to a no policy intervention scenario. From these results, the most cost effective mix of policy intervention is selected to provide an uptake target for both types of AFVs.

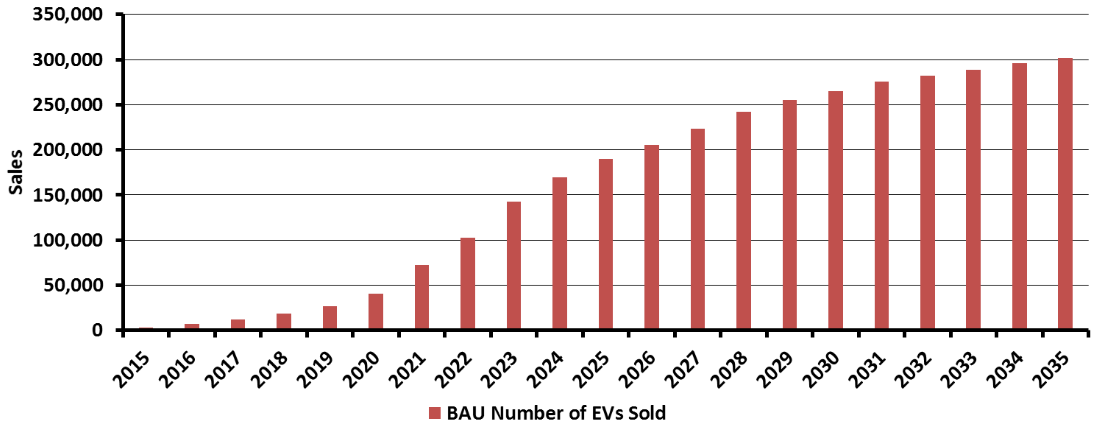
5.1 Electric Vehicles

5.1.1 No Policy Intervention

Energeia's model of AFV uptake under a no policy intervention scenario is driven by financial return on investment and vehicle model availability over time[78]. Accordingly, our modelling shows EV uptake following a similar trend to HEVs and diesel vehicles under the baseline scenario.

For BEVs under this scenario, we expect sales to be slow until a 2% level of vehicle model availability is reached, after which time there is a period of relatively fast growth and a levelling off at around 33% of all models being BEVs. This driver, combined with a modest improvement in return on investment over time, gives rise to a steady increase in BEV sales as shown in Figure 23.

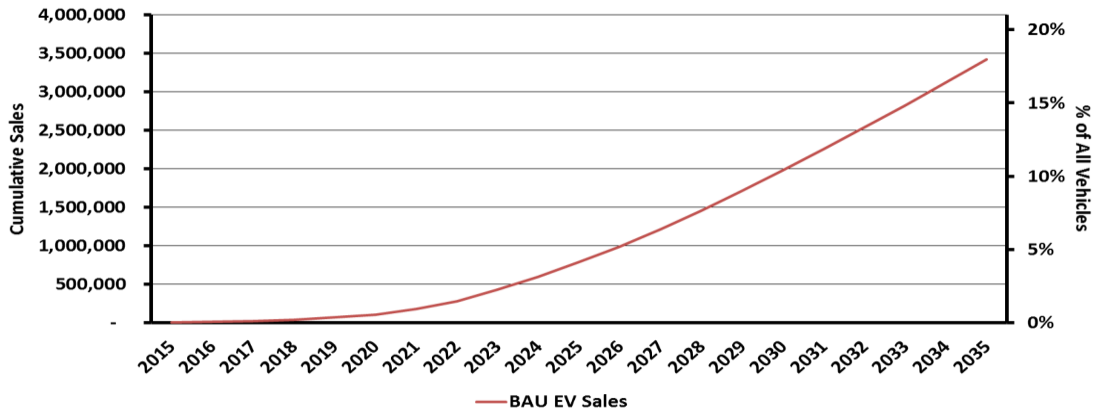
Figure 23 – No Policy Intervention EV Annual Sales



Source: Energeia

The year on year sales give rise to a total of over 3.4 million vehicles by 2035 representing over 18% of the Australian vehicle fleet as shown in Figure 24.

Figure 24 – No Policy Intervention EV Uptake



Source: Energeia

[78] Model availability is defined as the number of alternative vehicle models available compared to the total number of vehicle models available.

5.1.2 Policy Interventions

Energeia's analysis has considered five main policy interventions based on our research and analysis of overseas policy frameworks and settings in light of Australia's specific circumstances. A summary of the policy interventions modelled is described in Table 10 below.

Table 10 – Policy Interventions for Electric Vehicles

Policy	Market Failure	Modelled
Demand Side		
Upfront financial incentives which directly lower the purchase price of AFVs	Negative externalities Bounded rationality and imperfect information	Yes
Annual financial incentives which improve the financial return on investment for AFVs	Negative externalities Bounded rationality and imperfect information	Yes
Non-financial incentives or rights which improve the utility of the technology for the consumer	Negative externalities Bounded rationality and imperfect information	Yes (priority access lanes)
Education and awareness	Bounded rationality and imperfect information	No (lack of data)
Supply Side		
Financial incentives which directly lower the cost of vehicle manufacture or charging infrastructure	Negative externalities Bounded rationality and imperfect information	No (no market failure likely to exist)
Obligations which require manufactures and/or fuel supplier to meet certain requirements	Negative externalities Bounded rationality and imperfect information	Yes (vehicle standards and manufacturing quotas)
Education and awareness	Bounded rationality and imperfect information	No (lack of data)

5.1.2.1 Upfront Financial Incentives

Energeia's modelling shows that from an economic perspective, even when externalities are taken into account, upfront subsidies are unlikely to ever deliver a net benefit on their own. Energeia notes that this conclusion is based on quantifiable direct and indirect benefits only, and placing a value on unquantified community benefits from greater energy security, jobs or $GVA could change this result.

For illustrative purposes a $7,000 upfront subsidy, typical of the level of subsidy offered internationally, has been modelled. This capital subsidy showed the following net benefits.

Table 11 – Benefits of Upfront Financial Incentive Policy (EVs)

	Benefit Implementation Year			
Benefit Category	**2015**	**2020**	**2025**	**Units**
Gross Costs	-$25,161.9	-$24,698.0	-$21,220.1	$ M (2015)
Gross Direct Benefits	$4,081.0	$4,167.1	$4,145.5	$ M (2015)
Gross Indirect Benefits	$519.7	$515.0	$443.6	$ M (2015)
Net Direct Economic Benefits	-$21,080.8	-$20,531.0	-$17,074.5	$ M (2015)
Net Direct and Indirect Economic Benefits	-$20,561.2	-$20,016.0	-$16,630.9	$ M (2015)
Economic Growth	$7,586.3	$7,481.8	$6,207.4	$ M (2015) GVA
Employment	728	726	688	Jobs in 2035
Fuel Security Improvement	153,008.5	151,326.5	128,084.8	PJ (domestic)
GHG Savings	21,291.3	21,142.2	18,581.3	$ktCO_2$-e
Air Quality Improvement	532.6	528.6	464.3	tPM_{10}

This suggests that a $7,000 subsidy introduced in 2015 would cost $25 billion over a twenty year period but provide only $4.6 billion in benefits, the majority of which occur in later years. While government is likely to scale down the subsidy level over time, our modelling showed no level of subsidy was cost effective.

Interestingly, there is a large potential benefit of an EV subsidy in terms of GVA. Subsidising EVs encourages a greater amount of expenditure in domestic industries compared to ICEVs, where significant expenditure is on imports. The majority of the growth occurs in the electricity supply sector.

There is also an improvement in fuel security as a result of a transfer from predominantly imported oil based fuels to domestically sourced fuels for electricity generation. The subsidy resulted in increased employment due to a due to growth in jobs in the energy supply sector.

5.1.2.2 Annual Financial Incentives

Energeia modelled the net benefits of a range of indirect incentives including tax concessions, reduced registration fees, parking fees and tolls by estimating their annual financial value and then discounting them to present value, assuming they were available over the life of the vehicle.

As with direct incentives, due to the expected lack of quantifiable benefits from electric vehicles for the next 10 years, the modelling showed that from an economic perspective, even when externalities were taken into account, there was no net benefit for introducing any indirect subsidies even if delayed until 2030.

For illustrative purposes, the results reported below assume that registration fees would not be paid by electric vehicle users providing an effective annual subsidy of $283 per year (population weighted average of registration fees for small petrol vehicles in each state). The benefits of this policy are shown in Table 12 below.

Table 12 – Benefits of Annual Registration Concession Policy (EVs)

	Benefit Implementation Year			
Benefit Category	**2015**	**2020**	**2025**	**Units**
Gross Costs	-$2,603.5	-$2,549.2	-$2,189.8	$ M (2015)
Gross Direct Benefits	$207.4	$259.8	$268.0	$ M (2015)
Gross Indirect Benefits	$48.4	$45.8	$31.0	$ M (2015)
Net Direct Economic Benefits	-$2,396.1	-$2,289.4	-$1,921.8	$ M (2015)
Net Direct and Indirect Economic Benefits	-$2,347.7	-$2,243.6	-$1,890.8	$ M (2015)
Economic Growth	$775.3	$716.4	$447.7	$ M (2015) GVA
Employment	51	50	42	Jobs in 2035
Fuel Security Improvement	14,918.1	13,980.0	9,115.4	PJ (domestic)
GHG Savings	1,882.0	1,800.1	1,269.8	$ktCO_2$-e
Air Quality Improvement	47.4	45.2	31.9	tPM_{10}

This suggests that a $283 per year effective subsidy implemented in 2015 would cost the Australian economy $2.6 billion over a 20 year period but result in only $255 million in benefits, mainly in terms of domestic economic growth and fuel security. Again, this result does not reflect any value being attributed to the energy security, jobs or economic growth benefits of BEVs.

5.1.2.3 Non-Financial Incentives / Rights

Non-financial incentives or rights provide improved utility to the EV owner relative to an ICE owner. This could be in the form of access to restricted vehicle lanes or parking spots.

For the purpose of this analysis, a priority access lane incentive with assumptions of EV uptake associated with the increased utility taken from a survey of EV drivers within California who have implemented such a policy.

Due to its relatively low cost (essentially painting and maintaining of the bus and high occupancy vehicle lanes), the benefits of this policy are realised immediately, as shown in Table 13 below.

Table 13 – Benefits of Priority Access Lane Policy (EVs)

Benefit Category	Benefit Implementation Year 2015	2020	2025	Units
Gross Costs	-$165.5	-$118.0	-$84.1	$ M (2015)
Gross Direct Benefits	$277.9	$352.3	$364.1	$ M (2015)
Gross Indirect Benefits	$65.6	$62.0	$41.9	$ M (2015)
Net Direct Economic Benefits	$112.4	$234.3	$280.0	$ M (2015)
Net Direct and Indirect Economic Benefits	$178.0	$296.3	$321.9	$ M (2015)
Economic Growth	$1,049.5	$968.5	$605.6	$ M (2015) GVA
Employment	69	67	57	Jobs in 2035
Fuel Security	20,189.2	18,905.2	12,337.2	PJ (domestic)
GHG Savings	2,548.8	2,437.2	1,721.6	$ktCO_2$-e
Air Quality Improvement	64.2	61.2	43.2	tPM10

As with all other BEV policies, the priority access lane improves performance in environmental indicators, fuel security and economic growth.

5.1.2.4 Vehicle Emissions / Fuel Efficiency Standards

Energeia's modelling of the incremental costs and benefits of increasing vehicle emissions or fuel efficiency standards to bring Australia into line with international fuel efficiency targets shows a net benefit. The modelling assumes that the standard becomes mandatory on an individual vehicle basis rather than a fleet basis which results in a $17 increase in the price of a petrol vehicle.

This has a minor improvement on the return on investment for BEVs which drives higher uptake and over time. The low cost of this policy borne by the manufacturing sector provides a net benefit over time as shown in Table 14. The optimal year for aligning with international standards is 2023, which produces the greatest net benefit. Action would be required before this time to minimise the cost of the transition.

Table 14 – Benefits of Vehicle Emissions/Fuel Efficiency Standards (EVs)

Benefit Category	Benefit Implementation Year 2015	2020	2025	Units
Gross Costs	-$6.1	-$2.9	-$1.0	$ M (2015)
Gross Direct Benefits	$39.2	$26.9	$14.0	$ M (2015)
Gross Indirect Benefits	$4.9	$3.1	$1.4	$ M (2015)
Net Direct Economic Benefits	$33.1	$24.0	$13.0	$ M (2015)
Net Direct and Indirect Economic Benefits	$38.0	$27.1	$14.3	$ M (2015)
Economic Growth	$141.8	$91.1	$45.5	$ M (2015) GVA
Employment	208	144	86	Jobs in 2035
Fuel Security	1,445.4	889.4	387.3	PJ (domestic)
GHG Savings	202.6	128.3	59.8	$ktCO_2$-e
Air Quality Improvement	5.0	3.2	1.5	tPM10

There are other potential mechanisms to drive this policy such as application of emission or efficiency levels across a fleet. This could potentially drive further benefits by allowing for the most efficient options for manufacturers to improve fuel efficiency to be developed.

5.1.2.5 Manufacturing / Sales Quotas

Increasing the number of vehicles manufacturers are required to sell into Australia could be achieved in several ways where Australia either acts as a fast follower or a manufacturing leader. This policy could be enforced through introducing a regulated or tradeable quota system which requires manufacturers with sales above a certain threshold to make overseas AFV models available in the Australia market.

The modelling assumes that Australia acts as a "fast follower", closely monitoring the policy actions of international countries to increase the number of electric vehicle models, and then enacting similar policies in Australia once more vehicles become available within the global market.

The modelling assumes that such a policy would increase model availability to international levels and bring their availability into Australia forward by three years. For example, a policy effective in 2015 would increase the number of BEVs available in Australia from four (iMiEV, i3, Model S and Leaf) to ten.

The direct costs of such a policy would be close to zero, assuming that the R&D and commercialisation costs are borne by other governments elsewhere. There may be indirect costs to consumers as the increased sales requirement is subsidised across the fleet. For the purposes of this modelling, it is assumed that the cost of the vehicles does not increase as a result of the quotas, but the vehicle model availability does.

Overall, this policy gives rise to a small net benefit if in effect post-2023 as shown in Table 15. Again, action would be required much sooner than this timeframe to minimise the potential costs of implementation.

Table 15 – Benefits of Overseas Model Availability Regulations (EVs)

	Benefit Implementation Year			
Benefit Category	**2015**	**2020**	**2025**	**Units**
Gross Costs	-	-	-	$ M (2015)
Gross Direct Benefits	-$534.2	-$96.1	$9.0	$ M (2015)
Gross Indirect Benefits	$43.1	$23.0	$1.5	$ M (2015)
Net Direct Economic Benefits	-$534.2	-$96.1	$9.0	$ M (2015)
Net Direct and Indirect Economic Benefits	-$491.1	-$73.1	$10.5	$ M (2015)
Economic Growth	$898.4	$435.1	$24.4	$ M (2015) GVA
Employment	19	11	1	Jobs in 2035
Fuel Security	14,963.8	7,655.1	472.8	PJ (domestic)
GHG Savings	1,429.4	798.1	57.5	ktCO_2-e
Air Quality Improvement	37.2	20.1	1.5	tPM10

An Overseas Model Availability regulation could also be implemented ahead of other jurisdictions, establishing Australia as a leader in alternative fuel technology vehicles. Such a policy would require overseas manufacturers to develop new models to bring to the Australian market with an estimated approximate cost of $600 million[79] per new vehicle model. This cost would in part require a subsidy in order to reduce the cost burden on OEMs.

The modelling suggest that with a subsidy of this size, there are unlikely to be net economic benefits in the foreseeable future. The impact of such a policy in terms of providing stimulus to the Australian vehicle manufacturing sector is not within the scope of this assessment.

[79] Estimate based on Australian Government subsidy of GM Holden's Cruze low emission vehicle under the Green Car Innovation Fund

5.1.2.6 Provision of EV Charging Infrastructure

The provision of charging infrastructure has been a core policy of several international governments to increase EV uptake by overcoming split incentive and bounded rationality. However, the provision of infrastructure has generally been coupled with other direct and indirect incentives and so it is difficult to ascertain the extent to which it has driven uptake in these jurisdictions.

Surveys undertaken within Australia suggest that the lack of sufficient public charging infrastructure is a barrier to EV uptake (See Section 3.2), but the same surveys are also suggesting that once vehicle owners have made the investment, public charging infrastructure is rarely used.

Further, EV manufacturers are now installing their own public charging infrastructure to increase sales by allaying range anxiety concerns and increasing public awareness of EVs more broadly. Additional, an investment in public charging infrastructure could potentially be made by other private sector players such as electricity retailers, shopping mall owners or by parking lot operators.

While there may be a case for public provision of EV charging infrastructure the jury is still out as to whether there is necessarily a market failure. Where EV manufacturers can successfully merge a charging infrastructure and EV sales business, the split incentive barrier will be overcome.

Finally, the cost of EV chargers is relatively high and, as described in Section 3.2 above, the benefits may not emerge for ten to fifteen years.

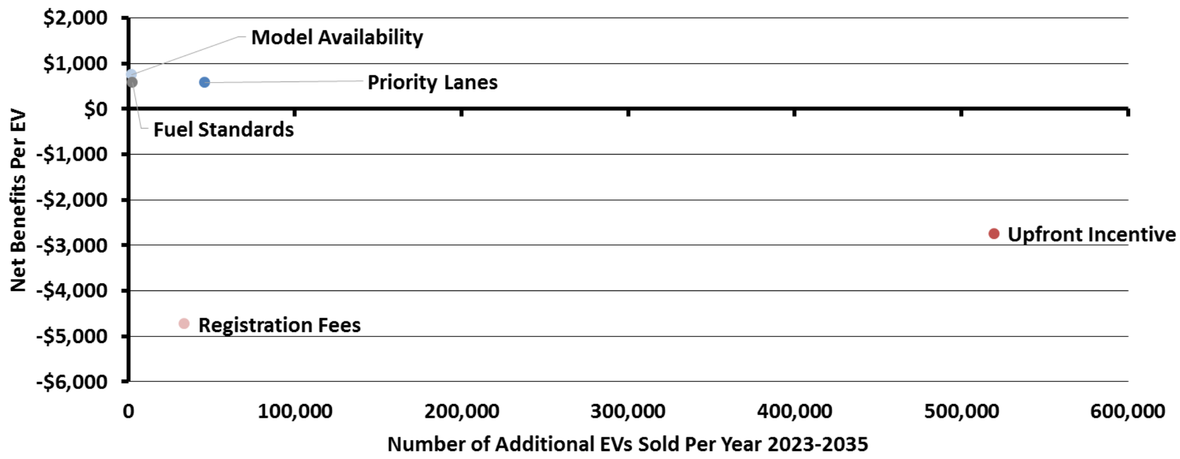
Due to the conflicting evidence regarding the incremental benefits of subsidized charging infrastructure, and the lack of a case for market failure overseas, Energeia has not found this policy would result in a net benefit if implemented in Australia over the study period.

5.1.2.7 Summary of EV Policy Interventions

For each of the policy options modelled above with a positive net benefit, it was found that the optimal year for the policies to have been in effect by was 2023. Minimising the cost of compliance means that the policies and regulations should be enacted as soon as possible to give those impacted as much time as possible to adjust.

For comparison purposes, the results of Energeia's modelling of the net present impacts of each policy in terms of net costs and vehicle uptake by 2023 is presented in Figures 25 and 26.

Figure 25 – Comparison of Impact of EV Policies



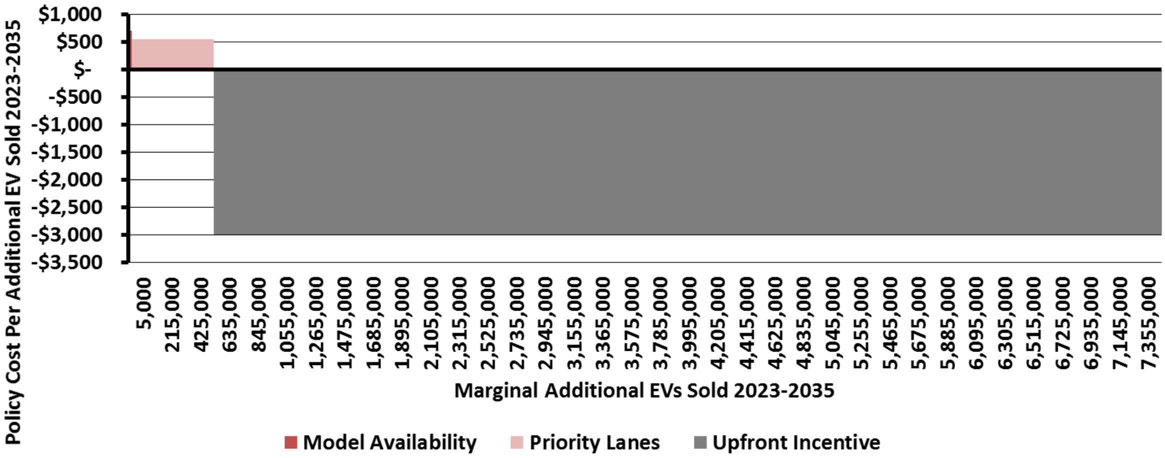
Source: Energeia

This demonstrates that the policy of priority lanes has the greatest potential impact bringing forward an additional 46,000 vehicles on average per year from 2023. Fuel standards and overseas model availability regulations, while showing a positive net benefit, have a relatively smaller impact on EV uptake. These policies increase vehicle model availability earlier in the period, but ultimately are not able to increase overall uptake beyond a certain threshold if not coupled with a reduction in return on investment.

Both the upfront incentive and annual incentive (registration fees) show a net cost. Should governments have other drivers (such as greenhouse gas emissions reduction, improvement in local air pollution or fuel security) they may choose to implement a more direct incentive. This analysis suggests that upfront subsidies are more cost effective than annual subsidies.

Overall, the analysis shows that priority lane policy in conjunction with an overseas model availability regulation could give rise to a net benefit. When these two policies are modelled in conjunction, the following uptake is observed. An upfront financial subsidy, although having zero net benefit, is included for comparative purposes.

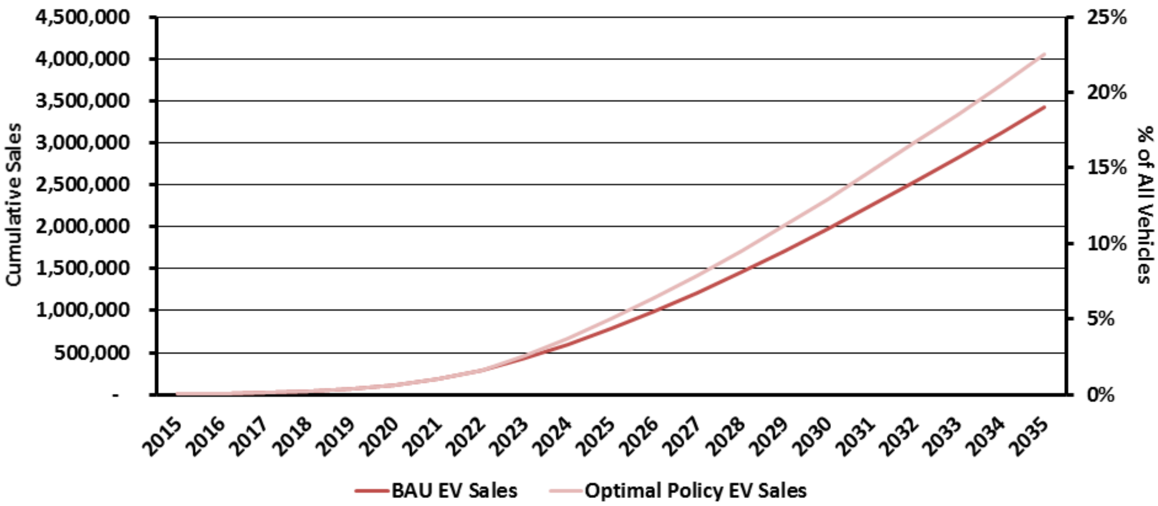
Figure 26 – Marginal Impact of Complementary EV Policies



This suggests that an additional 620,000 EVs could be added to Australia's vehicle fleet over the period of 2023 to 2035 via cost effective policy interventions. A further 6.9 million could be added through the provision of a direct subsidy although this would come at a net cost of approximately $3,000 per vehicle.

With the two cost effective policy interventions a total EV target of 4 million by 2035 could be achieved representing approximately 22% of Australia's vehicle fleet as shown in Figure 27.

Figure 27 – EV Targets with Policy Interventions



Source: Energeia

5.2 *Natural Gas Vehicles*

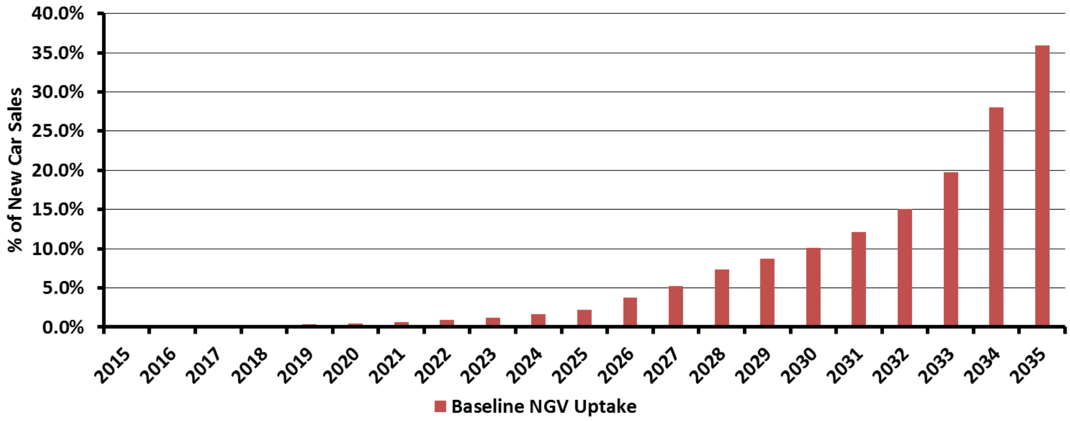
5.2.1 No Policy Intervention

Under a no policy intervention scenario, uptake of passenger natural gas vehicles is initially driven by return on investment with fluctuations in annual sales responding to fluctuations in natural gas prices relative to crude oil. From around 2026 the financial return on investment begins to improve driven by declines in vehicle prices[80].

However year on year sales continue to be constrained by vehicle model availability. Unlike electric vehicles, availability of OEM passenger CNG vehicles is limited in Australia. Without its own vehicle manufacturing industry, Australia will need to rely on the US implementing an aggressive NGV policy as other traditional suppliers of vehicles to Australia such as Japan and Europe have limited drivers to develop a NGV manufacturing industry. Alternatively the Australian Government could encourage trade between non-traditional suppliers of vehicles such as Argentina where OEM NGV industries are emerging. A further option is the subsidisation of after-market conversions which has not been considered in this modelling.

The forecast sales volumes, given the likely restraints to vehicle model availability are shown in Figure 28.

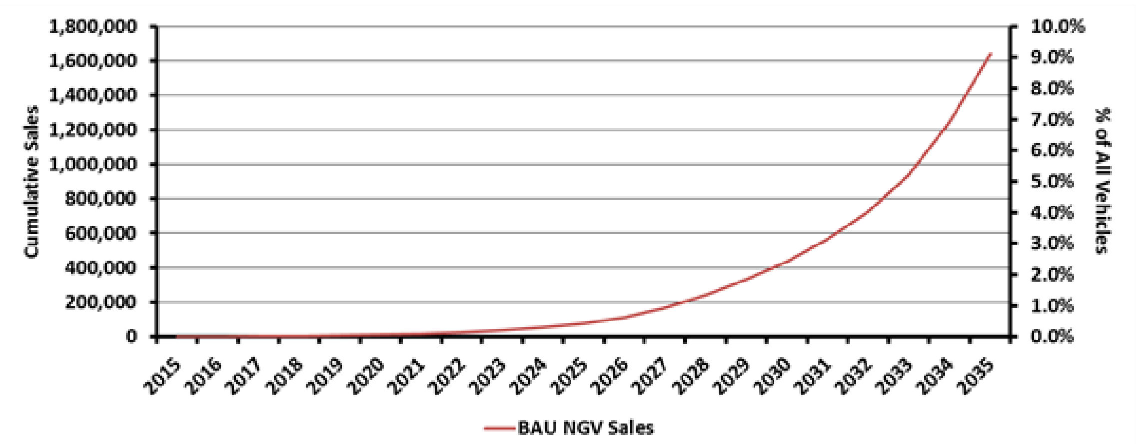
Figure 28 – No Policy Intervention NGV Sales



Source: Energeia

These sales volumes give rise to a total of 1.6 million vehicles by 2035 representing 9% of the Australian vehicle fleet as shown in Figure 29.

Figure 29 – No Policy Intervention NGV Uptake



Source: Energeia

[80] It should be noted that this analysis focuses on the passenger vehicle market, which accounts for 75 percent of the Australian vehicle fleet, and not the commercial vehicle market for which a different set of policies should be considered to encourage uptake.

5.2.2 Policy Interventions

Energeia's analysis has considered five main policy interventions and whether or not each policy is likely to give rise to a net economic benefit (including both direct and indirect benefits). A summary of the policy interventions modelled is described in Table 16 below.

Table 16 – Policy Interventions for Natural Gas Vehicles

Policy Type	Policy Mechanism	Basis for Cost Estimates	Basis for Uptake Estimates
Upfront financial incentives (Demand Side)	Capital payment	Optimised to maximise welfare	Modelled based on increased ROI
Annual financial incentives (Demand Side)	Avoided registration fees	Optimised to maximise welfare	Modelled based on increased ROI
Non-financial incentives/ rights (Demand Side)	Access to priority lanes	Cost of establishing lanes and marketing campaigns	Observed increases in EV uptake in California associated with EV lanes
Obligation (Supply Side)	Mandated vehicle emission/fuel efficiency standards for all vehicles	Increased cost of ICE vehicles of $17 per vehicle.	Modelled based on increased ROI
Obligation (Supply Side)	Mandated manufacture/sales quota for all manufacturers/retailers	NGV Manufacturing Leader: $600 million per additional model Fast follower: $0	Modelled based on increased vehicle model availability

5.2.2.1 Upfront Financial Incentives

The original intention of the modelling was to identify the level of incentive which would be required so that the marginal cost of the incentive scheme was equal to the marginal benefit. However in the early years, due to a lack of clear benefits from natural gas vehicles, the modelling showed that from an economic perspective, even when externalities were taken into account, there was no net benefit for introducing any subsidy. As the benefits begin to emerge in later years, there is still no benefit to a subsidy as uptake is restricted by vehicle uptake.

For illustrative purposes a $7,000 upfront subsidy, typical of the level of subsidy offered internationally, has been modelled as capital subsidy showed the following net benefits.

Table 17 – Benefits of Upfront Financial Incentive Policy (NGVs)

	Benefit Implementation Year			
Benefit Category	2015	2020	2025	Units
Gross Costs	-$8,451.3	-$8,355.3	-$7,772.0	$ M (2015)
Gross Direct Benefits	$1,355.6	$1,377.3	$1,381.0	$ M (2015)
Gross Indirect Benefits	$237.3	$233.4	$206.1	$ M (2015)
Net Direct Economic Benefits	-$7,095.7	-$6,978.1	-$6,390.9	$ M (2015)
Net Direct and Indirect Economic Benefits	-$6,858.4	-$6,744.7	-$6,184.9	$ M (2015)
Economic Growth	$2,233.0	$2,186.9	$1,901.2	$ M (2015) GVA
Employment	2487	2474	2340	Jobs in 2035
Fuel Security	149,545.7	147,477.5	131,840.9	PJ (domestic)
GHG Savings	10,298.8	10,153.5	9,065.3	$ktCO_2$-e
Air Quality Improvement	665.8	656.4	586.1	tPM10

These results suggest that a $7,000 subsidy per vehicle effected in 2015 would cost around $8.5 billion over a 20 year period and would contribute only $1.6 billion of benefits. While governments are likely to scale down the subsidy level over time, our modelling showed no level of subsidy was cost effective.

Interestingly, there is a large potential benefit of an NGV subsidy in terms of domestic economic growth, employment and fuel security along with environmental benefits. Subsidising NGVs encourages a greater amount of expenditure in domestic industries in comparison to petrol vehicles where significant expenditure is on imports. The majority of the growth occurs in the gas extraction and gas supply industries.

5.2.2.2 Annual Financial Incentives

As with direct incentives, the original intention of the modelling was to identify the level of indirect incentive which would be required so that the marginal cost of the incentive scheme was equal to the marginal benefit. The form of the indirect financial incentive (such as tax concession, reduced registration fees, parking fees or tolls) would then depend on the appetite of various governments to implement these schemes, but in total the effective subsidy should not be more than the marginal benefit.

However due to the lack of clear benefits from NGVs in the early years, the modelling showed that from an economic perspective, even when externalities were taken into account, there was no net benefit for introducing any indirect subsidies even if delayed until 2030.

For illustrative purposes, the modelling assumed that registration fees would not be paid by NGV users providing an effective annual subsidy of $283 per year (population weighted average of registration fees for small petrol vehicles in each state). The benefits of this policy are shown in Table 18 below.

Table 18 – Benefits of Annual Registration Concession Policy (NGVs)

	Benefit Implementation Year			
Benefit Category	**2015**	**2020**	**2025**	**Units**
Gross Costs	-$662.1	-$656.2	-$623.3	$ M (2015)
Gross Direct Benefits	$154.3	$156.7	$157.3	$ M (2015)
Gross Indirect Benefits	$21.1	$20.6	$18.8	$ M (2015)
Net Direct Economic Benefits	-$507.9	-$499.5	-$466.0	$ M (2015)
Net Direct and Indirect Economic Benefits	-$486.8	-$478.8	-$447.2	$ M (2015)
Economic Growth	$193.2	$188.2	$169.2	$ M (2015) GVA
Employment	331	330	321	Jobs in 2035
Fuel Security	13,720.8	13,498.2	12,470.4	PJ (domestic)
GHG Savings	941.9	926.2	854.7	ktCO_2-e
Air Quality Improvement	60.9	59.9	55.3	tPM10

This suggests that a $283 annual subsidy effected in 2015 would cost $662 million over a 20 year period and result in only $175 million in benefits, suggesting a poor policy option from an economic perspective.

As with direct incentives, there is a large potential benefit of an NGV subsidy in terms of domestic economic growth, environmental benefits and employment.

5.2.2.3 Non-Financial Incentives / Rights

Indirect non-financial incentives or rights provide improved utility to the NGV owner relative to a petrol vehicle owner. This could be in the form of access to restricted lanes or parking spots.

For the purpose of this analysis, a priority access lane incentive with assumptions of NGV uptake associated with the increased utility taken from a survey of EV drivers within California which has implemented such a policy.

Even though this policy is relatively low cost (essentially painting and maintaining of bus and high occupancy vehicle lanes), the benefits of this policy are constrained by limited vehicle model availability.

Table 19 – Benefits of Priority Access Lane Policy (NGVs)

Benefit Category	Benefit Implementation Year			
	2015	2020	2025	Units
Gross Costs	-$165.5	-$118.0	-$84.1	$ M (2015)
Gross Direct Benefits	$155.6	$158.9	$159.8	$ M (2015)
Gross Indirect Benefits	$22.0	$21.4	$19.1	$ M (2015)
Net Direct Economic Benefits	-$9.9	$40.9	$75.6	$ M (2015)
Net Direct and Indirect Economic Benefits	$12.1	$62.3	$94.8	$ M (2015)
Economic Growth	$203.0	$196.2	$171.9	$ M (2015) GVA
Employment	399	397	386	Jobs in 2035
Fuel Security	14,302.9	13,999.8	12,682.1	PJ (domestic)
GHG Savings	982.1	960.8	869.1	ktCO_2-e
Air Quality Improvement	17.5	13.9	10.1	tPM10

5.2.2.4 Vehicle Emissions / Fuel Efficiency Standards

Increasing vehicle emissions or fuel efficiency standards to bring Australia into line with international fuel efficiency targets shows a potential benefit. The modelling assumes that the standard becomes mandatory on an individual vehicle basis rather than a fleet basis which results in a $17 increase in the price of a petrol vehicle. This has a minor improvement on the return on investment for natural gas vehicles which drives higher uptake.

Table 20 – Benefits of Vehicle Emissions/Fuel Efficiency Standards (NGVs)

Benefit Category	Benefit Implementation Year			
	2015	2020	2025	Units
Gross Costs	-$13.9	-$7.1	-$2.7	$ (2015)
Gross Direct Benefits	$80.1	$55.5	$32.9	$ (2015)
Gross Indirect Benefits	$8.0	$5.5	$3.1	$ (2015)
Net Direct Economic Benefits	$66.2	$48.4	$30.1	$ (2015)
Net Direct and Indirect Economic Benefits	$74.2	$53.8	$33.3	$ (2015)
Economic Growth	$137.9	$88.7	$44.5	$ (2015) GVA
Employment	179	124	76	Jobs in 2035
Fuel Security	5,502.0	3,753.0	2,160.7	PJ (domestic)
GHG Savings	375.9	256.3	147.5	ktCO_2-e
Air Quality Improvement	24.3	16.6	9.5	tPM10

There are other potential mechanisms to drive this policy such as application of emission or efficiency levels across a fleet. This could potentially drive further benefits by allowing for the most efficient options for manufacturers to improve fuel efficiency to be developed.

5.2.2.5 Manufacturing / Sales Quotas

As with electric vehicles, increasing the number of NGVs that manufacturers are required to produce and sell into Australia could be achieved in several ways where Australia either acts as a fast follower or a manufacturing leader. The issue with NGVs is that relatively few of the traditional suppliers of vehicles into Australia are likely to implement NGV quotas, with the US the only likely candidate. The ability of Australia to become a fast follower is therefore strongly dependent on US policy.

Notwithstanding, the modelling assumes that Australia is able to act as a “fast follower” monitoring closely the policy actions of the US and then to increase the number of electric vehicle models and then enact similar policies in Australia once more vehicles become available within the global market.

The modelling assumes that such a policy would bring forward vehicle model availability by three years.

The direct costs of such a policy would be close to zero, assuming that the R&D and commercialisation costs are borne by other governments elsewhere. There may be indirect costs to consumers as the increased sales requirement is subsidised across the fleet. For the purposes of this modelling, it is assumed that the cost of the vehicles does not increase as a result of the quotas, but the vehicle model availability does.

Overall, this policy gives rise to a small net benefit immediately and the benefit can be maximised if the policy is effective by 2026.

Table 21 – Benefits of Manufacturing/Sales Quotas (NGVs)

	Benefit Implementation Year			
Benefit Category	**2015**	**2020**	**2025**	**Units**
Gross Costs	$0.0	$0.0	$0.0	$ (2015)
Gross Direct Benefits	$6.1	$9.4	$10.1	$ (2015)
Gross Indirect Benefits	$4.6	$4.1	$2.4	$ (2015)
Net Direct Economic Benefits	$6.1	$9.4	$10.1	$ (2015)
Net Direct and Indirect Economic Benefits	$10.7	$13.6	$12.5	$ (2015)
Economic Growth	$924.6	$918.7	$900.9	$ (2015) GVA
Employment	94	92	84	Jobs in 2035
Fuel Security	2,703.2	2,452.0	1,483.6	PJ (domestic)
GHG Savings	187.6	169.9	102.5	ktCO_2-e
Air Quality Improvement	12.1	11.0	6.6	tPM10

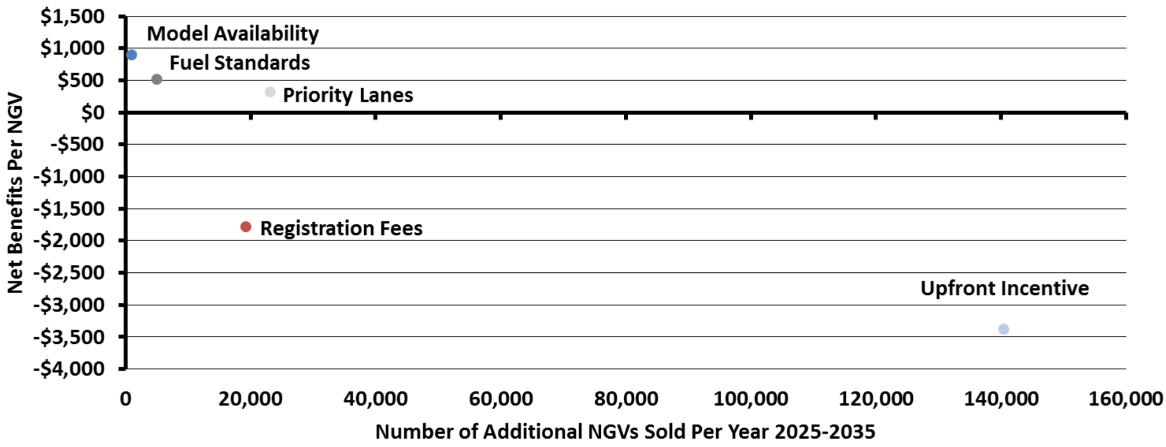
As with electric vehicles, an overseas model availability regulations could also be implemented *ahead* of other jurisdictions, establishing Australia as a leader in NGV technology. Such a policy would require manufacturers to develop new models to bring to market which would at least part be required to be subsidised in order to reduce the cost burden on Australian manufacturers.

The modelling suggest that with a subsidy of this size, there are unlikely to be net economic benefits in the foreseeable future. The impact of such a policy in terms of providing stimulus to the Australian vehicle manufacturing industry however is not further considered.

5.2.2.6 Summary of NGV Policies

For each of the policy options modelled above with a positive net benefit, it was found that the optimal year of effect was 2023 or 2026 depending on the policy. For the policies with no net benefit over the assessment period (upfront and annual incentives), there is no optimal year. For comparative purposes, the impact of all policies in terms of net costs and vehicle uptake for effect in 2025 is presented in Figure 30.

Figure 30 – Comparison of Impact of NGV Policies



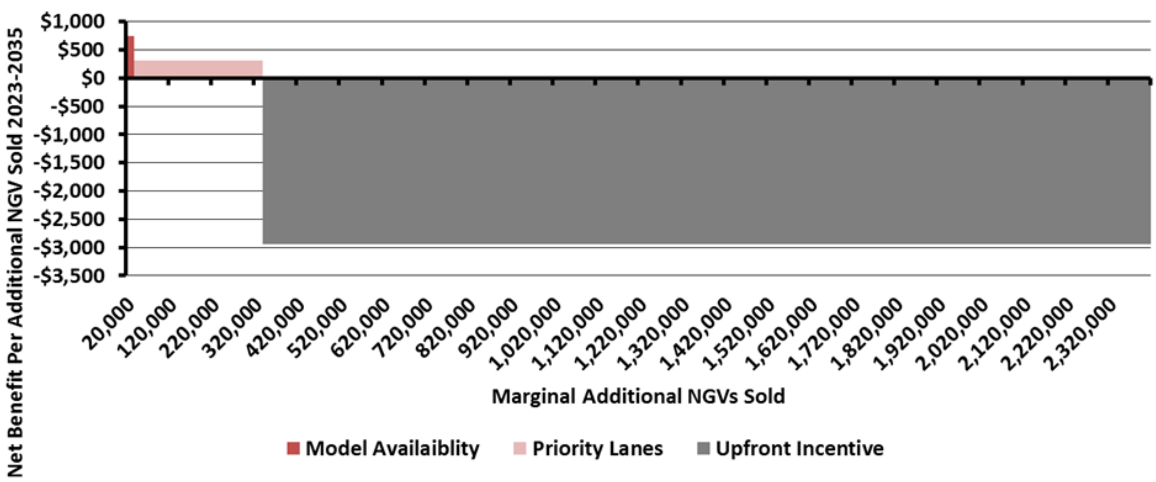
Source: Energeia

These results demonstrate that fuel standards, priority lane access and overseas model availability regulations have a positive net benefit if effective from 2025, a few years before NGVs show economic benefits. Overseas model availability regulation in particular bring forward NGV availability and then when coupled with a relatively high ROI drive additional uptake.

Overall, the NGV uptake is limited by vehicle model availability. As the vehicle model availability for NGVs remains low throughout the period, incentives such as priority lanes and subsidies do little to increase uptake.

Figure 31 shows the impact of the optimal policy mix on NGVs. The optimal policy is to introduce an overseas model availability regulation to increase availability in 2023 and then to introduce priority lane access for NGVs in 2026. An upfront incentive policy introduced in 2026 is also included for illustrative purposes.

Figure 31 – Marginal Impact of Complementary NGV Policies

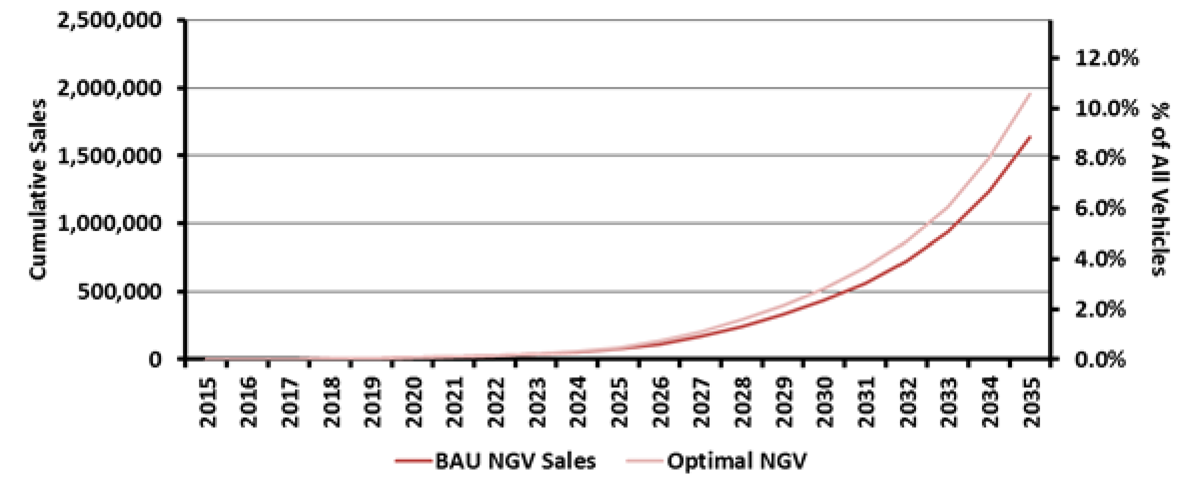


Source: Energeia

This suggests that an additional 320,000 NGVs could be added to Australia's vehicle fleet over the period of 2023 to 2035 via cost effective policy intervention. A further 2.1 million could be added through the provision of a direct subsidy although this would come at a net cost of $3,000 per vehicle.

With the two cost effective policy interventions, a total NGV target of 2.0 million by 2035 could be achieved, representing approximately 10.5% of Australia's vehicle fleet as shown in Figure 32.

Figure 32 – NGV Targets with Policy Interventions



Source: Energeia

5.3 Conclusions and Recommendations

5.3.1 Government Policy

Energeia's analysis has revealed that there may be a case for low cost government intervention of AFVs which delivers measurable net benefits over the assessment period. The case for intervention could be further strengthened if some of the additional benefits that have not been factored into Energeia's analysis are considered. However for EVs, we find that direct subsidies and/or provision of charging infrastructure, which have driven EV uptake in other countries, is not likely to be cost effective in Australia.

For EVs there is the potential for Australia to become a "fast follower", taking advantage of Overseas Model Availability Regulations that may be implemented in other parts of the world where there are stronger policy drivers. If Australia adopts regulations requiring right handed BEV models to be available in Australia, then our economy can take advantage of the R&D investments and subsidies made by governments elsewhere

For NGVs, policies which increase vehicle model availability deliver measurable net benefits from 2026. However, the impact of such policies is likely to be limited due to the lack of overseas models. There may be a stronger case for policies supporting NGV deployment amongst the heavy vehicle fleet, which has gained prominence in countries such as the US. Without its own vehicle manufacturing industry, Australia will need to rely on the US implementing an aggressive NGV policy or encourage trade between non-traditional suppliers of EVs such as Argentina, which offer OEM NGVs. A further option is the subsidisation of after-market conversions which has not been considered, but has a precedent in the recently abolished subsidies for LPG conversions.

5.3.2 Energy Supply Industry Policy

For the energy supply industry, AFVs have the potential to deliver improved utilisation of existing assets. Improvement in utilisation has the potential to reduce the cost of energy supply and in doing so provide a lower cost fuel for both transport and stationary energy use.

The energy supply industry, given the potentially significant industry benefits of EVs and NGVs, should therefore consider its own actions to support broader uptake. This could include increasing public awareness through procurement of EVs/NGVs for its own commercial fleets, provision of attractive tariffs for AFV owners to encourage increased utilisation of networks and potentially provision of charging/refuelling infrastructure.

It is understood that the Energy Networks Association is already investigating opportunities for the natural gas industry to encourage the development of a natural gas vehicle industry in Australia.

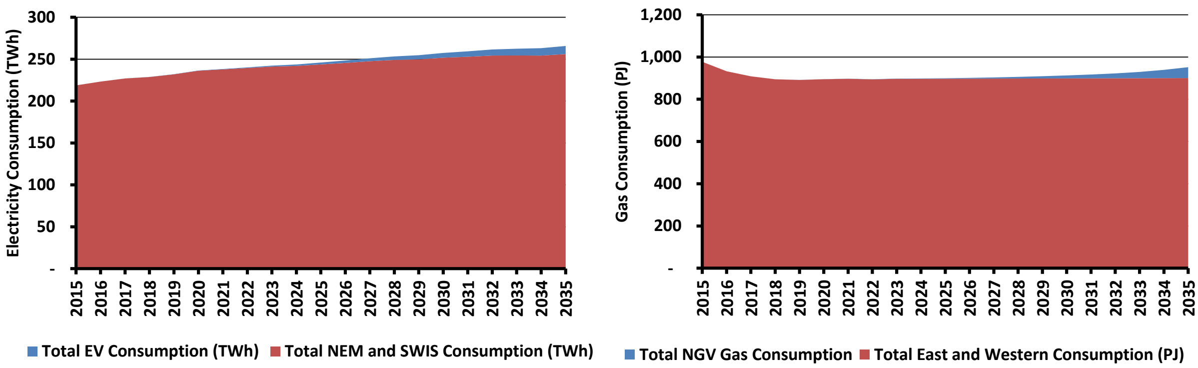
The industry stakeholder engagement activities undertaken as part of this study has revealed there are is a mix of attitudes towards AFVs among industry players. Some stakeholders see AFVs as opportunity and are already considering ways to support further uptake at a strategic level, albeit at a very preliminary level. Other stakeholders are adopting a "wait-and-see" approach preferring to focus on managing potential engineering impacts on assets rather than a strategic business approach.

The analysis of the benefits of AFVs and the net benefit of policy options has revealed that even when indirect benefits are taken into account, economic benefits from AFVs, are not likely to occur until around 2023 for electric vehicles and 2026 for natural gas vehicles. At this point there may be a case for low cost government intervention. However for EVs, direct subsidies and/or provision of charging infrastructure, which have driven EV uptake in other countries, is not likely to be cost effective. For NGVs, the largest issue is in improving vehicle model availability within the Australian market.

For the energy supply industry, there is an argument that, under current forecasts of declining or at least slowing of growth in stationary energy consumption, AFVs have the potential to deliver improved utilisation of existing assets. Improvement in utilisation has the potential to reduce the cost of energy supply and in doing so provide cheaper fuel source for both transport and stationary energy use. The benefits of improved utilisation on gas or electricity prices has not been modelled as part of this assessment for this require analysis on the impact of EV charging patterns on the maximum system demand. Rather, it is assumed that this remains constant over time. However, improved utilisation of energy supply assets could give rise greater economic benefits of AFVs than modelled here and improve the case for broader intervention.

Energeia has however modelled the impact of the forecasts produced for EV and NGV uptake under the optimal policy scenario on system wide consumption within Australia's electricity and gas networks. Figure 33 below shows that the optimal target of 4 million EVs by 2035 will lead to a 4% increase in the combined NEM and SWIS electricity consumption for that year. Similarly, gas consumption in the Eastern and Western gas regions would increase by 6% by 2035 if the optimal target of 2 million NGVs was reached.

Figure 33 – Impact on Consumption from EVs and NGV Uptake under Energeia's Optimal Scenarios



Source: Smart Grid, Smart City, AEMO

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Appendix 1 – Policy Optimisation Framework

The question of whether or not government has a role in shaping an emerging industry's future has been the focus of many major economics schools of thought throughout history. Among the most notable include the Austrian School[81] and the School of Welfare Economics[82].

The key issues raised by those against government intervention include heightened risk of unintended consequences. Unintended consequences as a result of government intervention are much more difficult to unwind than where caused by the market alone, which is able to respond much more dynamically.

Among the most compelling and influential arguments of those in favour of government intervention are the Welfare Economists, whose theoretical framework for maximising community welfare largely underpins modern international policymaking and regulatory economics.

Energeia's approach to determining the optimal course of action for Australia is based on the tenets of Welfare Economics, which provide an analytical framework for optimal government intervention in the market, while respecting the counter arguments of one of its most widely respected critics, the Austrian School, and in particular the risks associated with long-term government involvement.

Our optimisation framework is therefore aimed at quantifying a set of direct and indirect economic impacts of electric vehicles across the Australian economy, including gross value added (GVA) economic value, jobs, local air quality (PM10 emissions), greenhouse gases (CO_2-e emissions) and key industries (e.g. electricity and gas).

Government Intervention

According to Welfare Economists, the role of government is to intervene in the market to achieve an optimal mix of goods and services, which would otherwise not arise, usually due to some market failure such as incomplete or imperfect information, split incentives or externalities.

In order to determine whether there exists a perfect combination of goods and services, one must first identify the relevant set of goods and services. Then one must quantify their current level of welfare[83], as well as the welfare of a range of feasible alternative combinations along with the risk adjusted, least cost approach to transitioning to the optimal mix of goods and services.

Energeia has included the following goods and services in our analysis of the market for passenger vehicle transportation:

- Petrol fuelled internal combustion engine vehicles
- Diesel fuelled internal combustion engine vehicles
- Compressed natural gas (CNG) fuelled internal combustion engine vehicles
- Petrol fuelled hybrid-electric (HEVs) engine vehicles
- Electric vehicles

Public transportation options have not been included in our analysis.

Energeia has included the following direct and indirect costs and benefits in our analysis of the welfare of the market for passenger vehicle transportation:

- Direct cost of travel, including vehicles and fuel production and supply, excluding the public road system
- Indirect health costs of air pollution
- Indirect costs of global warming as a result of anthropogenic greenhouse gas emissions

[81] Von Mises, Ludwig; Interventionism: An Economic Analysis; Edited by Bettina von Graces, First Edition; (1947)

[82] Two fundamental theorems of welfare economics as stated today is generally attributed to Kenneth Arrow (1951) and Gerard Debreu (1959)

[83] For the purpose of this report, Energeia defines welfare to be net direct and indirect benefits.

The analysis also considers the impact of policy options on:

- Economic growth
- Employment

The determination of economic growth and employment benefits considers changes in the relative mix of fuel supply to the transport sector, reflecting changes in generation mix over time in the electricity supply sector, but assuming that the economic productivity and employment intensity within each fuel supply sector are constant.

The analysis excludes any knock-on impacts upon the broader economy as a result of the modelled changes in expenditure within the electricity supply industry. The assessment also excludes any analysis of the impact of policy reform on the contribution of Australia's vehicle manufacturing sector to economic growth.

Energeia's analysis estimates the net benefits of each change in passenger vehicle technology from the baseline technology (petrol fuelled ICE vehicles) on the five metrics above. This is achieved by netting off the incremental costs and benefits of the alternative fuel technology vehicle against the incremental lost benefits or avoided costs of the baseline petrol vehicle.

The potential second order and strategic benefits to the electricity industry from increased demand from a major new, highly flexible load are addressed at a qualitative level.

The types of government interventions broadly considered in our analysis include:

- Upfront subsidies (e.g. rebates for vehicles)
- Annual subsidies (e.g. registration concessions)
- Rights or privileges (e.g. priority lanes)
- Regulatory obligations (e.g. vehicle or charger quotas, vehicle emission/fuel efficiency standards)

For each potential government intervention, Energeia has sought to identify and to quantify its direct costs, and its expected impact in terms of additional alternative fuel technology vehicles on the road, the net benefits of which can then be assessed using our welfare analysis.

We then consider whether there is a welfare maximising policy position for Australia by ordering the range of policies based on their cost to implement relative to their vehicle adoption impact, and including all policies up to the point where marginal cost is higher than marginal benefit.

Complementary electricity and natural gas industry policies are also identified, but the calculation of their incremental net benefits to the country is beyond the scope of this report.

Technology Commercialisation Issues

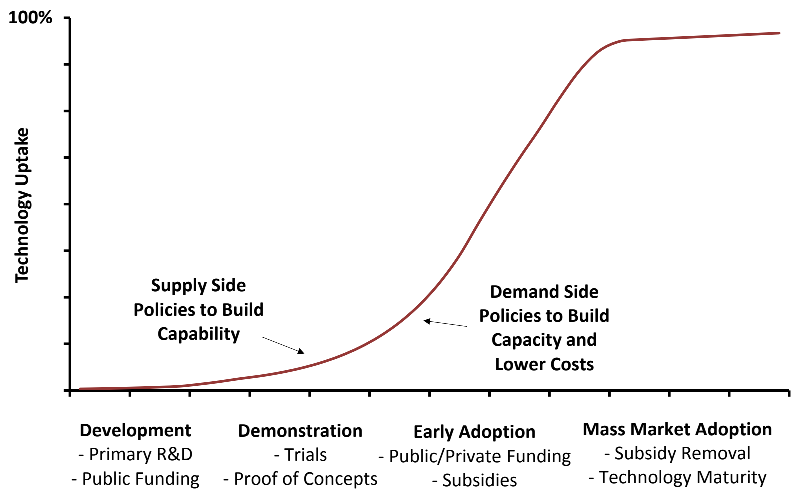
Once the optimal mix of goods and services is identified, where it includes greater adoption of an emerging energy technology, the specific issues associated with technology commercialisation must then be taken into account in order to arrive at the most effective policy roadmap over time. In particular, any government intervention must account for the development of technology and the market over time.

In Energeia's view, the most important risks to manage in the case of Australian passenger vehicle policymaking involving emerging technology is the inadvertent picking of winners through narrowly defined eligibility criteria. This involves crowding out what might otherwise prove to be better options in the future for meeting the welfare maximising policy objective, and the establishment of durable interventions that outlast their usefulness, and increasingly reduce overall community welfare.

Rather than pre-determine which type of electric or natural gas propulsion and fuel combination will provide the greatest overall level of welfare to Australia, Energeia has proposed a net benefit assessment framework that includes what we believe to be a comprehensive set of quantifiable performance metrics. This evaluation framework can therefore be applied to new technologies as they emerge, for example fuel cell vehicles.

Figure 34 displays a typical technology commercialisation framework with examples of best practice government interventions.

Figure 34 – Technology Commercialisation Framework



Source: Energeia

Energeia's approach to managing the risk of sub-optimal policy settings over time is to assess the net benefits of AFVs as well as the net benefits of each category of policy intervention over time. Given the commercialisation framework outlined in Figure 34, this is expected to lead to greater net benefits from supply side interventions initially, which give way to demand side policies as the supply side constraints are increasingly lessened.

Importantly, explicit consideration of dynamic technology, market and policy conditions helps ensure that policy recommendations are consistent with the expected conditions over time. This approach can also be used to trigger a review of policy settings should there be material changes to the assumed conditions. In other words, this approach, when practiced correctly, helps guard against distortions from out-of-date government policies.

Vehicle Uptake Model

Determining the optimal policy mix and settings over time, consistent with the principles of efficient government intervention and effective technology commercialisation, requires a model of passenger vehicle technology uptake to:

1. Estimate the expected adoption of passenger vehicle technology without intervention
2. Estimate the impact of key interventions on adoption
3. Estimate the timing of changes in technology maturity for dynamic policy adjustments

Energeia's assessment of the modelling options and specification of the selected modelling approach are outlined in the following sections.

Modelling Options and Issues

Energeia's review of the existing range of modelling options against the requirements for this engagement has found that the range of current electric vehicle uptake models in Australia do not cover the necessary range of economy wide costs and benefits, nor do they cover the range of potential policy and regulatory interventions, particularly those aimed at the supply side (see Tables 2 and 3).

Another key issue with the suitability of approaches used to date in Australia is that they all presume EVs will ultimately lead to a 100% rate of adoption. Energeia's own empirical analysis of diesel and HEV technologies discussed in Appendix 1 suggests this assumption does not appear to be valid. If our analysis is correct, previous estimates could be overstating future EV uptake under a baseline, no intervention scenario.

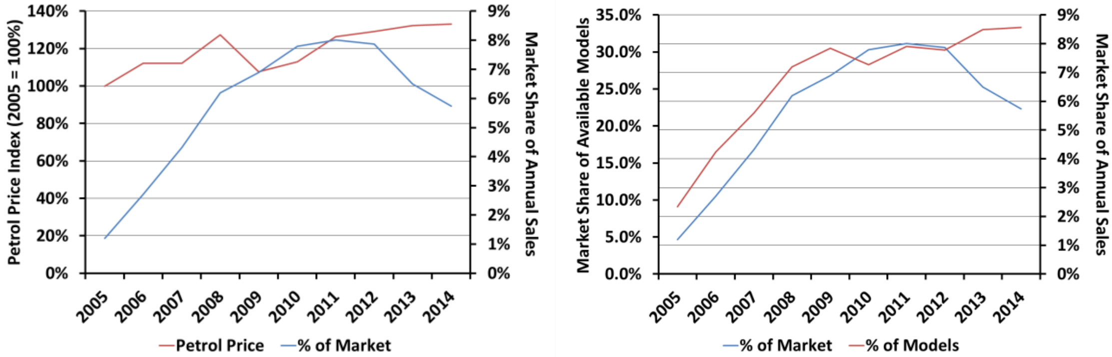
In addition to the assumed upper limit of AFVs in the absence of policy intervention, Energeia's analysis of historical factors driving diesel adoption over time described below suggests that vehicle cost may not be as strong a factor in uptake as current uptake models are based on stated preference surveys. This could affect the suitability of these models to deliver the requirements listed in Appendix 1, i.e. the impact of interventions.

Energeia's Model and Baseline Inputs

Based on our review of the existing uptake models relative to the modelling requirements, Energeia developed a fit for purpose model based on empirical analysis of alternative vehicle technology uptake over time in Australia. The most comprehensive dataset available is for diesel and HEV uptake, which we used to extend and widen the analysis beyond the 3 years of data available for BEVs alone.

Figure 35 (LHS) shows the relationship of petrol prices to diesel vehicle sales over a ten year period to 2014, with petrol prices being a proxy for financial performance of the alternative technology. Figure 35 (RHS) shows the relationship of diesel vehicle model availability (defined as number of diesel models available on the market compared to the total number of models available) to diesel vehicle sales over the same ten year period. These figures reveal a relatively strong relationship between vehicle model availability and diesel vehicle sales, and a relatively weak relationship between petrol prices and diesel vehicle sales over the same period.

Figure 35 – Comparison of Key Drivers of Diesel Technology Uptake (2005-2014)



Source: Energeia, HIS, EIA

Energeia undertook regression analysis of the two factors to further characterise the empirical relationship. Regression analysis of alternative modelling specifications found that a composite factor using both conventional fuel cost (petrol) and vehicle model availability (that excluded the last two years of data when the relationship started to break down) resulted in an improvement over either factor alone, as shown in Table 22.

Table 22 – R-Squared Results of Various Model Specifications

Modelling Factors	R^2
Petrol Cost	0.47
Vehicle Model Availability	0.95
Petrol Cost + Vehicle Model Availability	0.98

Source: Energeia

Energeia's composite factor multiplied the petrol cost, a proxy for overall cost effectiveness of diesel technology, by the vehicle market share factor. We believe this relationship makes intuitive sense in the context of our analysis as the availability of model options will magnify the influence of cost effectiveness.

The key baseline inputs needed to drive our adjusted two factor model are the baseline vehicle model availability forecast, which we estimated using a simple regression of diesel, HEV and BEV data, and a baseline relative cost forecast, which we estimated using a forecast of future oil, electricity and gas prices.

While Energeia recognises the limitations of our two factor model with an upper limit of around 35% uptake for a given technology due to its empirical foundations resting on diesel and not BEV or NGV uptake data, we believe it nevertheless represents the most appropriate approach for satisfying the modelling requirements set out above with respect to baseline and policy enhanced AFV technology adoption forecasts.

Appendix 2 – Summary of Stakeholder Engagement

Scope and Approach

Energeia was engaged by the Energy Supply Association of Australia (esaa) to develop optimal policy and industry support framework and settings for alternative fuel vehicles (AFVs) in Australia based on a review of international best practice in an Australian context. As a key part of this review Energeia conducted interviews with companies identified as potentially significant players in the future AFV market in Australia.

The purpose of these interviews was twofold:

- To gain insight into how Australia's leading DNSPs and retailers are developing and implementing strategies, programs, trials and tariffs to integrate EVs and NGVs into their networks/customer base through offerings to customers; and potential appetite for support
- To identify current activity and future plans for using EVs and NGVs in DNSPs fleets and how fleet managers are overcoming barriers to EV and NGV adoption

Energeia conducted nine telephone interviews in total, including seven interviews of the following DNSPs and retailers:

- GDF Suez
- AGL
- Energy Australia
- Ergon
- Ausnet Services
- SAPN
- Citipower-Powercor

In addition, Energeia interviewed fleet managers from the following companies:

- Jemena
- PowerCor

The following sections document the key findings from this series of interviews.

Summary of Key Insights

- Generally the DNSPs and retailers were more focused on EVs, with the exception being AGL whose key interest was in developments of a CNG refuelling network
- Major opportunities relating to mass EV adoption for retailers are additional electricity demand, customer retention and reducing customer churn
- Major benefit for DNSPs is improved utilisation of under-utilised networks
- Most DNSPs viewed the opportunity from greater network utilisation as greater than the augmentation costs associated with proofing the network for EV charging
- EVs and HEVs are being phasing out of DNSP vehicle fleets with government trials ending and no strong business case for keeping them
- The incorporation of EVs into DNSP vehicle fleets was politically motivated
- A number of barriers restricting EV uptake in Australia were identified including: inflexibility around charging; lack of policy support; high electricity prices; driving range anxiety; unfamiliarity with EV

technology; purchase price; availability of vehicle models, the driving range anxiety; and lower petrol/diesel fuel prices.

Responses by Topic (DNSPs and Retailers)

AFV Objectives and Strategy

Overall Findings

- None of the retailers and DNSPs have a detailed public business strategy on EVs (although one DNSP had an EV customer focused strategy document). Most consider their strategy to be "emerging" or "on the radar" (Gentailer); "not well formed" (DNSP); or simply did not have a strategy.
- The three retailers promoted wider adoption of EVs for the following reasons:
  - "Major business opportunities are from additional electricity demand, customer retention and reducing customer churn" (Gentailer)
  - "We are supportive of growth of AFV industry in terms of its contribution to grid utilisation, fuel security" (Gentailer)
  - "At this stage, it is conceptual, but we recognise the potential of EVs as a major demand driver for the energy industry" (Gentailer)
- DNSPs support EV uptake primarily because of the opportunity to improve network utilisation
  - "We recognise the potential of EVs as a key potential enabler in improving utilisation of the network" (DNSP)
  - "Integration of EVs is a priority issue for our corporate strategy and senior management, and is seen as an important piece of its market enablement and effective market reform programme." (DNSP)
- Most retailers and DNSPs are more closely engaged with EVs than NGVs, the exception being AGL whose focus is on gas

Key Issues

- "There is a significant challenge from a policy perspective in terms of separation of legislation and lack of coordination between government departments. Need a dedicated committee focusing on AFVs." (Gentailer)
- We believe that "governments need to lead the way in introducing incentives that remove barriers to EV/NGV uptake. These may include reduced registration costs and dedicated policy funding to support greater deployment of trials." (Gentailer)
- A number of respondents acknowledge they are still trying to understand the suite of benefits and costs.

AFV Incentives

Overall Findings

- Most of the respondents believe they had a role to play in offering AFV incentives
- For retailers the main purpose of these incentives is customer retention and increasing demand volume
- Retailers and DNSPs see opportunities to offer preferential tariff rates to EV customers and incentives for EV charging
- Retailers and DNSPs are considering different structures of time of use (ToU) and/or demand based tariffs specific for EV charging.

- “Tariff reform is currently our key focus – including investigating ToU, critical peak, and seasonal time of use maximum demand based tariff structures which could act as incentives for EV charging.” (DNSP)

- One DNSP recognises that they have a role to play in supporting the installation of private charging infrastructure and have “investigated offering an upfront subsidy (approx. $300-500) to customers connecting charging stations to the network.” (DNSP)

Key Issues

- Lack of return on investment in charging structure
    - “The network has a role to play in supporting development of charging infrastructure. However currently there is not much incentive for us to invest in this given that the company may be leased and ownership structure may change.” (DNSP)
    - “Public charging solutions, these are more an enabler for uptake, rather than an attractive business opportunity.” (Gentailer)
- Pricing regulation is limited flexibility over tariff development that could target EV customers
    - “Retailers are currently limited by the price controls in certain states (except Victoria). This reduces flexibility in introducing tariffs such as critical peak pricing, etc. which may be effective for EV customers.” (Gentailer)

EV Tariffs

Overall Findings

- Majority of retailers and DNSPs do not offer specific tariffs for EV customers. However, a number of DNSPs have ToU and demand based tariffs, although none of these specifically target EV customers.

Specific Initiatives

- A numbers of DNSPs are developing, trialling or implementing tariffs that are/could be applicable to EV customers
    - One DNSP is considering a separate tariff for EV customers, which would apply to whole load (rather than separate meter or meter element). Ideally, this would only be available to EV customers in constrained areas but there are regulatory barriers to location specific tariffs (currently required to offer networks tariffs network wide).
    - “We have two ToU tariffs and a controlled load tariff which can be used by customers to charge their EV during low cost periods.”
    - Another DNSP are trialling a residential maximum demand tariff, although none of the customers on this are currently EV customers. It will be rolled out again in February potentially targeting EV customers.

Key Issues

- Not all respondents agreed that there was an a business need for specific EV tariffs
    - We “do not necessarily believe that specific tariff offering for EV customers is the way forward. Focus is on general tariff reform, there are no specific investigation into EV tariffs.” (Gentailer)

Connection Policies (DNSPs only)

Overall Findings

- None of the DNSP respondents have a documented connection policy specific for EVs

- Not a great business need for a connection policy at this stage given low EV uptake in network
  - Considerations over connection policy "are still in early phase and there is no real need to consider any further at this stage until EV sales pick up." (DNSP)
  - There are "no formal connection policy, no means to identify EV customers within the network." (DNSP)
  - There is "no obligation to notify the network if an EV charger is connected to the network." (DNSP)

AFV Trials

Overall Findings

- Most retailers and DNSPs have previously been involved in trials, but no ongoing trials were identified.
  - "We are not undertaking any further trials. We are keeping a watching brief over the industry and penetration and consider it early in the process." (DNSP)
  - "All trials have now been completed. And the appetite for further trials is currently limited." (DNSP)

Key Issues

- There were some issues during the Victorian Government EV trial
  - "Regarding setting standards for demand response controlled load of EV charging. Not all vehicle models trialled were compliant with the initial standard specifications, and ultimately these standards had to be loosened."
  - "Regarding controlling load the duty cycles of the Mitsubishi i-MiEV battery" (DNSP)
- Even though, most retailers and DNSPs have been involved in trials, there is a lack of understanding of future market penetration and price trends
  - "The likely penetration of EVs/PHEVs in regional areas (where customers have more complex travel patterns and generally a longer driving range) is still unknown. Moreover, we need a better understanding of future prices of EVs." (DNSP)

AFV Uptake Benefits

Overall Findings

- Most retailers and DNSPs have not done any specific customer surveys to identify key AFV benefits to their customer base. There is currently reliance on 3rd party evidence.
- A number of potential benefits and drivers for purchasing an AFV were discussed:
  - "Economics will be the strongest driver (same as solar). Only a handful of customers will do it for "green" reasons." (DNSP)
  - "Aesthetics, performance, price – same drivers for purchase of other vehicles. The novelty factor of owning an EV will be short lived." (DNSP)

Key issues

- Lack of publicity over AFV benefits
  - "The benefits of EVs and HEVs do not receive enough publicity. We have done polling of taxi driving fleets using HEVs, and had positive things to say about the benefits." (Gentailer)

Barriers to AFV Uptake

Overall Findings

- There are a range of EV barriers that need to be overcome
    - "From a customer point of view, the purchase price, availability of vehicle, the driving range anxiety and associated lack of charging infrastructure, the technology anxiety, lower petrol/diesel fuel prices are the main EV barrier." (Gentailer)
- Some respondents believed that the lack of public charging was not a major barrier
    - "Believe it is a myth that the lack of public charging infrastructure is a significant barrier to EV uptake. Most of the population will not need public charging." (DNSP)
- However others believed lack of public charging was an important barrier
    - "In terms of AGL's fleet there have been concerns about procuring EVs due to limited driving range and the significant distances that need to be covered to service some parts of the network, and the lack of availability of public charging infrastructure." (Gentailer)
- Lack of policy support was identified as a key barrier
    - "Lack of incentives – tax benefits, discounts on registration and stamp duty, cheaper insurance, etc." (DNSP)
    - "From an industry point of view, the lack of direct and indirect policy support is a key issue." (Gentailer)
- Electricity price growth over recent years is a potential barrier
    - "Year on year electricity price rises, may discourage certain customers." (DNSP)
- Lack of knowledge of EV technology
    - "With ICE vehicles buyers know what to look for in terms of technical specifications. It is not the case with EVs, where buyers are unfamiliar with what quality is and what is not." (DNSP)
- "Interoperability between public and private charging infrastructure could be an issue." (DNSP)

Responses by Topic (Fleet Managers)

Fleet Inventory

Overall Findings

- Only one DNSP provided details of their fleet.
- Key statistics of the fleet are:
  - 1,957 vehicles.
  - No EVs, previously leased 6 Toyota Prius HEVs, currently only leasing 1.
  - In total use on average 580,000 l of fuel a year. 60% diesel, 40% petrol
  - Total average fuel bill is $780,000 excl. GST
  - Average vehicle does 500 trips in a year but it varies according to type/purpose. Passenger vehicles do 18,000-22,000km average distance and EWPs do 35,000km average annual distance
- DNSP prefers diesel for passenger/light commercial vehicles for different reasons:
  - Diesel are more fuel efficient compared to petrol.
  - "Diesel allows greater cost control over fuel bill."

Charging/refuelling infrastructure

Overall Findings

- The respondent are refuelling/charging their fleet mostly offsite.
  - "Vehicles are refuelled offsite, through supplier depots. We do not own any refuelling infrastructure." (DNSP)
  - "All refuelling is done through external facilities, there is no in-house facilities - exception being two fast chargers owned by DNSP and located at the two depots. Electricity powering the chargers is provided by the retailer at the same rate as for the complex i.e. no special EV tariff." (DNSP)

Key Issues

- One DNSP has experienced technical issues with his EV chargers.
  - "Fast chargers were not being plugged into power sockets correctly." (DNSP)

AFV Fleet Uptake

Overall Findings

- Even though, the respondents have previously had EVs or NGVs in their fleet, these vehicles are phasing out.
  - "We previously leased 6 Toyota Prius HEVs, but we are currently only leasing 1 Prius." (DNSP)
  - "We have two Mitsubishi iMiEVs and approximately 50 hybrid (Honda Civic, Toyota Camry and Prius) but they are phasing out" (DNSP)

Key Issues

- A number of reasons for the phasing out of EV vehicles were discussed:
  - "EV are being phased out due to maintenance and driver control concerns. We are considering getting rid of our 2 iMiEVs due to concerns about driver safety, trouble finding specialist mechanics to do repairs and uncertainty regarding charging of vehicles." (DNSP)

Drivers

Overall Findings

- The respondents believe the incorporation of EVs into the fleet of vehicle was politically motivated
    - "A main driver for incorporating HEVs into fleet was enhancing corporate image; being seen to be actively addressing CO_2 fleet emissions is an important business driver." (DNSP)

Barriers

Overall Findings

- There are a range of EV barriers that need to be overcome
    - "Inflexibility around charging is a barrier given that many of the light/heavy commercial vehicles need to make emergency service and repair trips" (DNSP)
- "There is no strategy to promote EVs at corporate level" (DNSP)
- "Functionality/performance and driving range of EVs are not a concern. Most of the vehicle trips made by our fleet are within the driving range of EVs" (DNSP)
- Lack of policy support was identified as a key barrier
    - "We did not renew leases for Toyota Prius because of the lack of economic incentive." (DNSP)

Key Issues

- Some of the respondents have conducted an economic analysis of the cost of charging infrastructure: "they will be a significant investment." (DNSP)

AFV Fleet Experience

Overall Findings

- The respondents return of experiences on the use of EVs in their fleet were the following:
    - "There were some challenges in term of driving control, the Toyota Prius HEVs took a while to get used to." (DNSP)
    - There were "no battery issues with the Prius" (DNSP)
    - "Economics of Prius did not stack up against Toyota's promised fuel bill savings. The vehicle only achieve a $30-50 saving per vehicle per month."

Appendix 3 – Summary of Data Sources

Australia's Energy Balance	Bureau of Resources and Energy Economics (2014), *Energy in Australia*
Gas Industry Upstream Efficiency	Dept. of Resources, Energy and Tourism (2013), *EEO in Gas Transmission Pipelines and Distribution Networks*
Electricity Industry Upstream Efficiency	Energy Supply Association of Australia (2014), *Electricity Gas Australia*
Industry Employment and GVA	Australian Bureau of Statistics (2013), *8155.0 – Australian Industry*
Projected Generation Mix	Arup (2014), *Smart Grid, Smart City: Shaping Australia's Energy Future. National Cost Benefit Assessment*
Retail Electricity Prices	Energy Australia (2015), *Energy Price Fact Sheets*
Retail Gas Prices	Independent Pricing and Regulatory Tribunal (2014), *Fact Sheet – Changes in Regulated Gas Retail Prices from 1 July 2014*
Sales of New Motor Vehicles	Australian Bureau of Statistics (2014), *9314.0 – Sales of New Motor Vehicles, Australia*
Australian Population Projections	Australian Bureau of Statistics (2013), *3222.0 – Population Projections, Australia, 2012 (base) to 2101*
Crude Oil Price Projections	Energy Information Administration (2014), *Annual Energy Outlook 2014*
Lithium Ion Battery Cost Projections	Energeia (2015), *Storage Market Insights 2015*
Vehicle Fuel Efficiency	Dept. of Infrastructure and Regional Development (2015), *Green Vehicle Guide*
Electricity Grid Emissions Intensity	ACIL Allen (2013), *Electricity Sector Emissions*
Foreign Exchange Projections	Australian Energy Market Operator (2014), *IE Economic Forecast 2014*
Particulates Emission Cost	PAE Holmes (2013), *Methodology for Valuing the Health Impacts of Changes in Particle Emissions*
Carbon Price Projections	ACIL Allen (2013), *Electricity Sector Emissions*