Research note

Electric cars for Perth

Introduction strategies and impacts on electricity demand

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ACIL Tasman
Economics Policy Strategy

ACIL Tasman Pty Ltd

ABN 68 102 652 148
Internet www.aciltasman.com.au

Melbourne (Head Office)
Level 4, 114 William Street
Melbourne VIC 3000

Telephone (+61 3) 9604 4400
Facsimile (+61 3) 9604 4455
Email melbourne@aciltasman.com.au

Brisbane
Level 15, 127 Creek Street
Brisbane QLD 4000
GPO Box 32
Brisbane QLD 4001

Telephone (+61 7) 3009 8700
Facsimile (+61 7) 3009 8799
Email brisbane@aciltasman.com.au

Canberra
Level 1, 33 Ainslie Place
Canberra City ACT 2600
GPO Box 1322
Canberra ACT 2601

Telephone (+61 2) 6103 8200
Facsimile (+61 2) 6103 8233
Email canberra@aciltasman.com.au

Darwin
GPO Box 908
Darwin NT 0801

Email darwin@aciltasman.com.au

Perth
Centa Building C2, 118 Railway Street
West Perth WA 6005

Telephone (+61 8) 9449 9600
Facsimile (+61 8) 9322 3955
Email perth@aciltasman.com.au

Sydney
PO Box 1554
Double Bay NSW 1360

Telephone (+61 2) 9389 7842
Facsimile (+61 2) 8080 8142
Email sydney@aciltasman.com.au

For information on this report

Please contact:

Simon Sagerer
Telephone (08) 9449 9600
Email s.sagerer@aciltasman.com.au

Synopsis

This paper presents a high level analysis of international electric vehicle (EV) market penetration strategies and of the impact a comprehensive introduction of EVs would have on the electricity supply infrastructure in Perth.

Since the benefits of EVs are mainly public goods, many countries have announced national introduction strategies. All strategies aim at reducing the cost gap between EVs and conventional cars by subsidising either the development of the final product, the development of a key input or the rollout of key infrastructure. In light of the proposed timelines in these strategies, a technological breakthrough towards cost efficient EVs within the next five years appears probable.

After this breakthrough a systematic introduction of EVs to Perth could commence. The key to a successful introduction is an adequate and comprehensive electricity supply infrastructure. Its quality would have to be measured against the current network of petrol stations. In order to replace petrol stations, electric charging stations will have to be available in homes, at car parks and along major highways.

The additional electricity demand created by EV charging will be substantial. Nevertheless, with a sophisticated demand management scheme, EV charging can be catered for without adding generation capacity to the grid. The intellectual property attained during the development of this scheme has the potential to unlock new export markets.

The paper is divided into two parts: The first part gives an overview of the current state of the electric vehicle industry and presents the resulting national R&D strategies (Sections 1 and 2). In the second part (Section 3) the framework of an infrastructure rollout strategy for Perth is developed.

1 Electric vehicles globally

To date electric vehicles (EV) are very rarely used as an alternative to conventional cars. Most EVs have a very short range (less than 30km) and are very slow (less than 40km/h).

The first generation of medium range (up to 250km) serial EVs is set to be introduced around 2012. It will consist of subcompact and compact vehicles, as well as some luxury sport vehicles. With prices around $50,000 the compact EVs will be very expensive compared to conventional cars of this class (see Appendix A for details).

Nevertheless governments all over the globe regard EVs as a key future technology, because:

1. In contrast to electricity, fossil fuel often has to be imported and reserves are limited.
2. The use of EVs can significantly reduce carbon emissions.
3. The advancement of the associated technologies has the potential to strengthen the global standing of the resident car manufacturing industry or to create new export markets.

Two major factors currently inhibit the rapid introduction of EVs:

- Energy storage for EVs is prohibitively costly.
- Charging infrastructure is inadequate.

The reduction of relative storage costs requires either a major breakthrough in battery technology or a significant price increase of the alternative fuel, oil. Given the current price of petrol ($1.25/litre), the ten year average fuel price inflation (3 per cent) and current domestic electricity prices ($0.2 KWh) the maximum difference of purchase prices which makes an EV a cost efficient alternative is $10,000. If the petrol price were to double in the next ten years (annual inflation of 7 per cent) - as predicted by experts - this difference could be as high as $13,000 (see Appendix B for detailed assumptions); i.e. an EV would be an attractive alternative if its purchase price was $13,000 higher than that of a comparable petrol vehicle.

The purchase price difference between the only currently available serial EV in Australia (the Mitsubishi i-MiEV) and its petrol driven brother (the Colt), is more than $30,000. This means that at this point of time an unbiased car buyer would have to receive purchase subsidies between $17,000 and $20,000 (depending on his fuel price expectations) to make the EV an attractive alternative.

The basic technology for the required charging network is available as EVs can be charged at household power points. Additionally quick charging stations are also readily available. However, a comprehensive network at public places (car parks) would be needed, so metering and payment options would have to be developed.

2 Strategy options

The resident car industry is often a key contributor to a country's economy[1]. Therefore its performance tends to be regarded as a matter of national interest. Additionally environmental and fuel security concerns are public goods and thus do not directly affect the car builders' bottom lines. Thus R&D enhancing strategies for EVs have to be analysed on a country basis rather than a company basis.

The realisation of the goals associated with EV - independence from foreign oil and climate protection – is not contestable. Therefore they are excluded from the following analysis. Becoming a technology leader in a certain field is contestable. Three straightforward components are of crucial significance to the long term success of EV technology:

1. Car (final product)
2. Batteries (key input)
3. Charging network (key infrastructure)

2.1 Final product

The goal of the final product strategy is to make the resident car companies global technology leaders by encouraging and accelerating the development and market introduction of electrical cars. The government aims to create a favourable market framework, e.g. by subsidies for manufacturers or purchasing incentives for customers, in order to encourage manufacturers to quickly ramp up production and thus exploit scale and learning curve effects.

Requirement: A large resident automobile sector with strong R&D capabilities.

As it is the most comprehensive approach the final product strategy promises the highest benefits but it is also associated with the highest cost. The major car producing countries such as Germany, Japan and the USA are pursuing this option. This is not an option for Australia.

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[1] For example, based on figures provided by the US Department of Labor, the Center for Automotive Research estimates that the automobile sector accounts for 10 per cent of the jobs in the US economy.

2.2 Key input

Becoming the leader in battery technology can be the basis of setting up a leading EV manufacturing industry and also creates the opportunity of exporting superior batteries to (other) EV producers. This strategy relies on supporting basic research.

Requirements: Strong R&D capability, key natural resources and significant results before final product development is at an advanced stage.

This strategy has been adopted by China which has become the world's dominant Li-ion battery manufacturer and whose R&D institutions currently lead the publication index in this field. Additionally China hosts 75 per cent of the currently known lithium reserves.[2]

Nevertheless key input development could also be an option for Australia. CSIRO has contributed to the field by developing batteries for hybrid cars and Australia has the second largest known lithium reserves. However, current research in Australia appears to be focussed on large scale electricity storage devices, not vehicle batteries.

2.3 Key infrastructure

The provision of key infrastructure aims at developing the intellectual property to cater for a large share of EVs in the total personal transport fleet. This knowledge can then be exported.

Requirements: Sufficient resources to develop and implement infrastructure. A relatively small and well defined market can be favourable in order to limit the number of EVs needed to create a critical mass and have an impact.

Denmark is committed to this option and plans to build a large number of wind-powered charging stations.

The infrastructure approach could also be a feasible option for the Perth metropolitan area. The SWIS electricity grid is relatively small and thus subject to similar weather conditions and demand patterns making average load patterns well known and daily conditions easy to predict. Additionally most households have garages which are attached to the house and contain power-points, therefore home-charging does not require the implementation of additional infrastructure (in contrast to e.g. European cities).

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[2] US Geological Survey (2009)

2.4 Probable global progress timeframe

Two very ambitious examples of implementation timeframes are those of the USA and Germany: The USA intends to have 1,000,000 plug-in hybrids on the streets in 2015 and Germany 1,000,000 EVs by 2020. China's goal is to produce batteries which could power one million EVs by 2012. These plans indicate that a wide range of affordable serial EV models has to be available by 2015.

3 EV infrastructure model for Perth

Future EV supply infrastructure has to replace the existing conventional car fuel supply infrastructure. Therefore it should be at least as reliable and convenient to use. This means that sufficient electricity has to be available at any point of time and that the charging-station network needs to be as comprehensive as the current network of petrol stations.

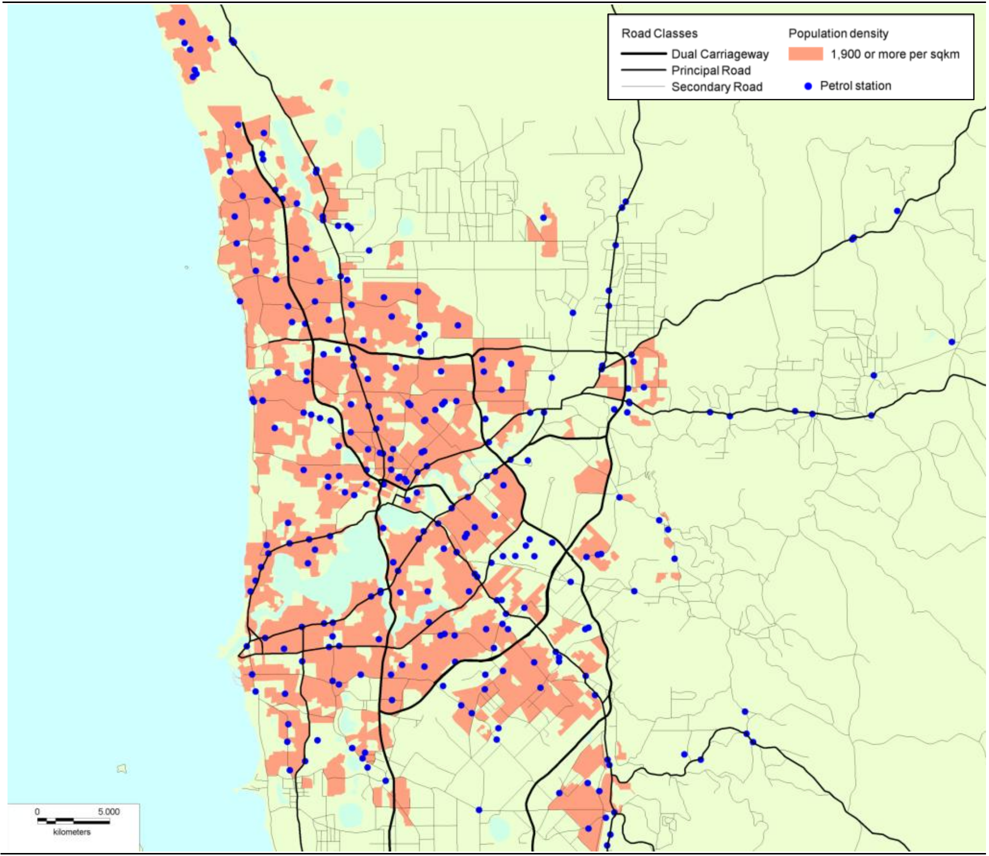
The development of a model for Perth follows this structure and is presented in two parts:

1. Spatial analysis (i.e. where is the demand created?)
2. Demand level analysis (i.e. how much demand is created?)

3.1 Spatial implications

The conventional equivalent of a charging station for an EV is a petrol station. Therefore the distribution of petrol stations in the metropolitan area provides useful insights into the car charging preferences of households. Figure 1 shows petrol stations and population density in Perth.

Figure 1 **Petrol station distribution vs. population density, Perth**



Data source: Australian Bureau of Statistics: Census 2006, Geoscience Australia and FuelWatch

The map indicates that petrol stations can be found in two types of location: densely populated areas and along major highways. This implies that drivers tend to refuel their cars either close to home or while they are travelling. Hence they are two basic demand types which have to be satisfied: habitual refuelling taking place close to home or work and contingency refuelling along major highways.

The infrastructure for habitual demand can be a power point where the EV is regularly parked for longer periods of time. As many households in Perth have power points in their garages part of this infrastructure is already in place. The second component would be charging stations at workplace car parks. The provision of car park charging stations might not appear essential and would require a significant investment but the benefits of this infrastructure expansion will become evident in the next chapter.

The key attribute of the contingency infrastructure is recharging speed. Therefore quick charging stations would have to be installed in strategic locations along major highways.[3]

3.2 Generation capacity implications

We have constructed a model to estimate the additional electricity demand created by the charging of EVs in a scenario in which the habitual charging infrastructure is in place. A load pattern for the South West Interconnected System (SWIS) for each year between 2010 and 2040 is calculated by the minute.

The model is based on the hypothesis that the key relevant household preferences will not fundamentally change in the next 30 years: Individual transport will still be the preferred mode of commuting and while individual consumption levels might change, the overall relative daily consumption pattern will remain the same (Figure 2).

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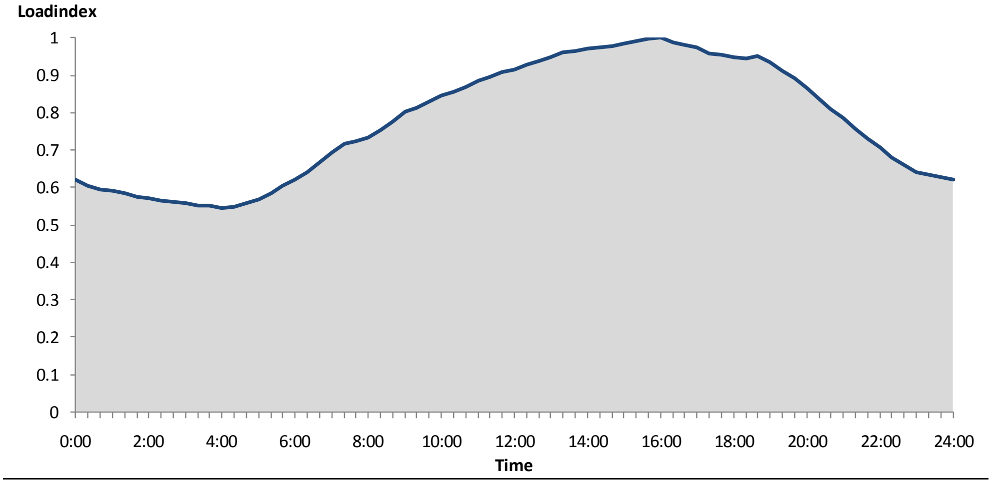
[3] The current generation of these stations are capable of recharging up to 80 per cent of an EV's battery in 30 minutes.

Figure 2 **Normalised daily load curve for the peak load day in the SWIS, 2010**



Note: Maximum demand = 1

Data source: IMO

3.2.1 Assumptions

1. EV usage

   Average daily driving distance is 30km. It is composed of the average daily commuting distance in Perth of 25km roundtrip (*Population growth, jobs growth and commuting flows in Perth*, Department of Infrastructure and Transport WA, 2010) and 5km for contingencies.

   a) Average consumption: 0.25 KWh/km
   Tesla Motors claim the Roadster's consumption to be 0.18 KWh/km but do not specify under which driving conditions this result was obtained. Mitsubishi estimate the consumption of the i-MiEV at almost 0.3KWh/km in urban traffic. The assumed figure is the average of the numbers with a slight bias towards Mitsubishi's results.

   b) Maximum wall plug capacity: 3.5 KW

   c) EVs are recharged for just over two hours every day.

      i In the morning cars are plugged in at work and recharged. On average for 53 minutes so the 3.125 KWh used during the 12.5 km commute are recovered.

      ii In the afternoon recharge time is 75 minutes. This longer period accounts for additional distances driven after work (shopping etc.) total charging volume is 5.375KWh or 17.5km.

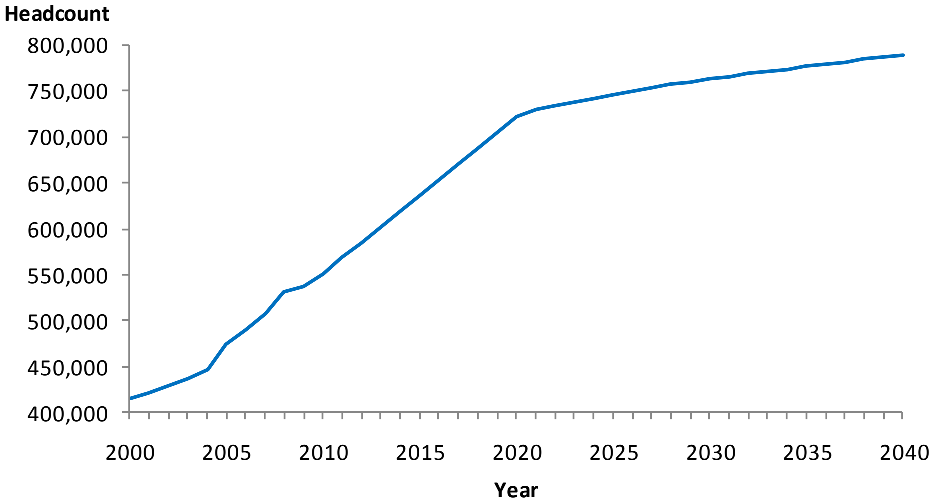
   d) Commuting follows a normal distribution with a standard deviation of one hour and occurs twice a day:

      i Morning: Expected time of arrival at work 8:50 am.

      ii Afternoon: Expected time of arrival at home 6:30 pm.

2. Population
   a) 65 per cent of total jobs in Western Australia are commutable within the Perth metropolitan area (compare *Population growth, jobs growth and commuting flows in Perth).*
   b) Share of workforce individually commuting remains constant at 70 per cent (compare *Population growth, jobs growth and commuting flows in Perth*).
   c) Until 2020 the workforce grows according to CCI predictions (*Building Western Australia's Workforce for Tomorrow*, 2010) and then follows the long term trend.

Figure 3 **Commuter development Perth, 2000 to 2040**

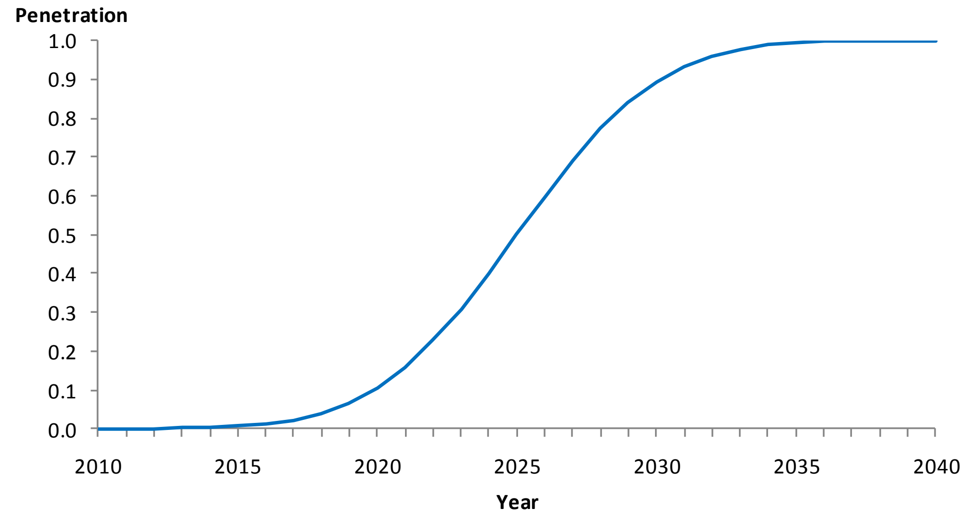


Data source: CCIWA, ACIL Tasman

3. Market introduction

   Market introduction follows a normal distribution calibrated to the data presented in chapter 2.4 (Mean for Australia = 2025, standard deviation = 4 years): In 2010 EVs are a marginal phenomenon, the market starts picking up in 2020, by 2025 50 per cent drive EVs and by 2031 more than 90 per cent of car commuters drive EVs. In this scenario WA would act as an early adaptor and would thus be able to benefit from early learning effects.

Figure 4 **Market introduction timeline**



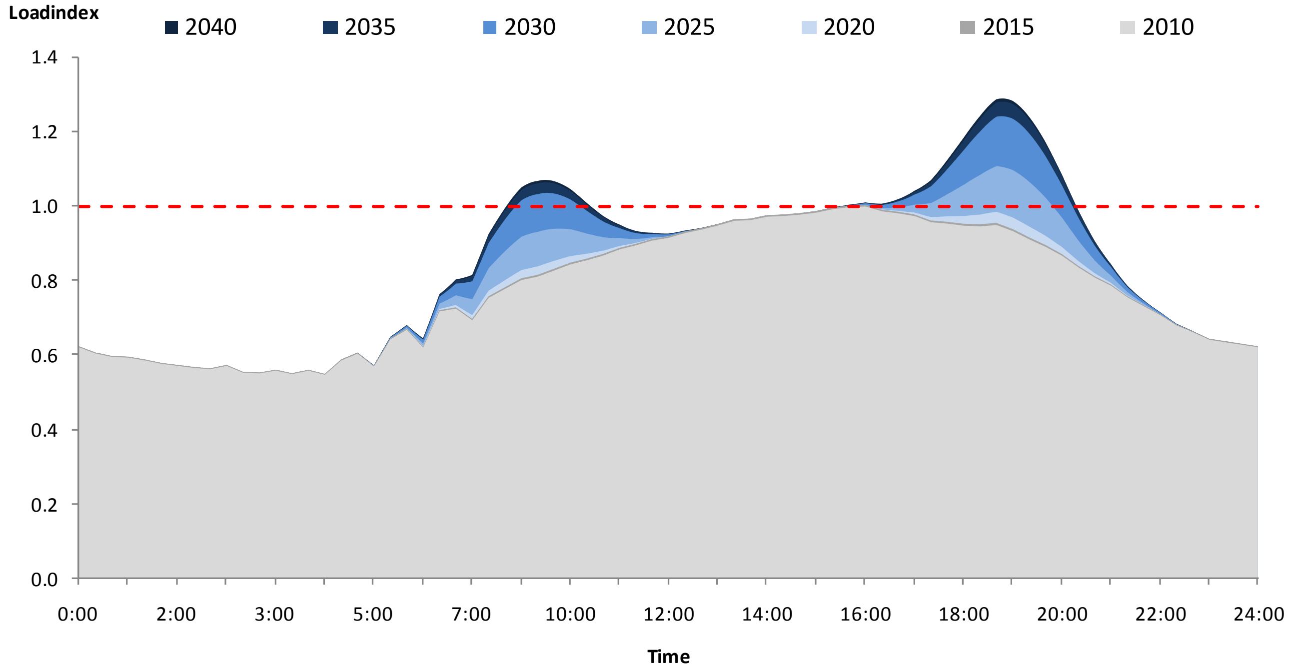
Source: ACIL Tasman

3.2.2 Results

EV electricity demand is calculated by determining the number of charging cars in each time interval and adding the result to the historic load pattern. This procedure is repeated for each year.

In accordance with the assumptions the model predicts new load peaks of annually increasing magnitude in the morning and the afternoon. Over time both exceed the existing peak; the morning peak in each year after 2028 and the afternoon peak in each year after 2020.

Figure 5 **Development of load pattern including EVs, 2010 to 2040**



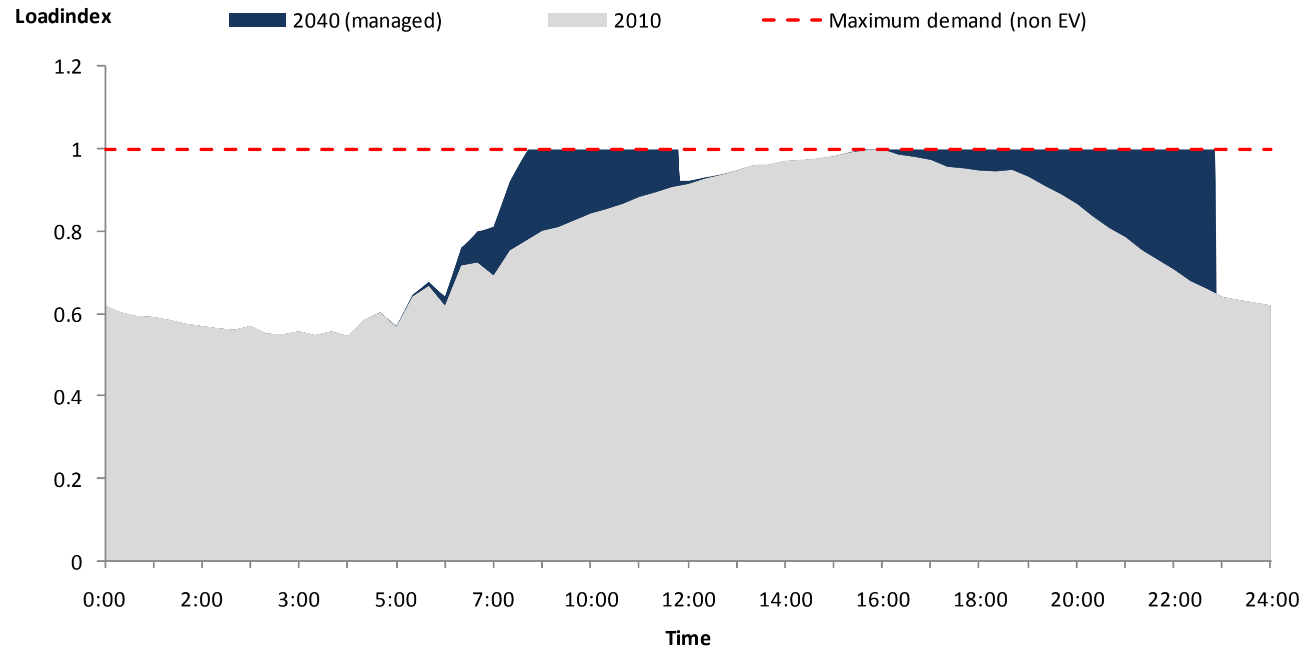
Source: ACIL Tasman

As there is plenty of spare generating capacity during off-peak periods, demand management has the potential to relieve the EV imposed load on the grid considerably.

A straight forward demand management method would be a first-come-first-serve approach with the non EV load peak as capacity limit (or alternatively the capacity of the generation available at that time). As long as the load is at least 3.5 KW below the limit each EV is charged straight away. Every EV whose charging would breach this limit enters the queue. The first EV entering the queue will be the first to commence charging as soon as a capacity slot is available. As Figure 6 shows this approach expands the duration of the peak but also leaves significant spare capacity during the night.

Immediate charging is not required since the range of this EV-generation by far exceeds the average daily usage. Therefore, as long as an EV is charged at work and some time at night on a daily basis charging limitations will not jeopardise personal mobility.

Figure 6 **Demand managed load pattern, 2040**



Source: ACIL Tasman

3.3 Conclusions

- Two types of charging infrastructure are needed:
  - Controlled power points in houses and at car parks.
  - Quick recharging stations along major highways.
- Non managed demand reaches a critical level in 2020 at the assumed introduction rate; i.e. EVs will cause a new system peak demand. This means that ideally infrastructure improvements and demand management schemes are in place by this time.
- Without demand management additional demand of up to 35 per cent of peak demand would be created by EVs (at current levels this amounts to 1,330 MW).
- Demand management could entirely mitigate the need for additional generation capacity. The underlying intellectual property could unlock new export markets.
  - EV charging control could be readily delivered by radio or ripple control from power system control centres.
  - The opportunity exists to develop and implement a standard device that connects the EV to the power supply and provides the necessary control to allow the EV to be charged at a time, at a rate and at an energy price that can be optimised and controlled.

A Expected global EV fleet in 2013

Table A1 **EV model summary**

Name	Class	Price (AUD)	Price of petrol version (AUD)	Introduction	Size of first series
Mercedes A-Class E-Cell	Compact	80,000	40,000	2011	500
Nissan Leaf	Compact	45,000	n/a	2011	Not limited
Renault Fleunece Z.E.	Compact	55,000	25,000	2012	Not limited
Volvo C30 DRIVe Electric	Compact	n/a		2011	250
VW Golf blue-e-motion	Compact	n/a		2013	Not limited
Mini E	Subcompact	55,000	30,000	2009	Test fleet
Mitsubishi i-MiEV	Subcompact	55,000	20,000	2010	Not limited
Citroen C-Zero	i-MiEV twin				Not limited
Peugeot iOn	i-MiEV twin				Not limited
Smart ed	Subcompact	35,000	20,000	2012	Not limited
Tesla Roadster	Sport	100,000	n/a	2008	Not limited
Audi R8 E-tron	Sport	n/a		2012	Miniseries
Mercedes SLS AMG E-Cell	Sport	500,000		2012	Miniseries

Note: Prices are estimates

Data source: Company websites

B Running cost assumptions

Table B1 **Running cost assumptions**

Variable	Electric car	Conventional car
Fuel price	$0.20/KWh	$1.25/litre
Consumption per km	0.25 KWh	0.1 litres
Usage per month	1,000 km	1,000 km
Oil change	n/a	$100 p.a.
Lifetime	10 years	10 years
Discount rate	5%	5%