Comments on AEMC Issues Paper, Energy Market Arrangements for Electric and National Gas Vehicles

Comments submitted by
Saturn Corporate Resources Pty Ltd

21 February 2012
(revised 4 April 2012)

1. Introduction

These comments on the AEMC Issues Paper on Energy Market Arrangements for Electric and Natural Gas Vehicles, 18 January 2012, have been prepared by Saturn Corporate Resources Pty Ltd (SCR). Note that the principle author, Graham Armstrong, was unable to edit the prepared submission due to hospitalisation from 16 February until 29 March 2012 (heart and hip replacement surgery).

Our comments are confined to electric vehicles: battery electric vehicles (BEVs) and plug-in hybrid vehicles (PHEVs), collectively referred to as PEVs. The context for our comments is a project we undertook in 2011, *Analysis of the Impacts of Electric Vehicles on the New South Wales and NEM Electricity Grids* for the NSW Department of Climate Change and Water, in association with Futura Consulting and the National Institute of Economic and Industry Research (NIEIR).

It had seven specific objectives, as follows:

- to forecast low, medium and high PEV adoption scenarios in NSW and the NEM in 2020, 2030 and 2040;
- to determine the potential impacts of these alternative take-up rates on PEVs on electricity distribution networks at the NSW state and NEM levels;
- to assess the impacts of the PEV charging on electricity generation requirements in NSW and the NEM;
- to advise on appropriate Government intervention such that future grid impacts are managed;
- to evaluate the impact of EV adoption on greenhouse gas emissions in NSW and across the NEM in future;
- to advise on the potential future economic and environmental benefits that could derive from consumer acceptance of PEVs; and
- to identify barriers within the electricity sector that would prevent these benefits from being realised.

Our response to the AEMC issues paper therefore addresses issues related to Question 1 – Assessing the take up of EVs; Question 3 – costs imposed by EVs on electricity markets, Question 7 - EV metering issues, Question 8 - Options for EV charging and Question 14 Network Issues: Network reinforcement and integration.

2. Methodology for estimating electricity grid impacts

The Futura, SCR, NIEIR study, 2011

Initially, high-level modelling was undertaken to assess the system-wide impacts of PEVs on the NSW and NEM electricity grids. For each of the regions, six baseline scenarios of annual electricity energy, maximum demand and the associated summer and winter 10% POE[1] daily load profiles for the period 2012 to 2040 were developed from the AEMO's 2010 and 2011 NTNDP forecasts. The scenarios represent varying levels of state economic growth and carbon prices (variables which have been found to be significant influencers of electricity consumption) and all exclude PEVs. Supply-side greenhouse gas emission coefficients were also modelled for each of the twelve BAU scenarios.

A transport model was developed: key variables included: the penetration of PEVs from 2012 to 2040; PEV charging characteristics, charging management regimes, and vehicle types. The model was developed to assess the annual energy and maximum demand (at time of system NSW or NEM system peak) requirements of PEVs. Hourly and daily demand profiles for PEV charging loads were also developed. Charging profiles (levels, timing) were developed from New South Wales vehicle travel data. For example, length and timing: departure, destination, home arrival.

Combining the electricity sector and the transport sector models enables quantitative assessment of the impact of incremental PEV loads on the NSW and NEM BAU baseline electricity scenarios, generation requirements and CO_{2e} emissions. Importantly, overlaying the hourly daily demand profiles for the expected PEV charging loads on the BAU summer and winter 10%POE load profiles demonstrates the benefits of Managed or Controlled charging regimes as a means of shifting PEV demand away from system peak periods and mitigating the impacts of the PEV charging load on the grid.

While the high level modelling provides an assessment of the 'average' system-wide impacts of increasing PEV penetrations across the NSW and NEM electricity grids, the impacts in localised areas of the distribution network may differ significantly from the 'average' in the short term if 'early adopters' of PEVs, or PEV charging infrastructure are concentrated in specific geographical areas. Case studies developed by the project team, in conjunction with Ausgrid and Essential Energy, were used to explore the potential localised impacts of PEVs at the distribution transformer and sub-feeder level and how this could translate to network augmentation requirements and associated capital expenditure.

The study reviewed and used a range of technical EV data from an earlier study for the NSW Department of Climate Change and Water (DECCW) by AECOM.

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[1] A forecast 10% POE maximum demand figure will, on average, be exceeded only 1 year in every 10 and thus represents a 'worst case scenario for assessing the impacts of PEVs on the power grid.

Scenarios and sensitivities

Six scenarios were used in the model to represent different levels of CO_{2e} intensity and economic growth for the BAU electricity sector in the absence of PEVs entering the marketplace.

- **Scenario A – Fast rate of change***:* There is sustained high economic growth in Australia and the rest of the world and high global energy prices. Low emission generation technologies are becoming economic. A high carbon price, corresponding to a 25% carbon reduction target from 2000 by 2020 is in place.
- **Scenario B – Uncertain world**: Economic growth is strong but without strong carbon incentives, R&D stalls, low-emission electricity generation technology costs remain high and the retirement of coal fired plant is delayed. The carbon price is low, corresponding to a minimal 5% carbon reduction target from 2000 by 2020.
- **Scenario C – Modest rate of change:** The economy is doing reasonably well. New generation low emissions technologies are developing and some low emissions technologies are maturing. The carbon price increases, corresponding to a 15% carbon reduction target from 2000 by 2020.
- **Scenario D – Independent climate action**: Economic growth is reduced and there is a high carbon price, corresponding to a 25 per cent carbon reduction target from 2000 by 2020.
- **Scenario E – Slow Rate of Change:** There is a low rate of economic growth world-wide. R&D in new low emission generation technologies is slow. A low carbon price equivalent to a 5 per cent carbon reduction target from 2000 by 2020 is introduced.
- **Scenario Alt B:** All dimensions of Scenario B remain unchanged but there is no carbon price leading to the lowest decline in GHG emissions.

The above scenarios, along with the associated annual MWh energy requirements, MW of MD in summer and winter and peak day hourly load profiles were derived from the AEMO's 2010 and 2011 NTNDP reviews. The outputs from the AEMO's 2011 reviews, which cover the period 2012 to 2030, were extended to 2040 by the project team.

The transport model covered the energy consumption and other performance attributes of four vehicle types: BEVs; PHEVs; HEVs (hybrid electric vehicles) and ICEs (internal combustion engines), covering five vehicle categories. Private vehicle with engine size <1.8l (small); private car with engine size >1.81l to 3l (medium); private car with engine size >3.1l (large); LCV; and Taxi. Three distinct market adoption cases, each based on PEVs entering the market in 2010 and penetrations over 2010-40 were developed, and from these three scenarios on EV potential impacts were developed. The first two reflect alternate views on the possible future development of PEV charging infrastructure and power (kW) levels developed by AECOM, and the third was developed by the project team.

- **Scenario 1 –** Household and public charging at 2.3 kW, 3.4kWand 6.3 kW (Level 1, Level 2-slow and Level 2 rapid) is available. Charging times range from around 3.8 hours/40 km to approximately 1.4 hours/40km. PEV penetrations are relatively low (termed **Low**);

- **Scenario 2 –** Level 1 and 2 charging is available at households and pubic charge point s and Level 3 (50kW to 190 kW with charging times of around 10 mins/40 km to 3 minutes/40km) is available at rapid charging stations. The additional infrastructure increases PEV penetrations (termed **AECOM High)**; and

- **Scenario 3** was developed by the project team as a sensitivity to Scenario 2 to 'test' the impact of oil and electricity prices and the inclusion of excise as a proxy for road user charges, on PEV take-up rates (termed **High).**

BEVs and PHEVs annual sales as a percentage of the total New South Wales fleet sales were estimated for the 2010-2040 period, see **Table 1**.

Table 1 **PEV (BEV, PHEV) annual sales as a percentage of total New South Wales fleet annual sales**

	2020	2030	2040
BEV	0.6% to 1.5%	2.2% to 5.9%	5.9% to 16.0%
PHEV	1.9% to 2.2%	25.2% to 32.2%	49.2% to 62.9%

PEV forecast fleet numbers for the NEM were derived pro- rata from the NSW numbers using data on the number of registered vehicles on the road by type in 2010 for each NEM region.

Finally, a simplified model comprising three specific charging regimes based on analysis of BTS NSW household survey data on current driving patterns was constructed:

- **Unmanaged charging** – with no price signals to shape behaviour, drivers will charge PEVs at their own discretion;

- **Managed charging** – price signals, such as TOU, are used to offer an incentive to drivers to charge their vehicles during off-peak time periods when the demand for electricity on the grid is lower (controlled charging in the AEMC is a subset of managed charging); and

- **Smart charging** – allows PEVs to interact with the grid and optimise the timing of the vehicle charging.

3. SCR team study evaluation and issues

Initially an earlier paper prepared for the NSW Department of Environment and Climate Change (DECCW) by AECOM, *Economic Viability of Electricity Vehicles* (4 September 2009) was reviewed. The analysis in this earlier study, which was not intended to cover the same objectives as the SCR/Futura/NIEIR study, was extended to cover a range of economic scenarios (see above), to assess recent studies on PEV penetrations, to update electricity and oil price forecasts, to detail grid and GHG emission impacts, and to assess the integration of PEVs with renewable electricity.

In the PEV penetration area a deficiency we found in a range of EV studies recently (2007-2011) undertaken was a failure to consider the issue of road user charges for electric vehicles. That is, although it is a blunt instrument, excise on fuels for internal combustion engine (ICE) vehicles, can be viewed as a road user charge.

If PEVs were exempted from some form of excise equivalent (PHEVs will not be completely exempt), albeit involving significant but not insuperable[2] administrative issues, PEV would have a significant advantage over ICEs. As PEV penetration increased, compared with a non-PEV scenario, some other revenue source(s) would have to be found to maintain a given revenue if PEVs were revenue exempt. Ideally universal direct road use charging would be introduced (as proposed by a range of economists (including the Nobel Laureate William Vickery in the 1960s). The level playing field issue for PEVs and ICEs is significant and would also include similar treatment of emissions (GHG, noxious) for ICEs and EVs. In the SCR team study “excise equivalence” for PEVs and ICEs was estimated.

Other areas of sensitivity analysis in projecting the comparative economics of PEVs and ICEs are:

(i) PEV costs, particularly the future prices (and performance) of batteries: see for example the Boston Consulting Group (BCG) study, *Batteries for Electric Cars: Challenges, Opportunities and the Outlook to 2020*, 2010;

(ii) comparative actual on-road fuel consumption of ICEs and EVs;

(iii) changes in electricity and ICE fuel prices; and

(iv) climate change policies affecting the greenhouse gas intensity (GHGIs) of PEV and ICE fuels.

These issues were addressed in the SCR team study but not adequately in most other reviewed studies. Expansion of these issues is set out below.

(i) Battery costs

A Boston Consulting Group (BCG) and several other studies suggest that the battery cost reductions, a significant determinant of PEV penetration increases, may be overly optimistic. Accordingly, the initial price gap between comparable (size, performance) PEVs and ICE vehicles may persist for much longer than is often assumed, thus slowing the penetration of PEVs.

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[2] Exempted metered charging points could be required for PEV charging.

(ii) Comparative actual on-road performance of PEVs and ICEs

We were not able to find a PEV study which comprehensively addressed this issue. For example, by considering actual on-road use of ancillaries, particularly internal vehicle heating and cooling which is included in on-road performance data for ICEs. It seems that more work is required on this operating cost issue.

(iii) Changes in electricity and ICE fuel costs

In their initial study for DECCW, AECOM appear to have assumed constant electricity and oil (petroleum product) prices. Both these sets of energy prices are likely to change significantly over the next 30 years and thus affect the operating costs of PEVs and ICEs. Factors influencing these prices are climate change policies and supply-demand conditions. Also, in the case of electricity changes in generation, fuel prices (at \$/t CO_2e) and fuel mixes, network costs and retail margins.

In the case of ICE fuels energy source mixes (petroleum products, biofuels, gas) and the prices of the energy sources in the mix must be considered. For example, crude oil prices, although likely to exhibit volatility, could be significantly higher or somewhat lower (on average) than current prices over the period to 2050.

The SCR/Futura team conducted a Delphi analysis of fuel prices: see **Attachment A**.

(iv) Greenhouse gas intensities (GHGIs) of PEV and ICE fuels

GHG emissions on a full fuel cycle basis (FFC) will depend on PEVs and ICEs, in addition to their actual on-road performance, on the energy (tCO_2e/MWh) mixes of their respective fuels.

In low GHGI electricity jurisdictions, such as Tasmania, Iceland, Norway and France, PEVs would have a clear GHG emission advantage, but in most of Australia, with the current fuel mix, the advantages may not be significant. However, over time with carbon pricing the GHG advantages of PEVs will increase as the GHGI of electricity drops, unless ICE fuels have a significantly higher alternative fuel component.

Note, however, that in the emissions area, PEV penetration may well be driven by urban air quality concerns and regulations. This will apply regardless of electricity GHGIs.

Renewable electricity/PEV integration issues

PVs: output not significant in peak electricity demand periods.

Vehicle to grid (V2G) issues include use of PEVs for renewable electricity storage, availability of stored energy and battery impacts.

Federal Renewable Electricity Target (RET) constraints.

Smart grid importance.

A presentation on the SCR/Futura study to the NIEIR Energy Conference, Melbourne, December 2011 is provided in **Attachment B**.

4. Key findings and recommendations of SCR/Futura/NIEIR study

1. Currently most studies project that PEV penetrations will become substantial after 2020, when initial costs of EV and ICE vehicles are comparable and ICE fuel prices rise relative to electricity prices. This PEV penetration projection depends, however, on a number of factors including:

   (i) reductions in battery costs and improvements in battery performance;

   (ii) electricity/ICE fuel prices diverging substantially; and

   (iii) treatment of road user charges for PEVs and ICEs.

2. Under the PEV penetration increases used in this study, before 2020 the impacts of PEVs on the New South Wales and NEM systems will be minimal in all scenarios. The most significant impacts estimated would occur after 2030 as PEV penetrations increase.

   This will allow jurisdictions and electricity system managers adequate time to:

   (i) monitor EV penetrations and their impacts; and

   (ii) develop strategies to manage potential EV impacts.

3. In New South Wales and the wider NEM winter electricity peaks are increasing due mainly to the increased use of reverse cycle air conditioners (RACs) for space heating. Accordingly, attention of EV impacts on system peaks and overall demands should not be focussed solely on summer peaks.

4. Unmanaged EV impacts (MW requirements) are significantly higher than Managed and Smart impacts when these charging control techniques are introduced post-2020. This indicates the need to commence exploring the options for deploying these techniques and to determine the timing of their introduction.

5. In the 100 per cent BEV scenarios, impacts (MWs) are significantly higher than the 50 per cent BEV and 50 per cent PHEV scenarios.

   PHEVs would probably be preferred to EVs for higher kilometre users (LCVs, taxis). This would reduce the need for peak charging by these categories.

6. Higher carbon prices depress overall electricity demands as electricity prices rise but may not significantly affect EV/PHEV purchase decisions because EV/PHEVs purchase prices could become more competitive with ICE vehicles if petroleum fuel prices increases offset electricity price increases.

   As a result, in the carbon price scenarios EV/PHEV impacts would increase relative to the no carbon price scenarios.

7. Managed charging, which encourages charging in off-peak periods (2000 to 0700) increases demands (MWs) relative to no PEV scenarios in the off-peak periods and thus raises system capacity factors. In virtually all cases (except for maximum 2040 NEM EV penetrations) MW demands do not increase above projected BAU (no to low PEV penetration) system peaks.

   The impact of Managed charging on off-peak demands needs to be carefully monitored as it has implications for the generation mix (potentially greater use of higher sent-out cost OCGTs). Thus, off-peak demands approach overall system peaks as PEV penetration increases under managed charging.

8. System peaks **without** PEVs are often similar to peaks **with** PEVs before 2030 and in lower PEV penetration scenarios, but are often earlier than PEV scenario peaks. This pattern has implications for system managers and participants (generators, networks and retailers). Higher PEV peaks imply increased peak capacity and potentially higher capacity factors for higher cost and higher GHGI peakers (OCGTs).

9. The phase-out of electric resistance water heating the load of which is predominantly in off-peak periods will free up significant off-peak capacity for PEV charging.

10. If large numbers of PEVs eventuate, TOU pricing is unlikely to be sufficient to manage PEV loads. 'Smart charging' capability would appear to be an essential function capability to enable load management of PEVs, as TOU pricing alone is unlikely to provide a firm limit on peak demands. Unless the distributor is able to directly control and manage the PEV charging load there may be occasions where, under certain cases, the PEV charging load could create new peak demands at the system (peak, off peak) and localised network levels.

11. The study analysis indicates potentially significant GHG benefits (net) as PEV penetration increases even as the electricity GHGI declines with carbon pricing. GHG results are however sensitive to carbon pricing, renewable electricity policies, actual on road efficiencies of PEV and ICE vehicles and future trends in ICE GHGI, as a result of policies (gm/km standards, for ICE fuels) and the economics of bio-fuels.

12. Further detailed study would be required to fully explore Vehicle to grid (V2G) technical and non-technical issues. But there are significant potential benefits from V2G. However, V2G potential benefits are only likely to be realised if smart charging is introduced post 2020 when it coincides with high EV market penetration.

13. Electric vehicles owners do not currently pay any excise duty on their electricity use. Excise duty on ICE fuels, although a blunt instrument, is a proxy for a road-user charge. Without similar imposts on PEVs road use by PEVs would be essentially free. Direct road user charges for all road-use vehicles would be preferred. Accordingly some form of road-user charge will eventually have to be applied to PEVs. Carbon pricing as currently proposed in Australia will apply to electricity but not to road vehicles under 4.5 tonnes. Also, PEV advantages in urban air quality must be addressed, for example by adjusting road user charges for PEVs in urban areas. These "level playing field" issues must be addressed as EV penetration increases. Road user charging is an important issue which must be addressed in PEV strategies.

14. There is considerable potential for the of use renewable electricity to charge PEVs. To realise this potential in the Australian context consideration will have to be given to future RE (small and large scale) economics, the characteristics of RE generation (intermittent/variable and base load), incentives to use RE for charging and how RE could be linked with PV charging in a smart grid system.

15. The study analysis and results indicate that:

    (i) PEV penetration projections may be optimistic when fuel (oil product, electricity) prices, battery cost level playing field issues are considered;

    (ii) potential negative impacts on the electricity system (generation and networks) can be managed with emerging techniques (time of use pricing, smart grid);

    (iii) there is scope to link renewable/green energy with electric vehicle systems; and

    (iv) emissions (urban, GHG) reductions from transport can be reduced through electric vehicle use.

With respect to PEV penetrations, note that despite substantial promotion by General Motors (GM) of their Volt (PEV) in 2011, 2011 sales totalled 7,500 units. GM's target for 2012 was 45,000 units and given the disappointing 2011 result Volt production was suspended in March 2012. These are early days for PEVs in the market place and these early results do not mean that expected market penetrations by 2020 and beyond will not be realised.

Attachment A

EV take-up/market penetration: Delphi analysis approach to important penetration factors

In forecasting EV take-up critical assumptions are:

- electricity prices;
- oil (petroleum product) prices; and
- road user charges for EVs (excise is a proxy).

Future electricity prices depend on electricity generation fuel prices (at $0/t CO_2e); network (transmission, distribution tariffs); program impacts (RET, ESS); and carbon pricing.

Oil prices depend on global supply and demand trends.

Road user charges: currently excise is a proxy for road user charges. It is not credible to assume that EVs will not be required to pay road user charges.

Sensitivity analysis on AECOM's analysis in these areas is required. To do this the Futura team undertook a Delphi analysis of these factors.

Delphi Panel approach

One way of estimating the future impact of significant analysis factors is to convene a Delphi Panel of persons knowledgeable in these areas. Each Delphi Panel participant attaches a probability to a range of values for these factors: at different times into the future. Future probability (which must add to 1 for a specific factor) values are averaged. Thus, based on probabilities attached to future factor values average futures values for each factor are derived.

In the Delphi factor exercise, six persons knowledgeable in the areas participated: two from Futura, two from SCR and two from NIEIR.

The Panel convenor presented a range of values for each factor over 2011 to 2040 and explained the rationale for the range of values presented.

Each panel member attached a probability to each value put forward and from these probabilities a probable value was computed for each factor in each time period.

Panel members were permitted to insert values outside the Panel convenor's range.

An example for oil prices is provided below.

Oil prices, 2011 to 2040 (A$/barrel, 2011 $'s)

Panel member A (PA input) probabilities attached to average annual prices

2011	2015	2020	2025	2030	2035	2040
100	140	160	180	200	220	250
PA = .2	PA = .7	PA = .7	PA = .7	PA = .7	PA = .7	PA = .6
120	100	125	150	160	160	160
PA = .6	PA = .2	PA = .2	PA = .3	PA = .3	PA = .3	PA = .4
80	80	80	80	80	80	80
PA = .2	PA = .1	PA = .1	PA = 0	PA = 0	PA = 0	PA = 0

Price range sourced from BITRE, IEA and a range of oil analyst views.

For Panel member A, higher oil prices are most probable and PA in 2015 and 2020 replaced some prices with higher prices. PA also believes that post-2020 low prices of $80/barrel have zero probability.

PA's probable prices are as follows.

2011 $(100 x .2 + 120 x .6 + 80 x .2) = $(20 + 72 + 16) = $108/b

2015 $(140 x .7 + 100 x .2 + 80 x .1) = $(98 + 20 + 8) = $126/b

2020 $(160 x .7 + 125 x .2 + 80 x .1) = $(112 + 25 + 8) = $143/b

2025

2030

2035

2040

Approaches to future electricity price analysis and to road user charges, together with background notes are set out below.

Electricity prices, 2011-2040, 2011 $'s

As retail electricity prices comprise several components (fuel prices, network costs, non-carbon pricing policy impacts and carbon pricing impacts) a discussion of each element and the factors affecting each element preceded the Delphi analysis.

This discussion was led by a presentation from the Panel convenor on a range of future electricity price estimates (SCR/NIEIR, IPART out to 2012-13, KPMG-Econotech) for the residential sector. Following this published electricity price forecasts were presented, followed by the Delphi analysis, again for the same time periods used in the oil price projections.

Particularly important elements are network (influenced by a number of factors, including EV penetrations) and carbon (CO_2e) prices.

Results of Delphi analysis energy prices and road user charges

Panel Members

Futura Consulting

John Fazio

Bonnie Fulford

National Institute of Economics and Industry Research

Ian Manning

Stephen McCalman

Saturn Corporate Resources Pty Ltd

Graham Armstrong

Bill Unkles

The 6 Panel Members were presented with a range of scenarios, which after discussion on key factors affecting the forecasts and a review of other agencies forecasts were weighted. The following table provides a summary of the weighted results.

Points to note in the table are that the Standard Deviation of panel members results widens as the forecast period lengthens, reflecting the greater uncertainty of longer term projections. However the opposite effect is evident with regard to the timing and level of application of road user charges for Electric vehicle users.

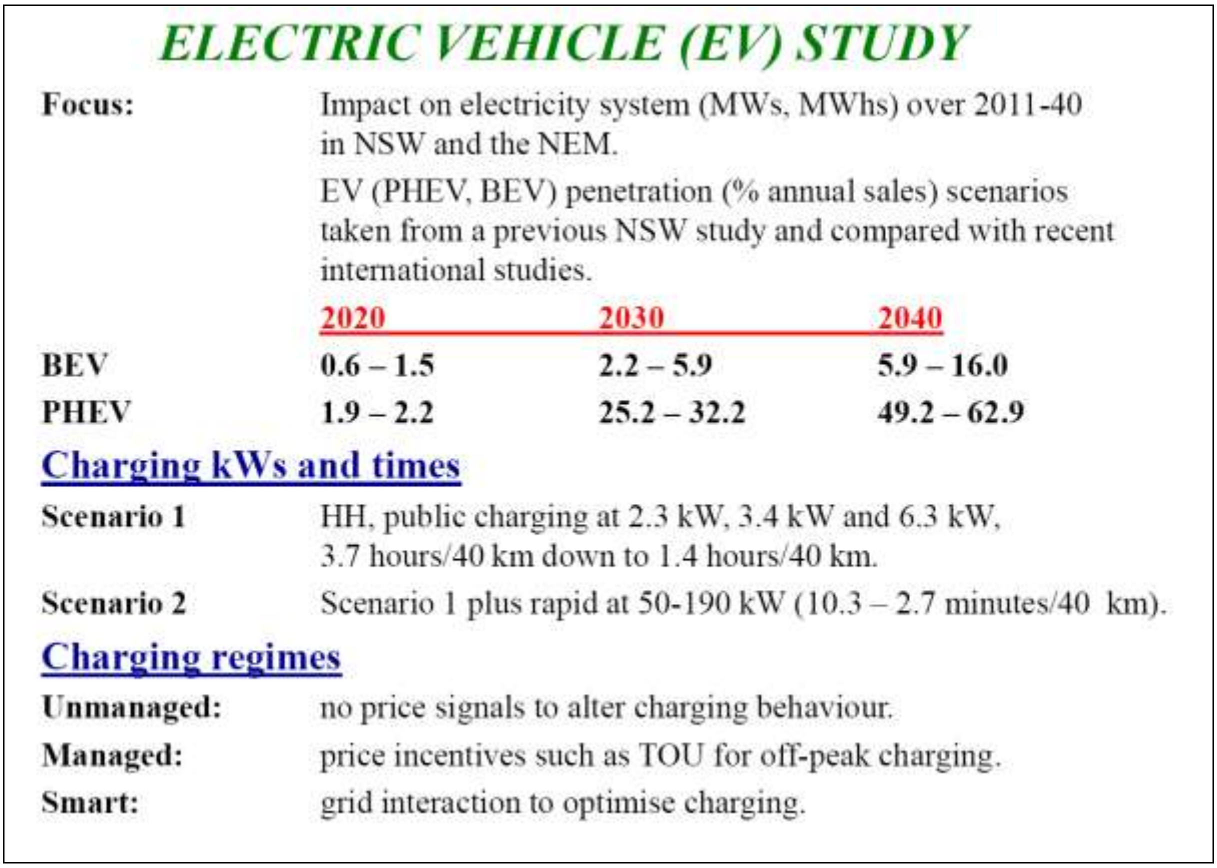
The results of the Delphi panel analysis are provided in Table A.1. Prices are in 2011 $s.

Table A.1 Results of Delphi analysis

	2011	2015	2020	2025	2030	2035	2040
Oil prices							
Mean	110.1	117.0	140.4	164.8	171.5	145.5	155.3
Median	112.0	110.5	145.0	174.0	164.0	153.4	163.3
Standard deviation	5.8	19.2	17.0	19.0	23.5	68.3	76.8
Electricity residential and commercial							
Mean	200.0	238.7	285.8	311.1	328.4	368.8	359.7
Median	200.0	234.0	283.3	308.4	322.5	365.8	347.5
Standard deviation	0.0	10.6	9.8	9.5	15.7	17.0	27.1
Road user charges, share of excise paid by EV users							
Mean	0.0%	5.0%	34.9%	53.8%	72.5%	88.3%	92.5%
Median	0.0%	5.0%	39.0%	62.5%	83.8%	100.0%	100.0%
Standard deviation	0.0%		28.6%	40.4%	31.1%	20.4%	11.7%
Likely date for introduction of road user charges							
Mean	0.0%	13.3%	46.7%	63.3%	96.7%	96.7%	96.7%
Median	0.0%	0.0%	40.0%	65.0%	100.0%	100.0%	100.0%
Standard deviation	0.0%	21.6%	45.5%	38.3%	8.2%	8.2%	8.2%

Attachment B

A presentation on the SCR/Futura study NIEIR Energy Conference, December 2011



Other study elements

- Vehicle categories: private (3 sizes), LCVs, taxis.
- Travel patterns and distances examined from State travel data.
- Alternative economic scenarios were assessed.
- BAU summer and winter demand projections were developed for economic scenarios.
- GHG emission trends for ICEs and EVs were developed.
- In Australia the phase out of electric resistance water heaters will free up significant off-peak (2300 – 0700 hours) capacity for use by EVs.
- In NSW, the client State, winter peaks are approaching summer peaks as reverse cycle air conditioners (heat pumps) are used for space heating.
- Similar but not as pronounced impact in other NEM regions.

Other study issues

- Fuel economy: actual versus rated for each vehicle category, over time.
- EV fuel economy (km/kWh) data for EVs did not appear to include energy for heating and cooling of EV interior.
- ICE fuel mix over time: will affect prices and GHGI of ICE fuel (biofuels).
- Comparison of EV penetrations with international studies (annual, cumulative)
  - cluster at 6%-12% (annual) in 2020 but wide dispersal thereafter.
- Future oil and electricity prices (Delphi panel used).
- Application of road user charges to EVs (excise proxy for ICEs).
- VKT ranges and home arrival parking patterns from State travel survey data.

VKT/day ranges

Low	<1 – 20 km	33% - 41%
Medium	21 – 60 km	34% - 36%
High	>60 km	23% - 33%

Arrival home: peaks at 1900, 16% arrive, cumulative 90%.

Results: summary

- Before 2020 impacts on electricity system is minimal with most significant impacts post 2030:
  - plenty of time to monitor and plan for higher EV penetrations.
- Unmanaged EV impacts (MWs) are much higher than managed and smart impacts.
  - strategy needed to introduce these EV charging techniques post 2020.
- Impacts are significantly higher for 100% BEV scenarios.
- PHEVs for higher VKT categories would reduce peak impacts.
- Encouragement of OP charging raises system capacity factors but can create new peaks in previous OP period (2300 to 0700).
- Potentially significant GHG net benefits as EV penetration increases:
  - results sensitive to climate change policies, actual on-road efficiencies of EV and ICE vehicles and transport fuel policies (bio fuels, gm/km standards).
- Vehicle to grid (V2G) potential benefits only likely to be realised under a smart charging regime introduced post 2020 coinciding with high EV penetrations.
- Study issues and results indicate EV penetration projections may be optimistic

Results: summary, continued

- Encouragement of OP charging raises system capacity factors but can create new peaks in previous OP period (2300 to 0700).
- Potentially significant GHG net benefits as EV penetration increases:

  - results sensitive to climate change policies, actual on-road efficiencies of EV and ICE vehicles and transport fuel policies (bio fuels, gm/km standards).
- Significant improvement in urban air quality at the expense of air quality near fossil fuel based plants.
- Vehicle to grid (V2G) potential benefits only likely to be realised under a smart charging regime introduced post 2020 coinciding with high EV penetrations.
- Local area (distribution impacts) may be quite significant depending on spare distribution capacity need for 3 phase etc.
- Study issues and results indicate EV penetration projections may be optimistic

Results for “typical” scenario, NSW, 2040