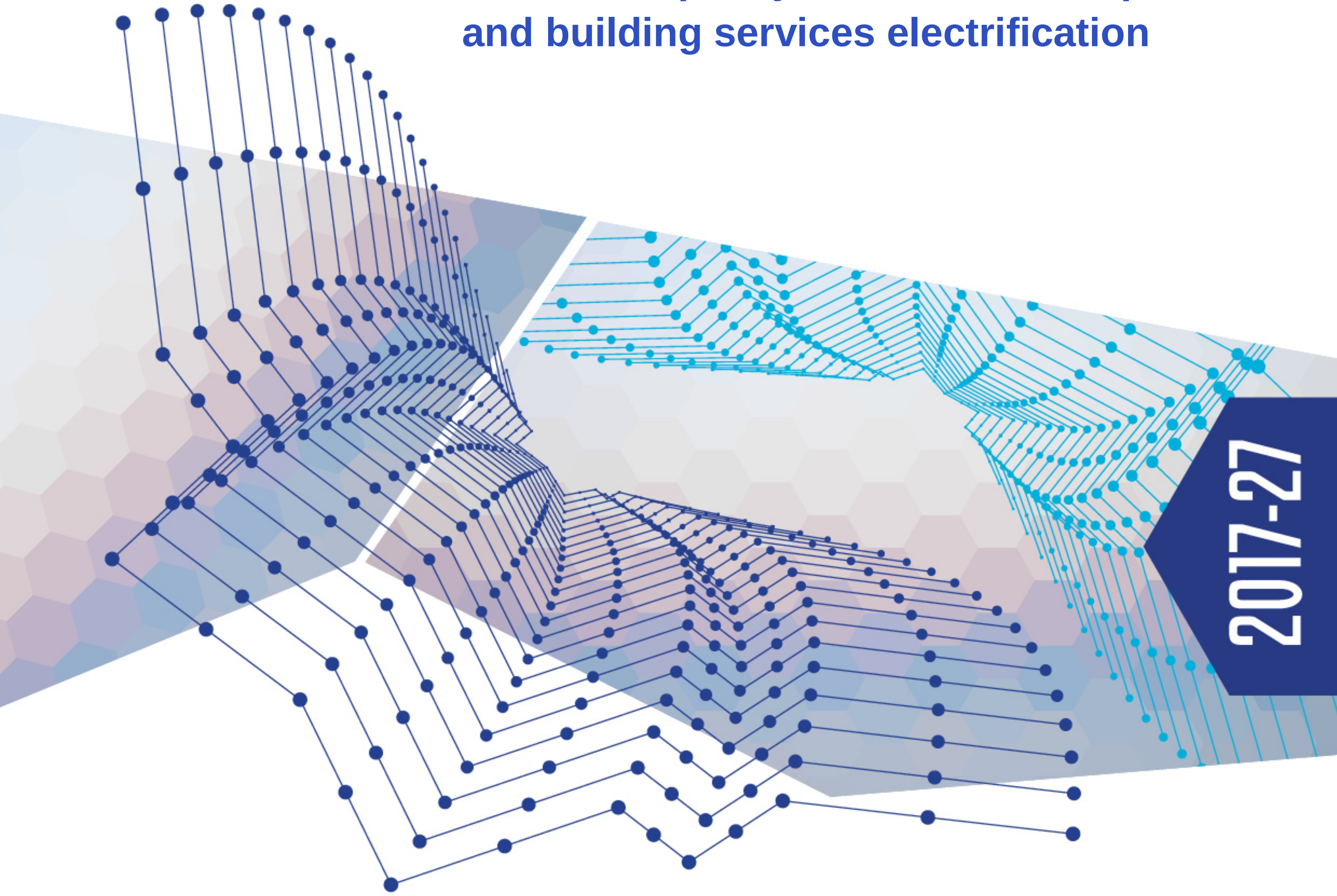
ELECTRICITY NETWORK TRANSFORMATION ROADMAP

Efficient capacity utilisation: transport and building services electrification



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A partnership between Energy Networks Australia and CSIRO

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Executive summary

A combination of new technologies, energy efficiency and structural change in the Australian economy is leading to a flat or declining outlook for grid-supplied electricity consumption. If this projection is realised without any compensating reduction in network peak demand, it will be difficult for the electricity sector to avoid price increases as it recovers the cost of maintaining supply capacity from less delivered energy and invests in new low emission electricity generation technologies to meet Australia's Paris climate goals. Conversely, if electricity growth can recover through new demand sources that do not add to peak demand there is an opportunity to improve utilisation and hence reduce unit prices to customers. Electrification of transport and some building services that are currently provided by natural gas provide plausible scenarios where the volume of consumption could grow strongly relative to peak demand.

While the analysis here is looking at this topic through the lens of how the electricity sector might benefit from opportunities for stronger electricity consumption, the approach is fuel/technology neutral. The analysis seeks to understand how customers' interests might change over time due to changes in relative energy prices and technology or products available. The analysis is not seeking to determine how to capture new markets for the sake of a single industry. Alternative energy sources should compete on economic, social and environmental merits.

Transport electrification

Growth in global sales of electric vehicles, increasing numbers of models available, reductions in battery costs, extended vehicle travel range, increased public charging infrastructure, tightening vehicle emissions standards in Europe and the United States and substantial direct subsidies or other incentives offered by a variety of countries and levels of government outside Australia all indicate growing electric vehicle adoption should be expected over time. There are an increasing number of modelling projections providing information on likely timing and quantity.

This report implements a medium projection of 20 percent light duty road electric vehicle adoption by 2035, consistent with other studies which tend to focus on the next 15- 20 years. The analysis here which extrapolates and projects to 2050 finds electric vehicle adoption would likely have wider benefits for consumers as a whole by improving the efficiency of the electricity system, and lowering electricity bills. By 2030, the additional consumption and demand from electric vehicle adoption is not large enough to significantly change electricity bill outcomes either up or down. However, by 2050 electricity vehicle adoption is projected to have a significant impact.

We first look at the introduction of electric vehicles using large (7.2kW) chargers and the majority of consumers using them in an unmanaged way due to slow changes in pricing and incentives. In this case, by 2050 the increased peak demand from unmanaged charging is more than offset by increased electricity consumption such that capacity utilisation improves. This drives a decrease in average residential electricity bills of $87 per annum by 2050. This indicates that while it would not be ideal, (from an electricity sector perspective) slow change in pricing and incentives leading to a greater proportion of unmanaged, high power electric vehicle charging behaviour will not lead to cost increases.

In the faster reform of pricing and incentives scenario, where the electricity sector gets the benefit of increased consumption without significant additional peak demand, electricity bills are $162 lower by 2050. This is a substantial saving which offsets the otherwise expected increase in electricity bills between 2027 and 2050 associated with the costs of decarbonisation.

Electric vehicles also deliver a number of co-benefits including reduced transport sector greenhouse gas emissions (assuming, with some confidence, that electricity generation is increasingly decarbonized), reduced criteria pollutant emissions, improving health outcomes and improved balance of trade (holding all else constant) through reduced oil imports.

Of course, it should be acknowledged that there are some potentially significant negative impacts associated with electric vehicles. If electric vehicles come to dominate passenger travel then this will mean significant structural upheaval in the motor vehicles parts, maintenance and repairs sector in Australia. The demand for internal combustion vehicles related services will decline, replaced with new demand for electric vehicle related services over a fairly long structural adjustment period.

On balance, the benefits of electric vehicles would appear to be significant and may not require direct intervention from government to be achieved given the strength of existing drivers for adoption. This is not to say that government intervention has no impact but rather that Australia is already receiving the benefit of overseas government interventions which are scaling up production and reducing the cost of electric vehicles and can expect to continue to do so in the future. Given the potentially low marginal value of domestic interventions to support electric vehicle adoption (i.e. they may have limited additional impact relative to no domestic intervention), any policy options should preference low costs. The current government vehicle emissions standards regulatory impact statement process is not specifically focussed on electric vehicles or their wider benefits. However vehicle emissions standards are potentially the least costly policy option for providing support for electric vehicle adoption. The electricity industry should therefore consider participating in the consultation process and support the eventual implementation of vehicle emission standards.

Building services electrification

In contrast to road transport electrification, the potential for increased building services electrification to 2030 is not at all clear from the historical records or the available projections. Both gas and electricity prices will be subject to trends which could modestly weaken or strengthen the relative competitiveness of household and commercial appliances. On balance the next decade will likely not see strong swings in either direction in the share of gas and electricity in building services energy supply.

In the long term (2030 to 2050) there are trends which might also swing the weight of argument in either direction. In regard to gas, we do not yet fully understand the size of the core of customers who value gas for non-price factors such as for its amenity in cooking. There are also benefits in having more than one source of energy that may begin to become more important over time to customers. Customers seeking to deploy an off-grid electric system could reduce the size and cost of their system considerably by retaining gas supply for some building services. Gas supply is also a useful back-up if more challenging climate conditions means a greater number of power blackouts.

Another reason gas may maintain competitiveness is that if gas peaking plant are used as a primary means of backing up intermittent renewables then gas and electricity prices may be naturally prone to move together over time rather than diverge. More longer term, as greenhouse gas emissions constraints begin to strengthen natural gas suppliers may look to technologies such as fuel cells, gas-based co/tri-generation systems, bio-gas, solar-gas and adding hydrogen to gas supplies to strengthen their environmental position.

One can also argue that there are trends in electricity supply which could point towards a strengthening position, the first and strongest point is that as electricity generation decarbonises it will seek to surpass gas as a means of greenhouse gas reduction in building services and in the direct combustion sector more widely.

The second is that as the prices of both electricity and gas prices are forced upward by carbon policies, residential and commercial electricity consumers have an additional means of reducing their exposure to cost increases (besides energy efficiency) whereas gas consumers do not. Electricity consumers can seek to generate a portion of their electricity on site through some type of rooftop solar based system with or without storage. The costs of these systems are expected to decline.

ClimateWorks Australia (2016) were commissioned to provide a projection of the likely electrification of building services by 2050 finding an additional 5 percent increase in electricity consumption. If realised it would improve the efficiency of existing electricity infrastructure so long as it doesn't significantly increase maximum demand. While more research is needed it appears that most new electric load is associated with heating, which impacts winter demand and is lower than summer demand in all states except Tasmania.

However, at the same time, any increased electricity demand would lead to a fourfold decrease in gas consumption (due to different power needs of appliances, considering that electricity losses occur upstream in generation while most gas losses are at the point of use). A decrease of this size deserves further investigation to understand its impacts. Decreasing consumption can lead to increasing prices. This situation could lead to perverse outcomes. For example, if existing gas customers switch to electric heating in large numbers but by doing so reduce gas throughput in total such that distributors have to raise the network charges for gas, then some of the expected calculated gas bill savings may evaporate as they are recovered from the remaining gas use (e.g. hot water or cooking).

Energy efficiency policy in the building services area is generally addressed through building standards and white certificate schemes for energy efficiency improvements. The CCA (2016) has indicated that these measures could be improved through harmonising white certificate schemes across States in Australia and with the national Emission Reduction Fund methodologies for building energy efficiency.

These existing policies are mostly energy supply neutral and it is difficult to develop any other policy options given the uncertainties in the projections for building services electrification. However, the impacts of building services electrification are potentially significant enough that they certainly require the attention of:

- The government: to determine the role of buildings services and other direct combustion emissions in meeting 2030 and 2050 greenhouse gas emissions targets and thereby provide more guidance on the likely need for emission reductions from these sectors
- The electricity industry: in realising the potential significant additional consumption without any significant increase in maximum demand in the context of an otherwise potential flat electricity demand outlook
- The gas industry: in understanding the extent of competitive threat of electricity in supplying energy to building services

Introduction

Due to the multitude of complex issues being faced by all links in the Australian electricity supply chain, major challenges are being encountered by the industry and their traditional electricity supply models. These challenges include the increasing deployment of on-site generation in the form of rooftop solar, the expected deployment of battery storage at various scales and locations in the system, decarbonisation of wholesale electricity with likely increased deployment of large scale intermittent renewables, a continuation of the trend of a decreasing share of heavy industry in contributing towards national income and growth and ongoing improvements and incentives for energy efficiency.

While there are a number of impacts flowing from these developments, a key expected outcome is for conditions of lower growth in the volume of electricity consumption and peak demand. In recognition of this, a key focus of the Electricity Network Transformation Project is to determine efficient pathways for facilitating new technologies and utilising existing assets.

However, even if measures identified in other components of the Electricity Network Transformation Roadmap are successful, it will be challenging to avoid increases in network unit costs to consumers under conditions where the volume of demand for electricity is growing significantly slower than peak demand. It is therefore appropriate to consider whether there are any opportunities to address the potential decline in network asset utilization through increased volume growth (relative to peak demand).

Electrification of transport and some building services currently provided by natural gas provide plausible scenarios where the volume of consumption could grow strongly relative to peak demand. Such scenarios could provide benefits to customers where associated with new value adding services, provide greater scope for network unit costs to decline and assist in measures to reduce greenhouse gases from the transport and direct combustion sectors (providing that wholesale electricity generation is decarbonised as planned). This report considers the scenarios for higher volume growth from these sources, their potential and their impact for customers and networks.

We examine the opportunity for transport electrification in the following section including an outline of scenarios developed to examine its impact, modelling results and potential policy options to encourage this activity. Opportunities for electrification of building services is addressed in the same manner drawing significantly from ClimateWorks Australia (2016) which delivered a commissioned report on the projected substitution of electricity for gas to 2050. Based on those and other projections we suggest some possible ways forward to address this opportunity.

Transport electrification

Scope, opportunity and projections

Rail

The highest use of electricity transport at present is in the rail sector which consumes around 2.7 TWh per annum, up from 2.2 TWh five years ago. Passenger rail transport uses electricity for 71 percent of its energy consumption while freight rail is 95 percent dependent upon diesel. It is understood that diesel is the preferred fuel for long haul, bulk rail freight transport in remote areas due to the lower cost of developing non-electrified rail infrastructure. As such, growth in rail electricity demand is mainly a function of urban transport planning. Current plans for urban rail expansion are fairly modest due to the difficulty of establishing new rail corridors. There remains periodic interest in superfast rail for inter-capital-city travel but no firm investment plans.

Road

Given the prospects for electric rail are modest we therefore focus this study on road transport. Current Australian deployment of electric road transport vehicles amounts to less than 3,000 vehicles. However, there are several factors supporting their plausible deployment as a mainstream vehicle choice for the future:

- Global sales of electric vehicles have grown substantially in the last five years reaching 540,000 in 2015[1]
- An increasing number of models are available indicating a growing maturity and sophistication
- Reductions in battery costs are projected and continue to be observed[2]
- Vehicle manufacturers have extended the travel range of electric vehicles and provided public charging infrastructure (sometimes for free) to overcome any range concerns
- Tightening vehicle emissions standards in Europe and the United States together with a tightening up of vehicle emissions tests (which had significantly diverged from on-road emissions outcomes)
- Substantial direct subsidies or other incentives offered by a variety of countries and levels of government (not so in Australia)

All of these factors combine to create conditions whereby the vehicle manufacturing sector has the confidence to prepare future production lines to deliver electric vehicles at scale and eventually at modest additional cost.

Light duty vehicle projections and drivers

The electric vehicle market has concentrated activity on light vehicles (passenger and light commercial vehicles) and it is not clear whether this means that short distance (e.g. intra-city) trucks would be unviable or whether they are just not a current priority – it is a much smaller market. Previous research has found that such vehicles could benefit from the fuel savings offered by

[1] http://www.ev-volumes.com/
[2] Note, Brinsmead et al (2015), page 95, finds that economies of scale in global manufacturing, rather than battery prices appear to be the most important factor in reducing electric vehicle costs

electrification (e.g. Graham and Reedman (2014) and Graham and Reedman (2015)) and several rigid electric truck models are already available[3].

For simplicity and comparability with other studies we confine the study to light vehicles only. We also do not review or try to predict the preferred type of electric vehicle but are focussed on any electric drive train that draws its energy from the grid (e.g. plug-in hybrid electric vehicles are considered equally valid for the purposes of this report). Figure 1 shows some of the more recent projections of electric vehicle adoption in Australia.

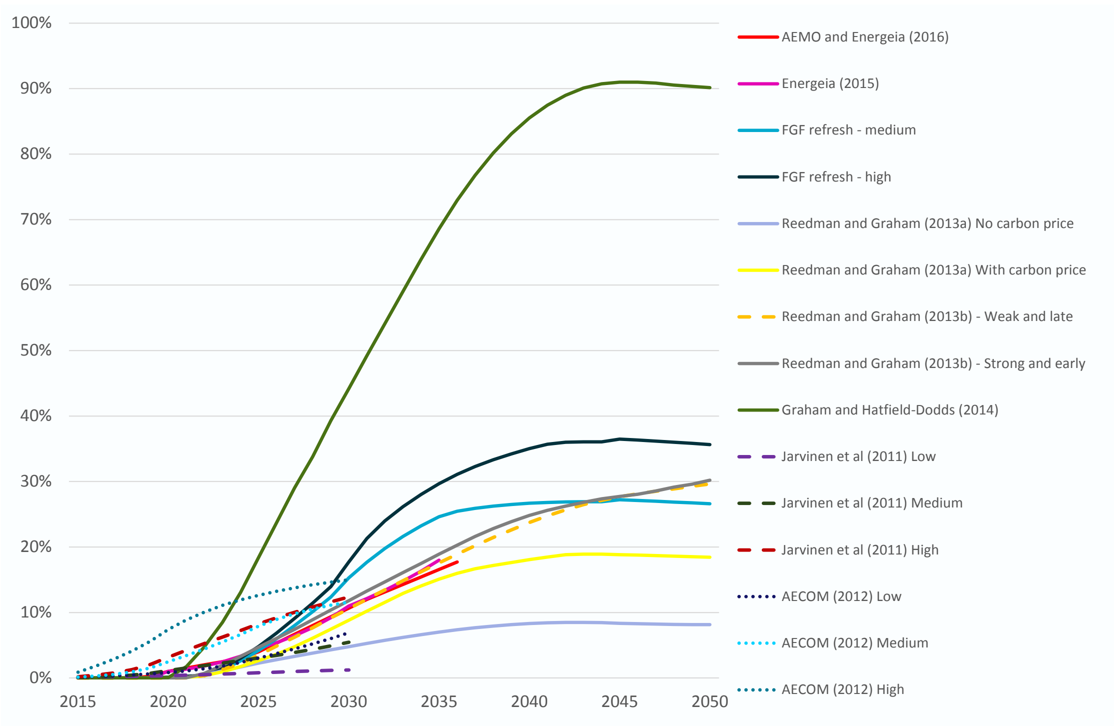

Figure 1: Selected projections of electric vehicle share of road vehicle fleet

The common thread of these projections is that electric vehicles will simply be more cost effective for consumers in the long run. While the return on investment or payback period for an electric vehicle is currently not attractive for most consumers (other than "early adopters"), in time consumer will eventually be persuaded by lower running costs offsetting any additional upfront investment.

A second key driver, which also explains the outlier in this group, Graham and Hatfield-Dodds (2014), is that vehicle electrification may be an important tool for reducing greenhouse gas emissions. Australia has committed to achieving a 26-28% reduction in greenhouse gas emissions compared to 2005 levels by 2030. Beyond 2030, Australia has supported the goal to limit the rise in temperature to no more than 1.5-2 degrees Celsius. While there is no formal national target for 2050 this implies that Australia reaches something close to zero net emissions by or soon after 2050 (depending on the global emission pathway and how abatement burdens are shared between countries). To achieve zero net emissions, the light vehicle sector would have no choice but to almost fully electrify. With other sectors and countries also trying to reach similar targets, transport could not rely on purchasing domestic or international credits. Also, Graham and Hatfield-Dodds (2014), together with

[3] See for example, https://www.daimler.com/products/trucks/mercedes-benz/urban-etruck.html

ClimateWorks (2014) found that there were insufficient biofuels available to decarbonize the transport sector.

The main downside risk for electric vehicle adoption is current low oil prices which have been in place since December 2014. Prior to this oil price fall, oil prices were around $100 per barrel and avoiding high fuel bills was a major concern of households. While oil prices may eventually recover to some fraction of their previous highs, they are no longer expected to be a primary driver of electric vehicle adoption (See Brinsmead et al. (2015) for a breakdown of upfront costs and how payback periods change over time relative to different high and low oil price outlooks.). Other downside risks include, lack of information and familiarity (leading to range anxiety and other concerns), aversion to higher upfront costs while they remain more expensive than internal combustion vehicles and safety (e.g. electric vehicles would be required to meet all road safety standards but issues that tend to be highlighted in various media are the potential for battery fires and reduced signalling to pedestrians due to quieter running).

In discussing downside risks some authors also point out that electricity is currently emission intensive in most states of Australia making electricity as a fuel unattractive (Advisian, 2016). However, there are almost no projections of the future of electricity that do not expect emission intensity to decline and the longer term prospects, consistent with meeting global climate change targets, are for a near zero emissions electricity sector (although this remains uncertain from a policy point of view). Finally, EVs will impact government road revenue, particularly fuel excise (Graham and Reedman, 2015a) and government may eventually move to find another way to recover costs which could moderate uptake (e.g. a reduction in fuel excise in favour of a kilometres travelled based mechanism would improve the relative competitiveness of internal combustion vehicles).

We conclude that a likely projection, based on clustering of previous projections (Figure 1) is for slightly under 5 and 20 percent adoption by 2026 and 2036 respectively. While there are some downside risks, as with all new technologies, the upside is much more significant with transport potentially being required to play a significant role in greenhouse gas abatement.

From a volume of electricity consumed perspective the clustered projections on vehicle adoption come to different conclusions due to different assumptions about growth in transport demand and vehicle sales, on-road vehicle performance (as opposed to manufacturer's test cycle fuel efficiency results) and mix of electric vehicle types and sizes. AEMO and Energeia (2016) project national electric vehicle consumption of 1.8 and 7.9 TWh in 2026 and 2036 respectively. For the same period Graham and Reedman (2013b) found consumption of 4.4 and 18.1 TWhs, respectively due to higher transport demand growth[4], larger EV vehicle sizes (including a small number of rigid trucks) and poorer on-road fuel efficiencies.

Possible approaches to vehicle charging

While the volume of electricity consumed is fairly well governed by daily travel distances and vehicle fuel efficiencies (including battery charging losses) the timing of the electric vehicle charging load at a given zone substation level is governed by a different set of factors including:

- the diversity of timing in customer road vehicle trips
- tariffs or other incentives provided to electric vehicle owners to modify their charging behaviour

[4] AEMO and Energeia (2016) assume slower increase in total light vehicle sales in their projection period implying a large shift to public transport or a reduction in per capita transport demand. ABS (2016) report an average growth rate in sales of 2 percent in the 10 years to 2016, however growth was only 1.2 percent in the last three years.

- the size and capability of electric vehicle chargers

Size

In regard to this last point, while many of the chargers in early electric trials and deployed at present have a maximum power demand of 3.6kW, the next wave of chargers appear to be converging towards twice that power rating, at 7.2kW. The reasoning behind this development is that larger chargers allow vehicle manufacturers to allay fears of range anxiety or delay in refuelling. A 7.2kW charger will replace the average days' entire electricity usage in an hour or top up the vehicle to go another 10 km in just over 15 minutes.

Given most electric vehicles are likely to have 2 to 3 times the capacity required for the average daily distance[5], and there are many hours during the night in which to charge vehicles at a lower rate, consumers may, as they become familiar with electric vehicles and their charging needs, eventually prefer smaller, lower cost chargers.

Electricity tariffs and incentives

In regard to tariffs and incentives, under the current dominant flat kWh tariff, there is no incentive for electric vehicle owners to do anything other than charge their electric vehicle at a time which is most convenient to them. Whilst there is a great deal of analysis which supports the idea that electricity pricing should provide greater signals for larger loads to be managed for the benefit of the electricity system and customers, due to the inherent inertia around policy change in a space which would impact household budgets, changes to electricity pricing and incentives in Australia is not a given outcome.

Diversity

Previous Australian electric vehicle trials have utilised charging of approximately 3kW. The Victorian electric vehicle trial (Victorian Government, 2013) which included 83 home charging customers found that, with diversity, the peak demand occurred around 8:00pm and was on average 12 percent of the rated capacity of the charger[6]. The majority of charging occurred during the night but with a low level occurring throughout the daylight hours. Fleet charging (41 participants) occurred mostly during daylight hours peaking at 4:00pm, at slightly less than 12 percent of charger capacity, and tailing off to near zero by midnight.

In the Western Australian electric vehicle trial (Mader and Bräunl, 2013) the majority of charging occurred at business or fleet style charging stations utilised predominantly during daylight hours. The business charging profile peaked at around 9:00am, whilst home charging peaked at around 8:00pm.

A recent larger international study was the My Electric Avenue trial in the UK (EA Technologies, 2016) which examined home charging. The trial utilised a 3.5 kW charger and 1000 customers were allowed to charge on a convenience basis. Peak demand from this diverse customer based peaked at 8pm and was on average 34 percent of the rated charger capacity.

From these trials we can conclude that, although charger capacities are large (similar to a heat pump air-conditioning system) and likely to get larger, population diversity means that zone substation peak demand will be a fraction of the sum of charger capacities and vehicles deployed.

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[5] ABS (2015) report average passenger vehicle travel of 13,200km per annum which is 36km per day. The current generation of electric vehicles have a minimum range of 100km.

[6] That is, due to diversity, the average profile did not peak at the rated charger capacity but rather a fraction of that capacity due to differences in population charging amounts and times.

Scenarios

Four modelling scenarios

A set of scenarios has been designed to examine the impact of transport electrification, specifically light duty road vehicles. Given the already significant body of work available on electric vehicle adoption levels, the scenarios are primarily targeted at understanding the impact of different charging regimes rather than exploring the uncertainty about the number or share of electric vehicles. The set of four scenarios are shown in Table 1.

Scenario 1 and Scenario 3 establish two counterfactuals where there is no electric vehicle adoption but where two different electricity pricing environments dominate: flat (kWh) tariffs remain dominant (Scenario 1) and demand (kW) based tariffs or equivalent incentives are increasingly adopted (Scenario 3). Two separate counterfactuals are required because the impact of changing the dominant electricity pricing environment is impactful on its own. Were we to use only one counterfactual, separating the impacts of electric vehicle adoption from the impacts of changing prices would be difficult.

Scenario 2 examines the impact of electric vehicle adoption under the slow change to pricing and incentives environment. In this pricing environment we assume customers will choose a larger charging capacity than generally required, at 7.2kW, and the majority who remain on flat kWh tariffs will charge when convenient (the share of flat tariff households decreases slowly from around 99 percent in 2015 to 50 percent by 2050).

Scenario 4 examines the impact of electric vehicle adoption under faster reform of pricing and incentives (the share of flat tariff households decreases rapidly from around 99 percent in 2015 to 15 percent in the 2020s and less than 5 percent by 2050). In this pricing environment customers are assumed to choose a smaller 3.6 kW charger optimized at off-peak periods according to the needs of the grid (and customers are rewarded accordingly for those services through avoided demand charges and lower kWh charges than under Scenario 2).

Table 1: Light duty vehicle electrification scenario set

Scenario	Pricing environment	Uptake	Charging pattern
1	Flat kWh tariff dominates	None - counterfactual	NA
2	Flat kWh tariff dominates	Medium estimate	7.2kW capacity charger, charged when convenient
3	Demand (kW) based tariffs or incentives dominate	None - counterfactual	NA
4	Demand (kW) based tariffs or incentives dominate	Medium estimate	3.6kW capacity charger, optimised at off-peak periods

Alternative scenarios considered

These scenarios represent a deliberate simplification of the future electricity sector environment. Previous analysis in stage 1 of the Electricity Network Transformation Roadmap (Graham et al, 2015) had no counterfactuals and combined electric vehicle adoption with all the other changes that are taking place in the electricity sector (i.e. the refreshed Future Grid Forum scenarios). While more realistic in terms of expected real world outcomes, this approach was unable to provide a clear indication of the specific impact of transport electrification separate from other drivers of change. A second simplification is that we ignore various potential important variations on how electric vehicles may be used in transport and integrated with the electricity sector. However in the following material we acknowledge these potential variations and discuss their possible impacts.

Is it the beginning of the end of private vehicle ownership?

There are some potentially significant changes in the transport sector which are relevant to electric vehicles. Specifically, there is a growing expectation that private ownership of vehicles may decline as the primary means of delivering passenger kilometres. Vehicle sharing business models incorporating automated driving, use of smart phone enabled communications and algorithms for vehicle dispatch are being trialled with a view to establishing and growing the market as an alternative to private vehicle ownership (see for example, Rocky Mountain Institute, (2016) and their provocatively titled report *Peak car ownership*). There are contrary views, however such changes could lead to increased vehicle utilisation, fewer vehicles (providing customers are more willing to share the vehicle with others in such an environment) and changes in preferences for vehicle sizes.

Where should charging infrastructure be located and who should own and operate it?

There are also potentially more sophisticated approaches to delivering electric vehicle charging (public or private charging infrastructure). Home charging is likely to be the most convenient for the majority of home owners. However, many will not have access to suitable off-street home charging due to the style or garaging capacity at their existing home or because they are renting and cannot make necessary modifications.

As electric vehicles become more prevalent, it will be in the interests of different parties in the electricity supply chain to seek to manage or exploit the charging profile or storage capacity of electric vehicles to meet system balancing needs. In particular, in order for electric vehicles to assist with addressing the impacts of high levels of midday rooftop solar output, they would ideally be connected to the grid at this point in time – that would only be possible at scale through public charging facilities. On the other hand, whether such a business model could pay for that infrastructure to be available is uncertain. Per vehicle, the charging service would only amount to a few dollars of electricity per day. However, like offering free Wi-Fi, it could represent a means of offering customers additional value upon which to sell other goods and services.

Vehicle to home or grid

We have up until now mainly considered the charging needs of the electric vehicle and the impact of that load on the grid. However, it is also plausible that the electric vehicle could be considered as an electricity source for the home or grid, not just a load. A 100km range vehicle is storing approximately 20kWh of electricity (and vehicles with much larger ranges considerably more). These amounts are not insignificant given average daily household electricity consumption is approximately 16kWhs. Also, given that human occupation is a significant predictor of load, vehicles will likely be located at the residence at the time of highest electricity consumption.

In regard to the grid, the low costs of wind and solar photovoltaic power has increased the expectation that electricity generation supply will be increasingly intermittent. As existing firm generation capacity retires due to age or greenhouse gas emissions limits or incentives the grid will likely have an increased need for storage capacity or other forms of firm capacity. Whilst there may be many ways to achieve replacement firm capacity, if there is a significant stock of storage available through the transport fleet at little additional marginal cost then it may be considered as a potential resource. For example, 5 million electric vehicles with a 100 kilometres range would represent grid-wide total battery storage capacity of 100GWh.

The main concern about using the battery capacity of electric vehicles in home or grid electricity consumption or load shifting is that, while it does not require additional immediate expenditure (expect perhaps in orchestration of that capacity) there are in fact longer term costs. Vehicle batteries with a typical cycle life of around 5000 would have an expected life of around 13.6 years on a simple daily deep charging cycle (but may degrade faster than that due to other considerations). If we increase that to two deep cycles to allow for daily charging plus an additional cycle for home or grid consumption, then battery life falls to under 7 years, considerably accelerating the battery replacement timing. Of course if batteries are low cost and the rewards from load shifting are high enough, this faster degradation of batteries may be less of a concern. However, initially we expect vehicle manufacturers will not be targeting this additional service and consumers will be cautious about managing their battery life.

Scenario modelling assumptions

The counterfactuals

The counterfactual or background growth in electricity consumption and peak demand is taken from Energeia (2016) which was commissioned by the Energy Networks Australia for the Electricity Network Transformation Roadmap to specifically examine how the electricity sector changes under different electricity pricing and incentive environments. We have re-run Energeia's implementation of pricing scenarios “1” and “5” (these numbers relate to Energeia (2016)) to reproduce them within the CSIRO electricity system models, checking that we are able to find similar outcomes within a reasonable tolerance. These scenarios then become our electric vehicle counterfactual scenarios “1” and “3” in Table 1. Energeia (2016) scenarios “1” and “5” most closely match the pricing environments we require.

Medium electric vehicle adoption

A medium electric vehicle adoption projection is implemented whereby electric vehicles reach a 19 percent market share of light duty road vehicles by 2035 or 4.9 million vehicles (Figure 2). This results in an additional 16.2 TWh of electricity demand at the national level in 2035 rising to 44.2 TWh by 2050. The projection was developed by targeting just under a 20 percent share by 2035, consistent with the cluster of projections presented in Figure 1. This required electric vehicles sales to gradually increase to around 40 percent of all light duty vehicle sales (including passenger plus light commercial vehicles). Total light duty vehicle kilometres increase by just under 50 percent or around 1.9 percent per annum so that the light duty fleet increases from 17 to 25 million vehicles in 2035 to meet this growth in demand for kilometres. Note that passenger vehicles only grow at 1.6 percent, reflecting population growth under the ABS populations Series A (ABS 2012). However light commercial vehicles historically grow faster at 2.2 percent reflecting economic growth.

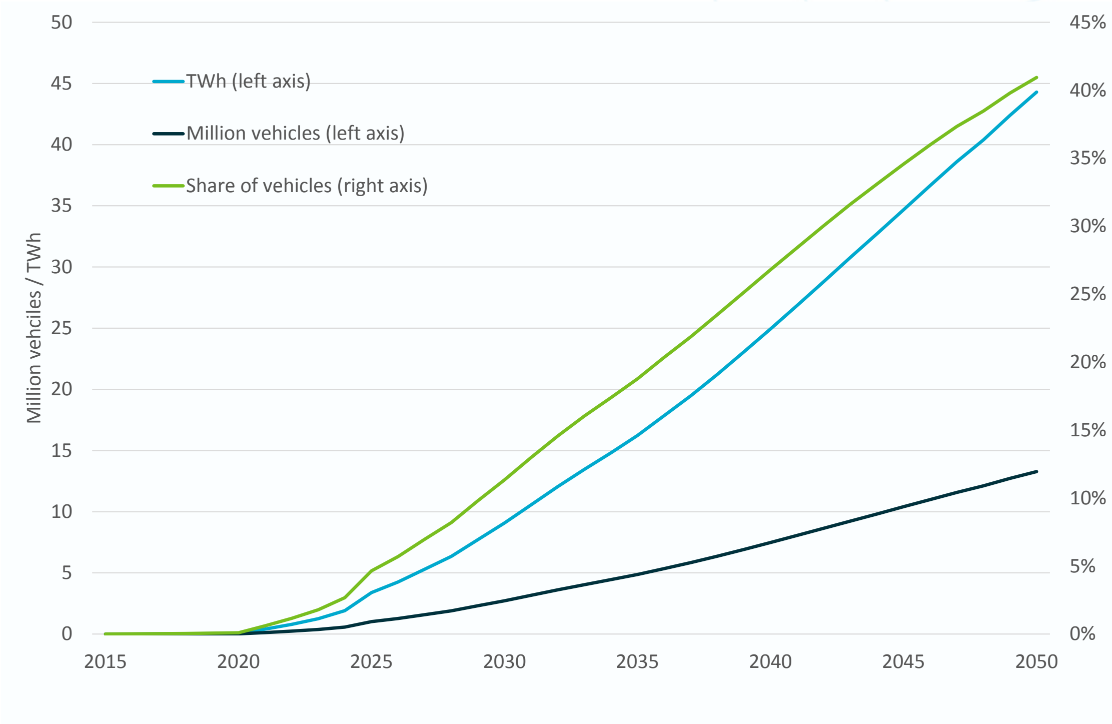

Figure 2: National electric vehicle projections in electricity consumption (TWh), million electric vehicles and electric vehicle share of total vehicles

Distribution of electric vehicle by substation

Electric vehicle adoption is not expected to be uniform across population regions. It is appropriate to try to capture some spatial differences so that impacts on respective zone substations are realistic. Higgins et al (2012) surveyed the buying intentions of a sample of Victorian households and was able to identify demographic features that indicate a greater propensity for purchasing an electric vehicle. Those factors included age, education, number of occupants, level of educational attainment and type of transport to work. Weights are applied to these demographics according to strength their desire to purchase an electric vehicle. Higgins et al (2012) apply higher weights, for example, to the middle aged, lower occupancy, higher educated and households who currently use a road vehicle to travel to work rather than other alternatives.

In this analysis we apply the method of Higgins et al. (2012) matching demographics of households connected to specific substations to the weights but with one modification. We assume that ownership of rooftop solar panels provides an additional attractor to electric vehicle ownership because it indicates a willingness to adopt new technology, environmental values and lower electricity bills[7]. We weight the demographic factors 75 percent in total and solar ownership 25 percent.

The resulting national distribution of electric vehicle adoption is shown in Figure 3 for the year 2030. As expected it indicates that electric vehicle adoption is concentrated in the densely populated coastal capitals although there are exceptions in both inland and coastal areas.

[7] This is an assumption. A new survey, which was out of scope for this analysis, would need to be conducted to confirm that solar ownership is an attractor for electric vehicle ownership. Rooftop solar panel adoption was in its infancy at the time of the Higgins et al (2012) survey

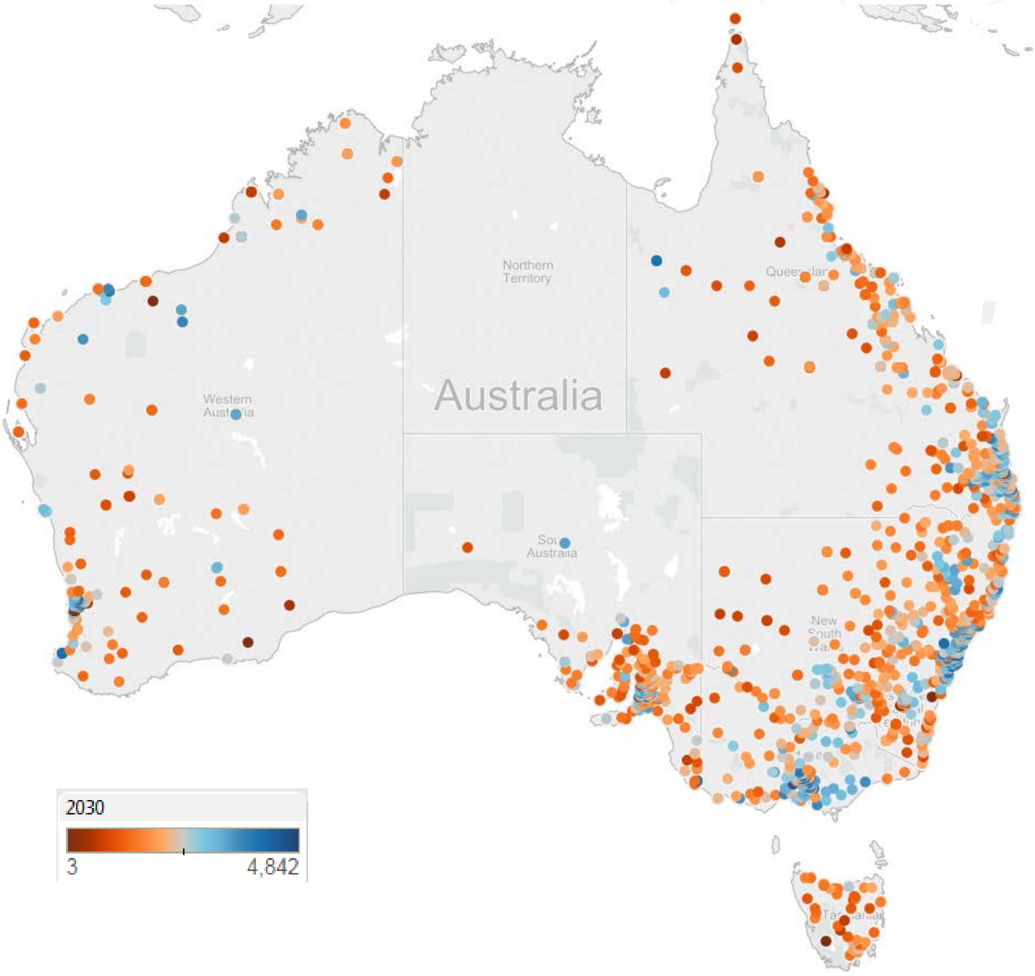

Figure 3: National map of number of electric vehicles per zone substation

To see the distribution more clearly, Figure 4 focusses in on the Melbourne region. It shows that the lowest electric vehicle adoption occurs in the centre of the city. This makes sense because these households would typically be located in apartments, without solar panels and whose occupants walk or use public transport for travel to work because of excellent access to such infrastructure. Highest adoption then follows on the outer city fringe where there is a high reliance on vehicles for travel to work and land is increasingly available for suburban housing and rooftop solar panel adoption. In the extreme outer fringe adoption would again fall to the lower range due to lower population.

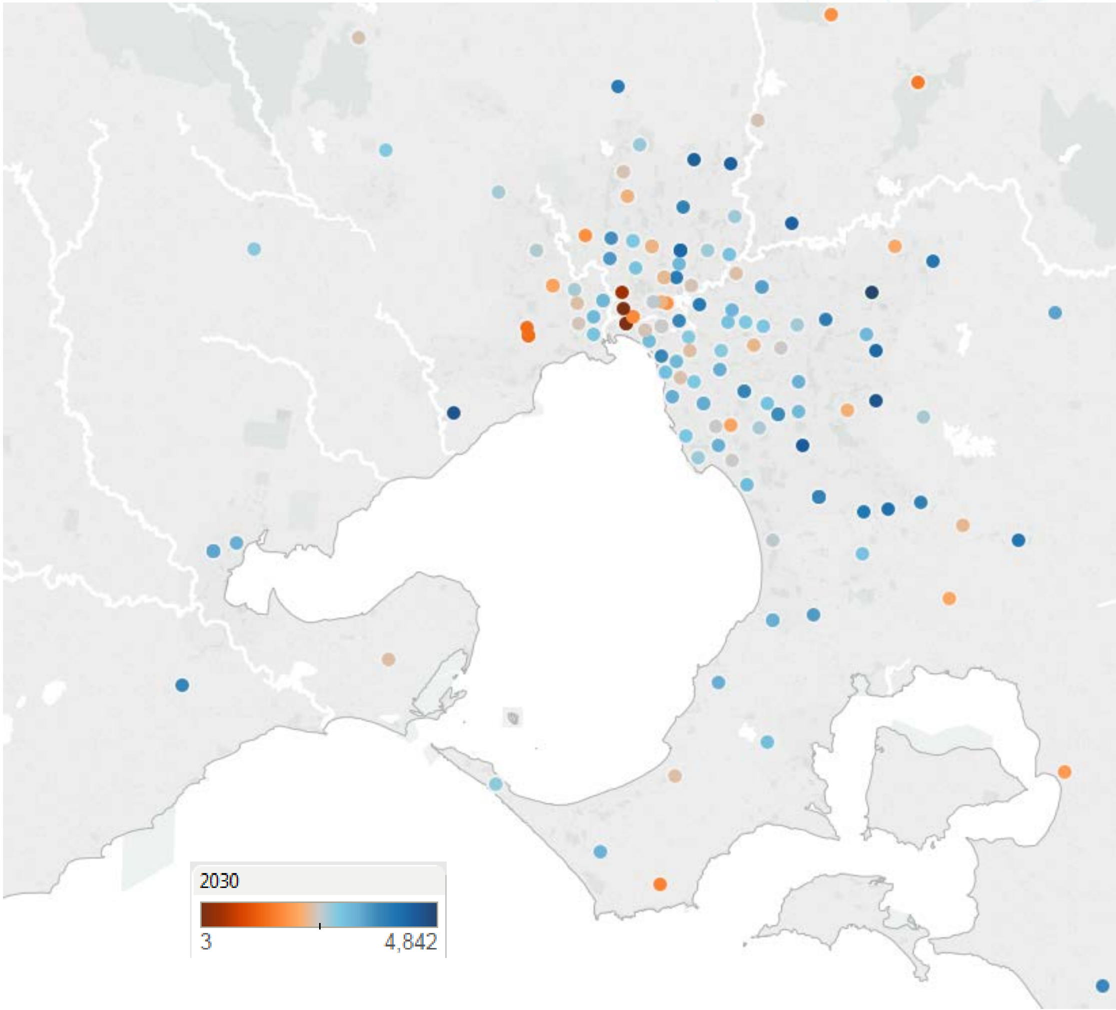

Figure 4: Melbourne region map of number of electric vehicles per zone substation

Charging profiles

For Scenario 2 we require a charging profile that reflects a convenience approach to charging since there are no price signals requiring or incentivizing managed charging. Since there were no population level 7.2kW charging profiles available in the literature, we have adapted the EA Technologies (2016) profile. This profile was very similar to other Australian trial charging profiles but has a larger population sample size. Figure 5 shows the original EA Technologies (2016) profile and the applied Scenario 2 profile. The following two adjustments were made:

- Increased the peak to reflect the shift from a 3.5 to 7.2 kW charger and as a consequence a narrower shoulder charging load as each vehicle will be charged faster
- Decreased after midnight load proportionally to maintain the indicated shape but deliver the daily energy associated with average passenger vehicle travel in Australia of 13,200km per annum (ABS, 2015)

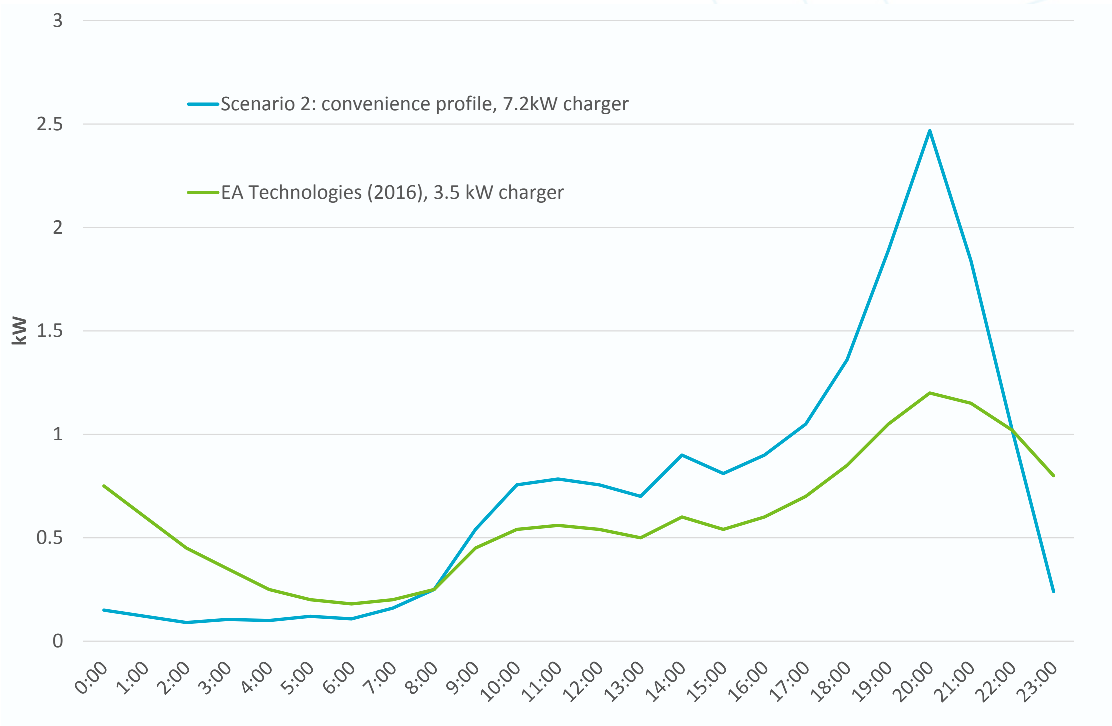

Figure 5: EA Technologies charging profile and convenience charging profile used in Scenario 2

Modelling framework and results

Modelling framework

The modelling framework is described in detail in Brinsmead and Graham (2016). However, in brief terms we utilise a whole of system model to determine the impact of electric vehicle uptake on the electricity system (Figure 6). As discussed under the scenario design, the first two steps in the whole of system approach of tariff and technology uptake have already been modelled in Energeia (2016) and we build upon that existing demand profile by adding electric vehicles over time according to the adoption curve and distribution by zone substation. We are then able to calculate distribution and transmission network, generation and retail sector expenditure required to meet demand and the resulting prices to recover those costs.

For simplicity we do not iterate the model. That is, we do not test if the Energeia (2016) technology adoption and tariff choices would change if the impacts of electric vehicles on the system change those choices through different pricing. Strictly speaking, if electric vehicles were to, for example, reduce electricity system costs through better asset utilisation then this might reduce prices enough that adoption of distributed energy resources (DER) might change. However, given Energeia (2016) showed a fairly similar level of DER adoption across the six scenarios they explored, we estimated this feedback effect to be small and chose not to iterate the adoption steps.

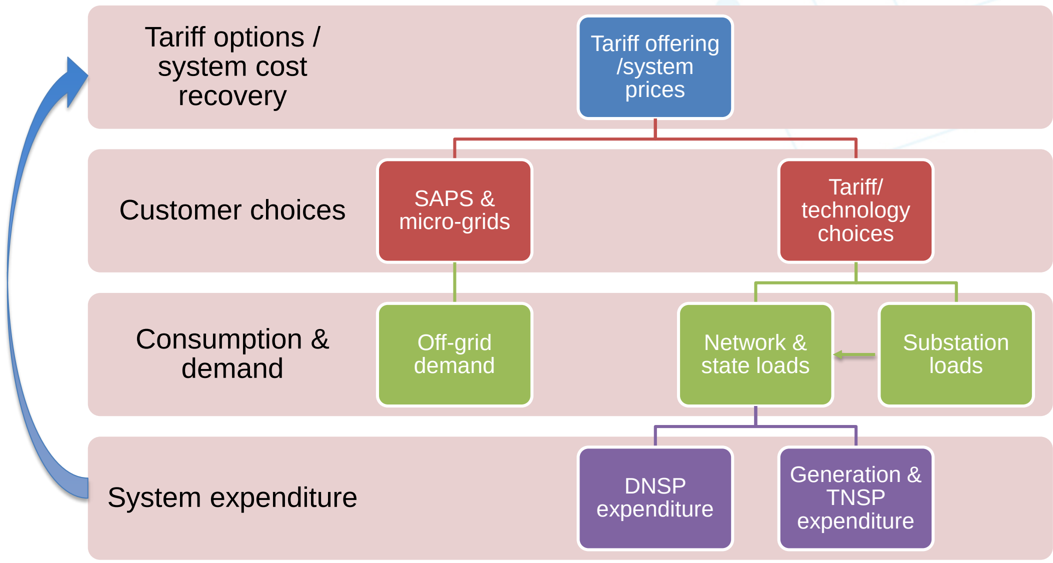

Figure 6: Modelling framework

Modelling results

Based on the assumed medium national adoption projection, the assumed distribution of those vehicles across Australian zone substations and the charging profiles assumed, Figure 7 shows the total national additional distribution network capacity required to be constructed in order to accommodate electric vehicle electricity demand. Under Scenario 2, the projected additional demand of just under 4000MW in 2035 is lower than a simple multiplication of the 4.9 million vehicles by the average population charging peak demand of 2.5kW for several reasons. Not all substations will peak at the exact time of the charging peak, some substations will have existing spare capacity and given the distribution of electric vehicles is skewed towards certain demographics not all substations will be proportionally impacted by electric vehicle uptake. By 2050 the additional demand in Scenario 2 is just over 12000MW.

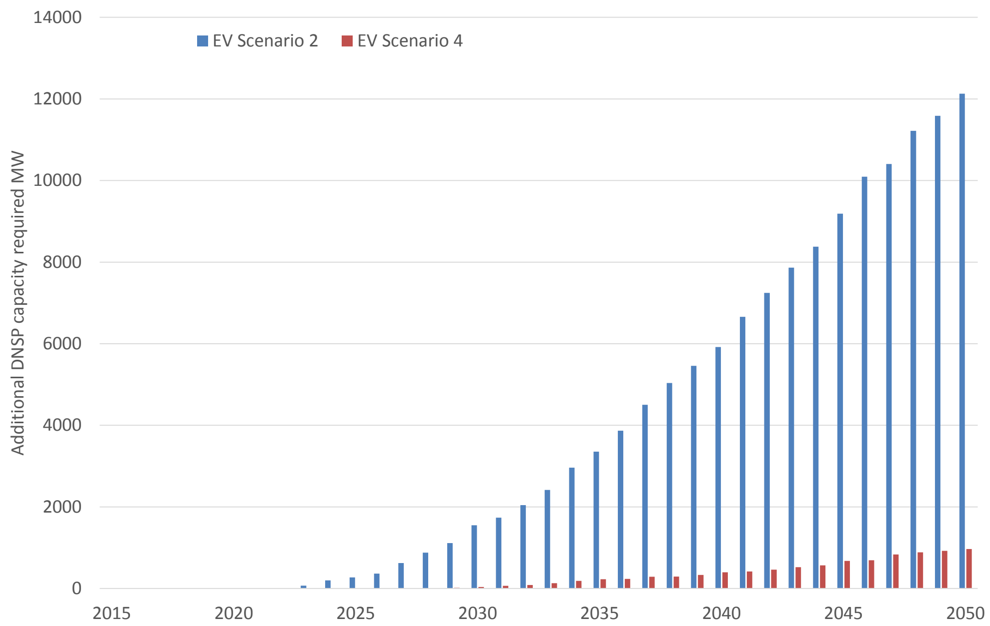

Figure 7: Additional distribution network capacity required due to electric vehicle electricity demand by scenario

The growth in demand from electric vehicles also impacts the generation and transmission sector which will need to invest in greater capacity to meet higher peak demand, depending on the scenarios. The additional capacity required further upstream in the electricity sector is around two thirds that of the distribution sector (varying by state) because of the diversity gained from aggregating non-coincident peaking zone substations (i.e. the coincident peak is lower than the sum of all the non-coincident peaks).

For the generation sector, we calculate the total cumulative expenditure to 2050 including plant capital, operating and maintenance and fuel costs. As expected, Figure 8 shows that Scenario 2 requires the most additional cumulative generation total expenditure reaching $65 billion dollars (in real terms). This is in the context of around $600 to $700 billion cumulative expenditure and so represents around 10 percent extra expenditure to cater for the additional 44 TWh (around 15% extra electricity consumption).In Scenario 4 the additional cumulative expenditure is lower at around $50 billion dollars.

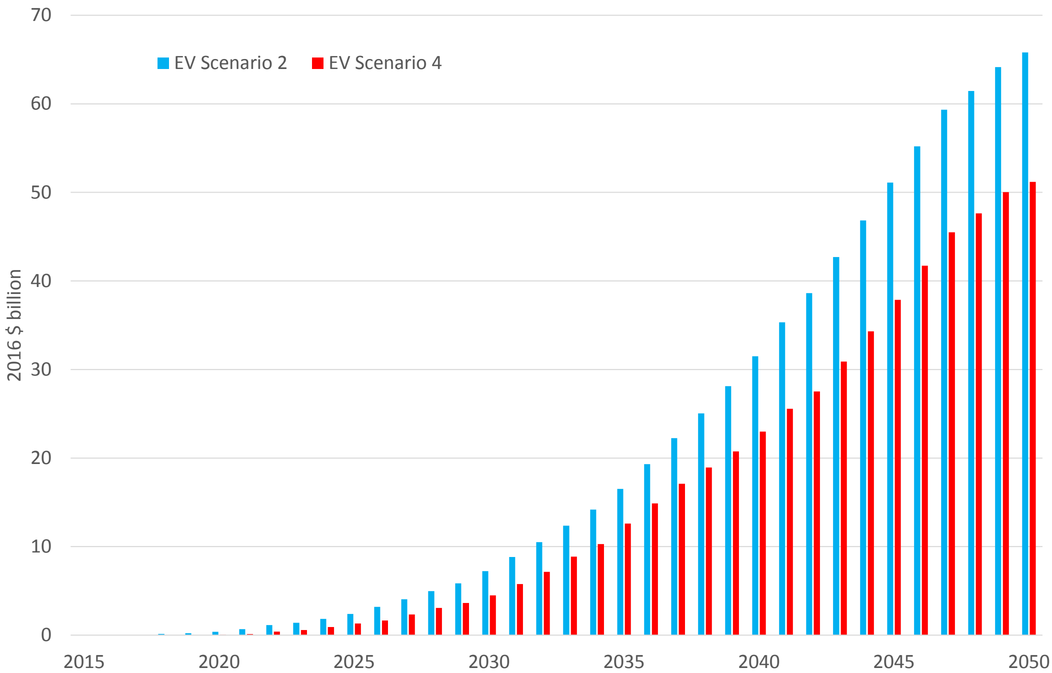

Figure 8: Projected additional total generation sector cumulative required in Scenarios 2 and 4 relative to their counterfactuals (Scenarios 1 and 3 respectively)

Taking into account projected wholesale electricity generation costs and required cost recovery in the network sector we are able to project the average residential electricity bill. However, care must be taken in designing a valid comparison of bills. In EV scenarios 2 and 4 the average bill is necessarily higher because average residential electricity consumption has increased due to adoption of electric vehicles. A direct comparison of average electricity bills would therefore not be indicative of the relative improvement in capacity utilisation between the two different electric vehicle pricing and charging environments.

To provide a more informative assessment of changes in bills we take the following steps for each scenario:

- Calculate the average residential bill which includes the cost of supply from both grid and distributed energy resources

- Calculate the implied average cost of residential electricity
- Apply the average cost of electricity to two customer types: a household *without* an electric vehicle consuming 5600kWh per annum and a household *with* an electric vehicle consuming 8240kWh per annum (in scenarios 2 and 4 only since there are no electric vehicles in 1 and 3).

We could have taken this analysis a step further and included internal combustion vehicle costs in the first household type and other whole of electric vehicle costs in the second household type. However, there are many studies which already establish that the fuel savings from an electric vehicle can neutralise or improve the cost of travel to offset any higher electric vehicle investment costs. This is not of primary interest. The primary point of interest is whether the cost of electricity is impacted by transport electrification.

Projected average electricity bills are shown in Table 2 for each scenario and household type for the years 2027 and 2050. Between 2027 and 2050, average bills are increasing, more so for grid supplied electricity, on account of increasing generation costs due to decarbonisation of the electricity sector. There are more details on assumptions on decarbonisation in Graham et al. (2017). However, in general, the electricity sector is expected to achieve slightly more than its proportional share in meeting the target of 26-28 percent below 2005 levels by 2030 and is expected to continue along that trajectory to make further reductions towards 2050.

Table 2: Projected average annual residential electricity bills for households with and without electric vehicles

		Scenario 1: slower change to pricing and incentives, no EVs	Scenario 2: slower change to pricing and incentives, large charger, convenience profile	Scenario 3: Faster reform of prices and incentives, no EVs	Scenario 4: Faster reform of prices and incentives, small charger, off peak profile
Household without EV	2027	$1,874	$1,876	$1,870	$1,865
	2050	$2,334	$2,248	$1,944	$1,782
Household with EV	2027	NA	$2,761	NA	$2,744
	2050	NA	$3,307	NA	$2,623

For households without electric vehicles there is only a very modest impact by 2027 of electric vehicles. This simply reflects that there are not yet enough electric vehicles to make a significant impact. The impact is between $-2 and $5 per annum (Figure 9). However, by 2050 electricity vehicle adoption is having an impact. In Scenario 2 where there is slow change to pricing and incentives and convenience charging is more prevalent, electricity bills are lower by $87 per annum.. This indicates that the increase in peak demand from those still remaining on flat kWh tariffs (around 50 percent) is not significant enough to offset the benefit of increased volume of consumption from electric vehicles. However, if there were more rapid reform of pricing and incentives, under Scenario 4, the electricity bills of households without electric vehicles would be $162 per annum lower. This reflects the positive impact of increased consumption without significant additional peak demand. This is a substantial saving, approximately offsetting the expected increase in electricity bills between 2027 and 2050 from generation sector decarbonisation.

Households with electric vehicles will have higher annual bills because they use more electricity. There additional electric use appears to benefit households without electric vehicles by improving grid capacity utilisation, even when changes to pricing and incentive reform are slow. The analysis shows that electric vehicle owners would have the lowest bill under faster reform of prices and incentives, with a saving of $684 per annum (Table 2).

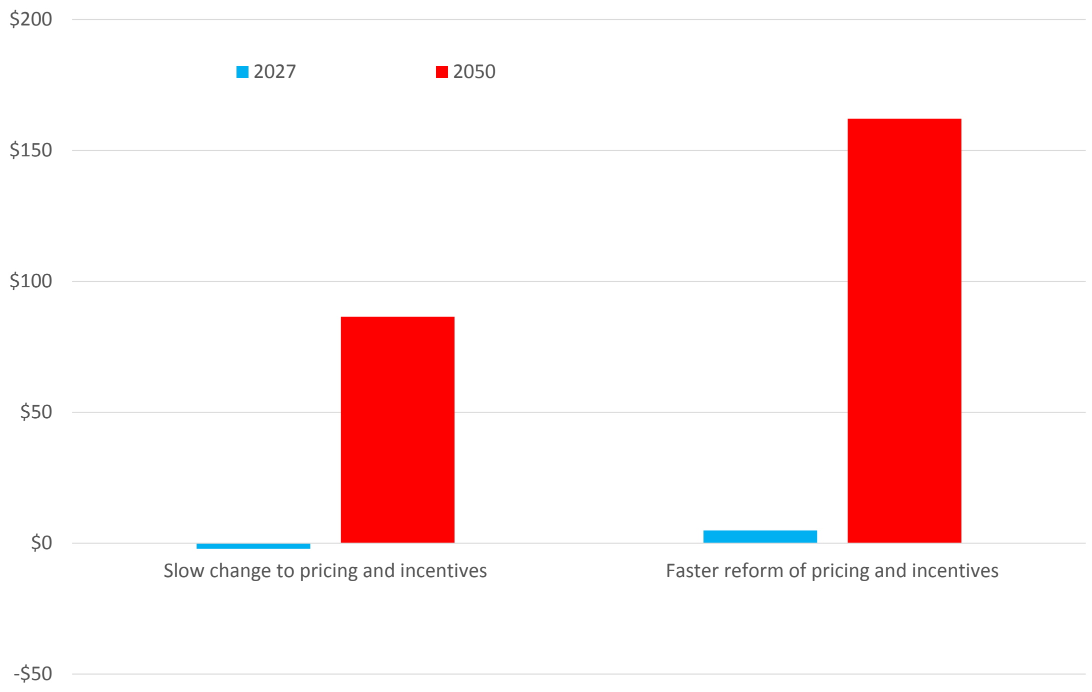

Figure 9: Estimated average saving in residential electricity bills for household consumption level before electric vehicles

Implications and policy options

Benefits, co-benefits and dis-benefits

As discussed in the introduction to transport electrification, there are a number of factors which indicate that increasing electric vehicle adoption should be expected in the long term and there are an increasing number of modelling projections which provide quantitative support for that scenario. The analysis of the impacts of electric vehicle adoption indicates that mid-range forecasts of electric vehicle adoption would likely have wider benefits for consumers as a whole because it would improve the efficiency of the electricity system, particularly the utilization of distribution network infrastructure. Electric vehicles also deliver a number of co-benefits including reduced transport sector greenhouse gas emissions (assuming, with some confidence, that electricity generation is increasingly decarbonized), reduced criteria pollutant emissions which improve health outcomes and improved balance of trade (holding all else constant) through reduced oil imports.

Of course, it should be acknowledged that there are some potentially significant negative impacts associated with electric vehicles. If electric vehicles come to dominate passenger travel then this will mean a restructure in the motor vehicles parts, maintenance and repairs sector in Australia. The demand for internal combustion vehicles related services will decline, replaced with new demand for electric vehicle related services. However, given this period of structural adjustment would likely occur over decades due to the slow turnover of vehicle stock, then business will have a greater capacity to adapt.

Policy options

Australia is already the beneficiary of overseas government policy interventions to scale up and thereby reduce the costs of electric vehicles through programs to encourage early adoption in those countries (which in aggregate allow the global vehicle manufacturing industry to move towards efficient scale manufacturing of electric vehicles[8]). As long as those policies continue and remain attractive Australia will continue to benefit by seeing the cost of electric vehicles fall as global adoption accelerates. While it appears there is a reasonable chance that Australian electric vehicle adoption may occur regardless of any domestic intervention due to falling electric vehicle costs, given the substantial benefits of transport electrification it may be appropriate to provide some incentives to increase the likelihood of significant electric vehicle adoption. However, given the potentially low marginal benefit of any interventions (i.e. they may have limited additional impact relative to no intervention), it would make sense to focus on policy options that are low cost.

Mostly outside Australia, governments have provided a number of incentives including direct vehicle subsidies, special road lane or parking access, vehicle emission standards, clarification of the rules around setting up charging infrastructure, prioritising electric vehicles in government fleet purchases, fuel consumption labelling and awareness and reduced taxation and registration.

Of these policies, direct vehicle subsidies are the highest cost. Some policies such as priority lane access and preferential taxation are only relevant in the early stages of adoption and would eventually need to be wound back. Vehicle emissions standards would appear to offer a good balance in that they can be tuned so that they do not impose significant costs on the government or consumers, whilst providing an ongoing incentive to deepen the penetration of low emissions vehicles into the fleet.

Vehicle emissions standards

Vehicle emission standards require manufacturers to lower the average emission intensity of their vehicles sold which they may do by changing the vehicles directly or changing the ratio of vehicles sold through cross subsidisation of lower emission vehicles within their current sales fleet. Some schemes also allow trade between manufacturers. Vehicle emission standard policies already exist in Europe and the United States. The lack of adoption of this policy in Australia[9] is widely regarded as owing to the Australia domestic vehicle manufacturing sector being more geared towards the production of larger more emission intensive vehicles as well as concerns about their long term financial viability.

However, these barriers to adoption are changing with the imminent closure of Australian vehicle manufacturing. In addition Australia's Paris Climate target provides new impetus to address transport emissions. Consequently there is increasing support to consider introduction of vehicle emissions standards in Australia.

The government announced the formation of a Ministerial Forum in 2015 that is supported by an interdepartmental working group led by the Department of Infrastructure and Regional Development. The working group is due to conduct a consultation process in late 2016 on three separate draft regulation impact statements (RIS) for noxious emissions, fuel efficiency (CO2) measures and fuel quality standards that will present a full cost benefit analysis of options. The working group will report

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[8] As discussed earlier, Brinsmead et al (2015) show that global manufacturing economies of scale rather than the rate of change in battery costs appear to be the main impediment to affordable electric vehicle prices.

[9] One of the recent policy discussion papers that did not result in any new policy was in 2011 http://aie.org.au/AIE/Documents/Light_Vehicle_CO2_Standards_Discussion_Paper.pdf

by 31 March 2017 to the Ministerial Forum on a draft implementation plan for new measures—aligning with the Australian Government's commitment to announce new measures to deliver Australia's 2030 climate change targets (DIRD, 2016).

Government and other stakeholders will naturally focus on vehicle emission standards achieving greenhouse gas reduction (see for example CCA (2014)) and DIRD (2016)) rather than the potential electricity sector benefits discussed here. However, ClimateWorks Australia (2016b) do focus on electric vehicles and recommend that the benefits of energy productivity and electricity supply should be included in any Regulatory Impact Statement undertaken.

The Climate Change Authority conducted a comprehensive analysis of the impacts of a light duty vehicle emissions standard in 2013. CCA (2014) found that:

> *Improving light vehicle efficiency is one of the lowest cost emissions reduction opportunities in the Australian economy…*
>
> *The benefits of a light vehicle emissions standard substantially outweigh the costs at both private and national levels. A 105 g CO2/km target could increase the average cost of a new car in 2025 by about $1,500, but this would be more than offset by fuel savings of $830 in the first year and $8,500 over the life of the vehicle, leaving motorists better off.*
>
> *A standard would also prevent emissions and save Australia $580 for each tonne of CO2 avoided….*
>
> *..a standard starting in 2018 and reaching 105 g CO2/km by 2025 generates the greatest emissions reductions and financial benefits for Australian motorists. It is broadly aligned with the targets introduced in the United States and trails the stronger European Union targets.*

In terms of electric vehicle adoption, CCA (2014) and the underpinning modelling study, Reedman and Graham (2013b), found electric vehicle uptake of 18 to 19 percent across a range of vehicle emission standard settings by 2035 and only 7 percent adoption with no incentives. This low adoption rate under no standards was based on the assumption of higher electric vehicle costs over time and as such is somewhat out of alignment with more recent forecasts which are based on lower costs and expect higher uptake without any standards. However, the gain of 11-12 percentage points in adoption of electric vehicles shows a positive impact on electric vehicle adoption from emission standards and indicates how standards might support electric vehicle adoption in the event that expected reductions in electric vehicle costs are not fully realised.

Building services electrification – gas electricity substitution

Opportunity and projections

Consumers have always had choices available when it comes to providing energy for building services. By building services we mean services such as heat for cooking, space heating and air conditioning and hot water. Electricity is the most versatile in terms of being able to provide energy for the widest range of building services (i.e. many more appliances are electrical). However, natural gas has historically been cheaper, particularly in states with gas resources closer to the capital cities. Gas has distinct advantages in particular applications such as cooking where the type of heat it provides is valued by customers above electricity. Also gas remains the lowest emission intensive energy source for most building services (due to the high use of black or brown coal in electricity generation in most states with the exception of Tasmania).

The historical trend for electricity and gas residential and commercial consumption has been flat or declining in the last decade (Figure 10 and Figure 11) due to higher energy prices and more energy efficient appliances and buildings.

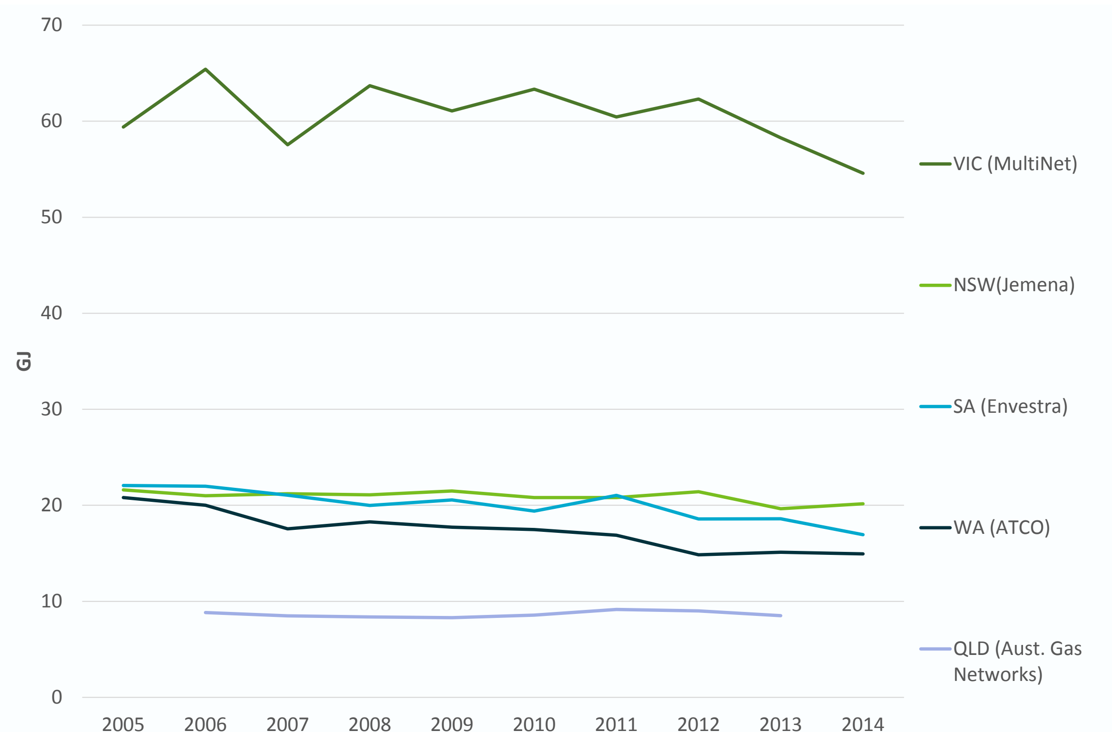


Figure 10: Historical household gas consumption, Source: Oakley Greenwood (2016)

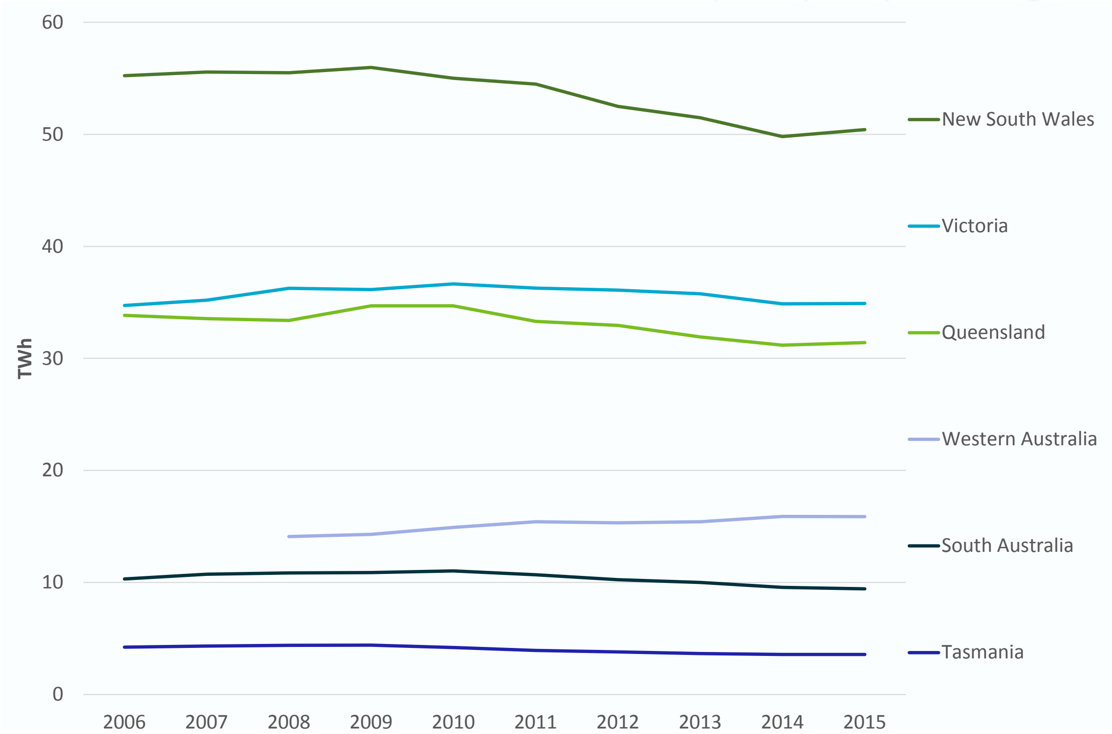


Figure 11: Historical residential and commercial electricity consumption, Source: AEMO (2016)

Projections

AEMO

While there does not appear to be a strong historical shift in either direction, AEMO (2015) in their *National Gas Forecasting Report* assume that more electric hot water and air-conditioning appliances will be chosen over the alternative gas appliance to 2036. They argue that despite an increase in gas connections there will be lower consumption per household because:

> *As dwelling preferences shift in favour of apartments and multi-unit developments, lower gas consumption and fewer gas appliance purchases are expected. This shift has been observed to slow gas penetration rates over the past five years. Inner-city apartments are increasingly all-electric, and have a smaller footprint.*
>
> *Gas to electric appliance switching is forecast to increase. Uptake of, and conversions to, solar hot water, and use of electric heat-pumps instead of gas heating, is expected to reduce consumption projections by 0.9% (1.7 PJ) per annum on average to 2020.*

Jacobs

In early 2016, the Energy Networks Australia commissioned Jacobs (2016) to examine alternative carbon policy formulations and targets to 2030. The Jacobs (2016) analysis did not confirm the AEMO (2015) projection but rather found that gas-electricity substitution would likely occur in the other direction with on average an additional 20,000 gas hot water systems sold relative to the current balance of electric and gas hot water system sales. This was calculated to lead to 1 percent reduction in residential and commercial electricity consumption by 2030.

Jacobs (2016) point to rising electricity prices (relative to gas) as the main driver of electricity to gas substitution in hot water heating. However, three sensitivities are noted:

- **Gas prices**: higher gas prices would erode the relative competitiveness with electricity

- **Renewable electricity technology costs**: Faster declines in the cost of renewable household and generation costs for technologies such as solar photovoltaics would make electricity more competitive
- **Timeframe for analysis**: If emission abatement trajectories become increasingly lower then gas-fired technologies would become increasingly untenable

Also, Jacobs (2016) did not specifically examine heating and air conditioning.

ClimateWorks

CSIRO commissioned ClimateWorks Australia (2016) to provide an alternative projection extending existing work by considering:

- A 2050 timeframe and associated impact of carbon policy
- The impact of new technologies such as rooftop solar and solar-battery bundles
- The impact on winter and summer maximum demand
- The potential for gas-electricity substitution in the industrial sector

The full ClimateWorks Australia (2016) report is available separately and details the methodology applied. However, we contrast their projection with AEMO (2015) and Jacobs (2016) in Figure 12 and following that discuss the key details of their analysis. The industrial sector is discussed separately in Appendix A since the main focus of comparison is building services.

ClimateWorks Australia (2016) project a stronger shift towards building services electrification with demand for electricity projected to increase by 4 percent by 2030 and 5 percent by 2050 by switching from gas to electrical appliances.

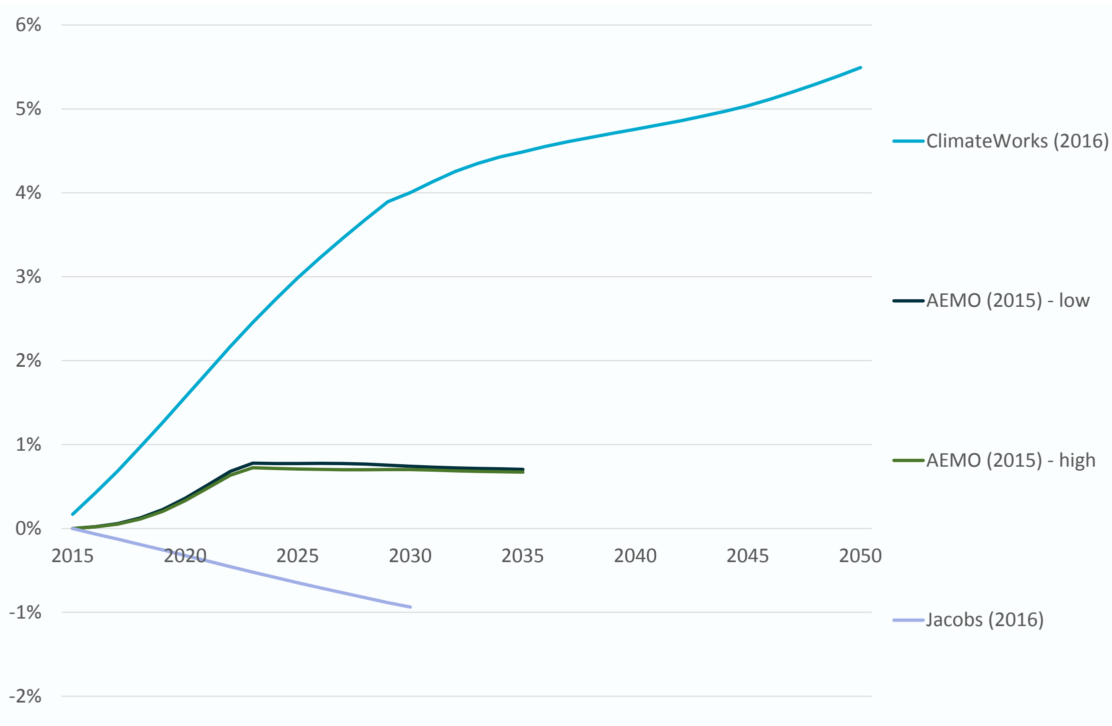


Figure 12: Projections of the percentage change in total electricity consumption due residential and commercial gas-electricity substitution from three studies

Like AEMO (2015), ClimateWorks Australia (2016) find that hot water and heating, ventilation and air-conditioning (HVAC) are the main sources of switching. Gas to electricity switching in the residential sector is 78 percent of the total of residential and commercial switching combined. In both sectors HVAC is the largest opportunity accounting for 77 percent of the total switching. This emphasis means there is in fact less of a difference with the Jacobs (2016) projection given that it is only concerned with gas-electricity switching in hot water.

Indeed, across the studies there is a significant amount of commonality between gas prices, electricity prices, carbon abatement context and assumed appliance turnover rates (e.g. ClimateWorks Australia (2016) source wholesale gas price trends from AEMO's own gas price forecasts). Although it is difficult to say with certainty due to lack of available detail in the other studies, the main reason for ClimateWorks arriving at a higher projection would appear to be its more sophisticated treatment of electricity costs being made up of both the costs of retail electricity supply and the cost of supply from distributed energy resources.

Consistent with other research in the Electricity Network Transformation Roadmap, our expectation is that over time, a growing number of customers will only be partly dependent on retail electricity prices. A significant part of their electricity supply will also be supplied by either a solar or solar-battery system. Investing in on-site electricity supply has two impacts – one obvious, one hypothesised. The obvious one is to stabilise total electricity costs since it locks in the cost of at least part of the household's electricity bill (the part the solar system supplies). This provides some cushioning against increasing retail prices. The second hypothesised impact is that it could make the householder more attracted to electrical appliances because electrical appliances would help them utilise their personal investment in electricity supply equipment. While this second impact is an interesting proposition, ClimateWorks Australia (2016) only took into account the first driver.

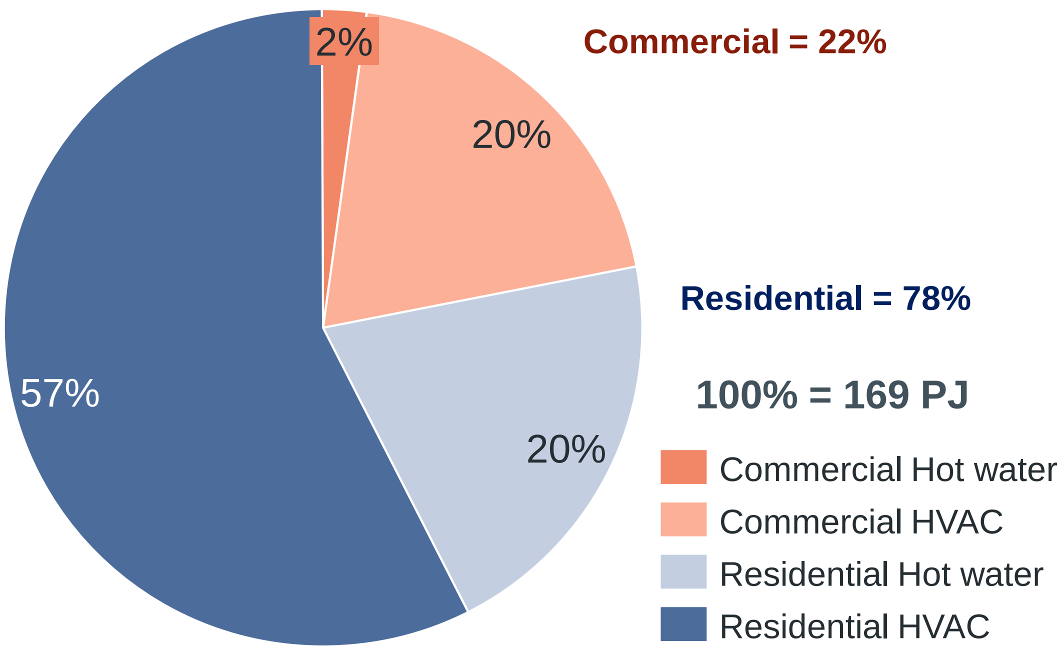
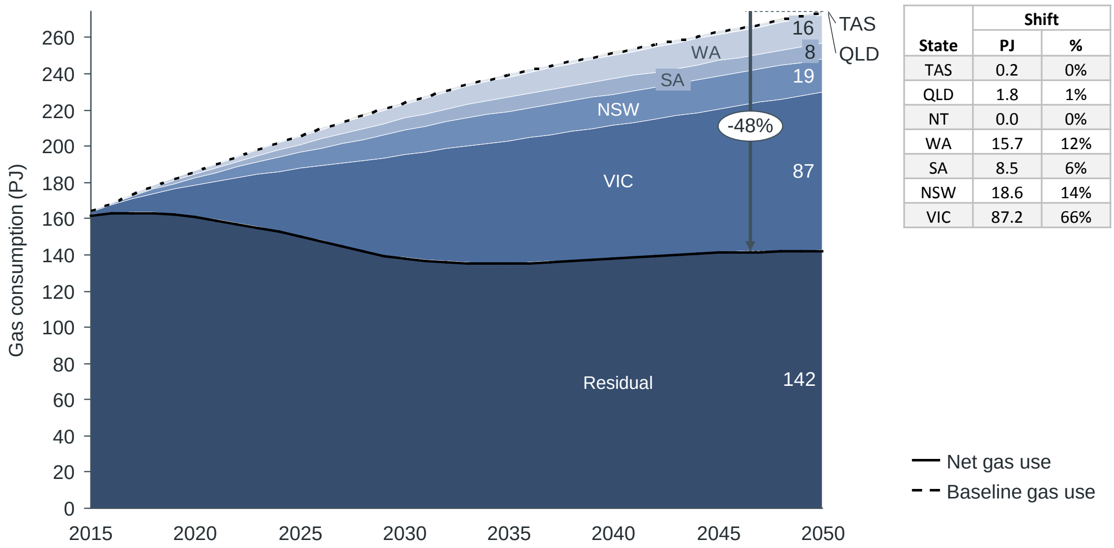


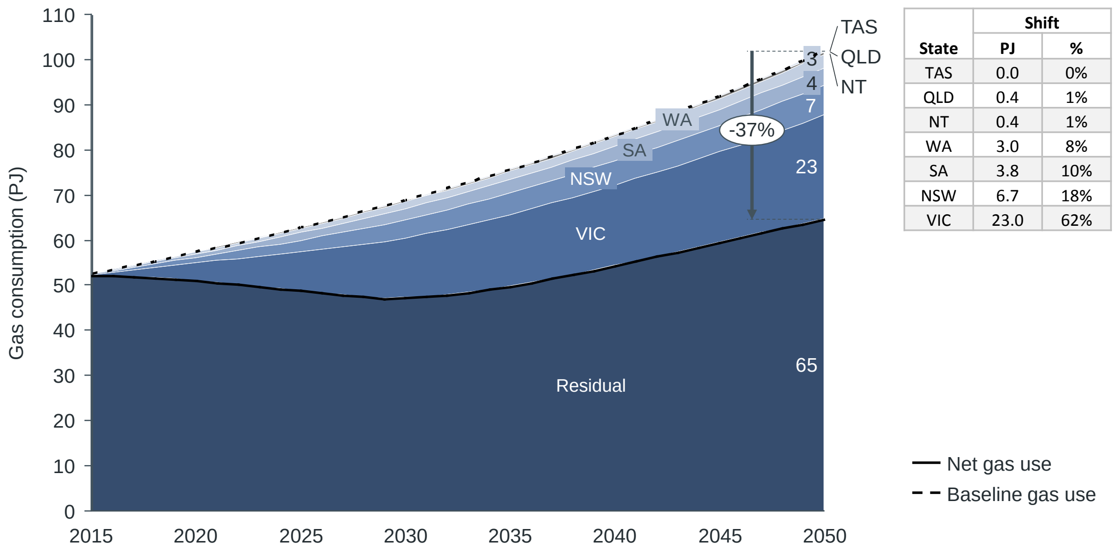
Figure 13: Share of gas consumption shifted to electricity in 2050 in residential and commercial sectors across Australia; by end-use. Source: ClimateWorks Australia (2016)

The gas-electricity substitution is not even throughout Australia (Figure 14 and Figure 15). Most of the electrification occurring in the residential sector can be attributed to Victoria (66%), New South Wales/Australian Capital Territory (ACT) (14%), and Western Australia (12%). Similarly, in the commercial sector, Victoria and NSW also accounted for most (80%) of the gas shifted. One implication of this finding is that the relative costs of gas and electricity in those states will be more important than the national picture in determining the relative competitiveness of gas and electricity.



State	Shift	
	PJ	%
TAS	0.2	0%
QLD	1.8	1%
NT	0.0	0%
WA	15.7	12%
SA	8.5	6%
NSW	18.6	14%
VIC	87.2	66%

Figure 14: Contribution of gas consumption shifted to electricity by state in the residential sector (ACT is included in NSW), Source: ClimateWorks Australia (2016)



State	Shift	
	PJ	%
TAS	0.0	0%
QLD	0.4	1%
NT	0.4	1%
WA	3.0	8%
SA	3.8	10%
NSW	6.7	18%
VIC	23.0	62%

Figure 15: Contribution of gas consumption shifted to electricity by state in the commercial sector (ACT included in NSW), Source: ClimateWorks Australia (2016)

Summer and winter maximum demand

The ClimateWorks (2016) study design included an assessment of the impact of any increased building services electrification on winter and summer maximum demand. The reasons for examining maximum demand impacts is to determine whether any additional electricity volume can be absorbed efficiently using existing electricity infrastructure or whether new infrastructure capacity (either in terms of generation or networks) would be required.

The analysis indicates that it is likely that increased electrification will increase winter peak demand but, as this is below summer demand in all states except Tasmania, and summer demand increases only slightly, maximum demand overall is not significantly impacted. To demonstrate, the case of Victoria, which experiences the largest increase in building services electrification, is shown in Figure 16. Victorian winter maximum demand is expected to increase by 11 percent by 2050 due to additional electric hot water and HVAC loads relative to the AEMO (2016) 50 percent probability of exceedance (PoE) projections. In summer, the additional load is projected to be 1 percent. The 10 and 90 percent PoE projections are also provided for context.

Note that, ClimateWorks Australia (2016) caution that they only evaluated the substitution of gas and electricity heating loads. That is, if an electric heat pump was not previously available in the household and is now used for cooling in summer as well as substituting gas in winter then this additional summer electrical load is not captured. Analysis of this topic was out of scope. As such the summer maximum demand forecast may be under-estimated.

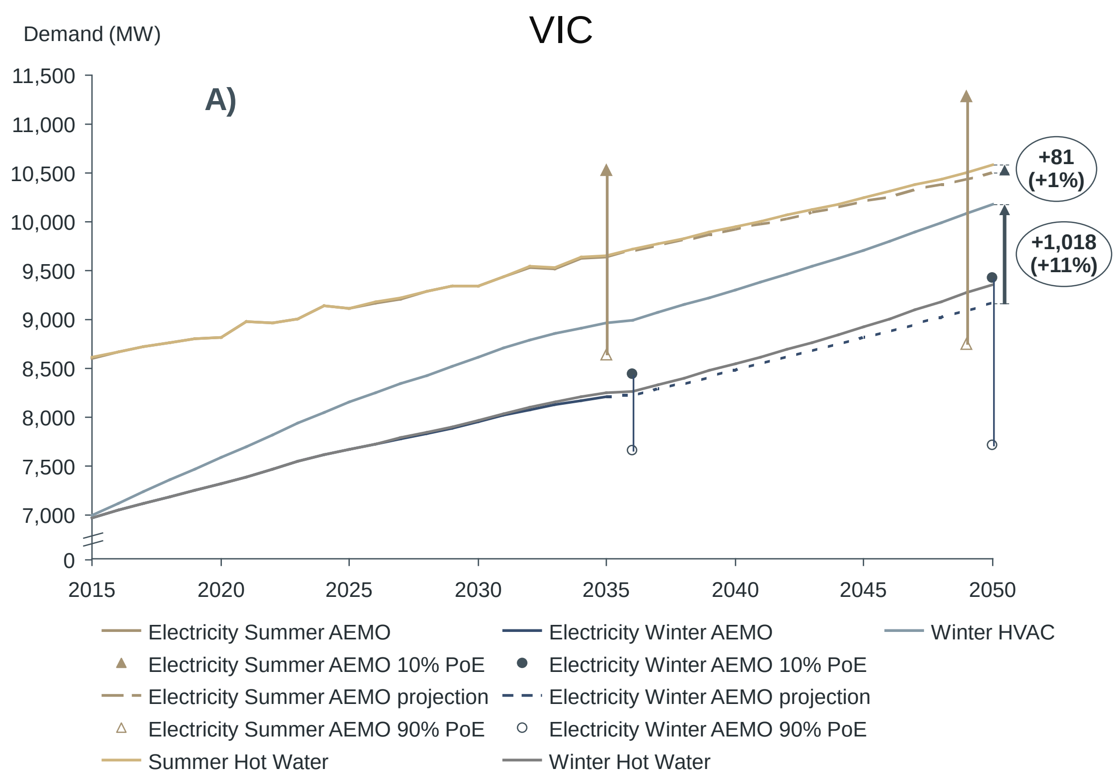


Figure 16: Impact of building services electrification on Victorian peak electricity demand, relative to AEMO (2016) forecasts, Source: ClimateWorks Australia (2016)

Implications and policy options

Implications

The potential for building services electrification to 2030 is not at all clear from the historical records or the available projections. Both gas and electricity prices will be subject to trends which could weaken or strengthen their relative competitiveness. On balance it may be best to conclude that in the next decade will not see strong swings in the share of gas and electricity in building services energy supply.

In the long term (2030 to 2050) there are trends which might also swing the weight of argument in either direction. In regard to gas, we do not yet fully understand the size of the core of customers who value gas for non-price factors such as its amenity in cooking. There are also benefits in having more than one source of energy that may begin to become more important over time to customers. Customers seeking to deploy an off-grid electric system could reduce the size and cost of their system considerably by retaining gas supply for some building services. Gas supply is also a useful back-up if more challenging climate conditions means a greater number of power blackouts.

Another reason gas may maintain competitiveness is that if gas peaking plant are used as a primary means of backing up intermittent renewables then gas and electricity prices may be naturally prone to move together over time rather than diverge. More longer term, as greenhouse gas emissions constraints strengthen natural gas suppliers may look to technologies such as fuel cells, gas-based co/tri-generation systems, bio-gas, solar-gas and adding hydrogen to gas supplies to strengthen their environmental position.

One can also argue that there are trends in electricity supply which could point towards a strengthening position. The first and strongest point is that as electricity generation decarbonises it will seek to surpass gas as a means of greenhouse gas reduction in building services and in the direct combustion sector more widely.

The second is that as the prices of both electricity and gas prices are forced upward by carbon policies, residential and commercial electricity consumers have an additional means of reducing their exposure to cost increases (besides energy efficiency) whereas gas consumers do not. Electricity consumers can seek to generate a portion of their electricity on site through some type of rooftop solar based system with or without storage. The costs of these systems are expected to decline.[10].

Should the projection of ClimateWorks Australia (2016) come about in 2050 the projected additional 5 percent increase in electricity consumption would improve the efficiency of existing electricity infrastructure so long as it doesn't significantly increase maximum demand. While more research is needed it appears that since most load is associated with heating, it mainly impacts winter demand which is lower than summer demand in most states.

However, at the same time, any increased electricity demand would lead to a fourfold decrease in gas consumption (due to different power needs of appliances, considering that electricity losses occur upstream in generation while most gas losses are at the point of use). A decrease of this size deserves further investigation to understand its impacts. Decreasing consumption can lead to increasing prices where monopoly distribution infrastructure has yet to be fully amortised through regulated formulas which typically favour straight line depreciation over the expected life of an asset (e.g. 50 years).

This situation could lead to perverse outcomes. For example, if existing gas customers switch to electric heating but by doing so reduce gas throughput in total such that distributors have to raise the price of gas, then some of the expected gas bill savings may evaporate as they are recovered from the remaining gas use (e.g. hot water or cooking). Such perverse price cycles are also evident in the electricity sector when it comes to adoption of energy efficiency or rooftop solar to save on electricity bills.

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[10] An important caveat on this point is that such actions by consumer can lead to a perverse price cycle whereby reduced consumption leads to higher prices (to recover cost of sunk regulated monopoly assets). As such, rising retail electricity prices are not as avoidable as they appear in a static analysis, excepting to those customers who go entirely off grid.

Policy considerations

Energy efficiency policy in the building services area is generally addressed through building standards and white certificate schemes for energy efficiency improvements. The CCA (2016) has indicated that these measures could be improved through harmonising white certificate schemes across States in Australia and with the national Emission Reduction Fund methodologies for building energy efficiency. Based on the results presented here, Victoria and New South Wales would be the most crucial states to address in terms of impacts on gas-electricity substitution.

For larger, industrial direct combustion emissions, CCA (2016) recommends the Safeguard Mechanism be broadened to include smaller sites and baselines lowered over time to provide abatement incentives.

These existing policies are mostly energy supply neutral and it is difficult to develop any other policy options given the uncertainties in the projections and immediate benefits of building services electrification. However, the longer term impacts of building services electrification are potentially significant enough that they certainly require the attention of:

- The government: to determine the role of buildings services and industrial electrification in meeting 2030 and 2050 greenhouse gas emissions targets and thereby provide more guidance on the likely need for buildings and direct combustion emission reductions[11]
- The electricity industry: in realising the potential significant additional consumption without any significant increase in maximum demand in the context of an otherwise potential flat electricity demand outlook
- The gas industry: in understanding the extent of competitive threat of electricity in supplying energy to building services

In regard to this last point, given the electricity focus of this study we have not fully surveyed the competitive options for gas in responding to supply competition. Some future options that might equally suggest gas could provide a competitive threat in building services in the opposite direction are:

- The potential long term availability of low cost natural gas fuel cells or co/tri-generation technology
- Decreasing the emission intensity of gas by adding hydrogen (including use of carbon capture and storage where the primary energy source for hydrogen is gas or another fossil fuel) or through using renewables, particularly solar and biomass, to synthesise or convert the methane supply
- Using gas as a means of supporting an off-grid electricity system (i.e. using gas for heating, cooking and hot water would substantially lessen the solar and battery requirements of such a system)

Even though our expectation in the long run is for highly decarbonised electricity to be available, given the technological uncertainty, in a balanced policy environment, any tightening of building standards should therefore target full fuel cycle emissions and not necessarily a specific fuel.

[11] This is not to suggest that the buildings sector should have a sector specific climate policy. Rather it acknowledges it is the role of governments to clarify emission targets and conduct the necessary whole of economy analysis of lowest cost abatement sources. Having a greater understanding of the targets and contribution of the building sector will assist energy suppliers and building developers to prepare to meet the abatement challenge.

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Appendix A: Industrial sector electrification

The most immediate opportunity for gas-electricity substitution in non-electricity stationary energy is expected to be in building services. However, this study also considered the longer term opportunity presented by the industrial sector.

The potential for greater use of electricity in the industrial sector is not specifically considered in AEMO (2015) or AEMO (2016) except to the extent that the projected outputs of specific industries (e.g. gas fired power generation and LNG exports in gas forecasting or mining and mineral beneficiation in electricity forecasting) are monitored and their traditional energy sources proportionally applied.

This approach would seem to assume that the direct combustion sector will play no part in meeting Australia's 2030 emission reduction target or is perhaps a direct result of AEMO's concern being limited to understanding the electricity sector's role in greenhouse gas abatement rather than how that sector and others combine to meet the target.

Any brief analysis of the topic indicates that it would be somewhat optimistic to assume direct combustion will not need to play a role in meeting national abatement targets. DoE (2015) show that Australia's business as usual emissions are projected to increase to 724 $MtCO_2e$ by 2030 compared to 609 $MtCO_2e$ in 2005. A further breakdown of emissions by sector is provided in **Error! Reference source not found.**. It shows that even if electricity sector emissions were to be completely removed, Australia would be short by 145 $MtCO_2e$ from meeting the target of 26 percent below 2005 levels (or around 450 $MtCO_2e$).

Technologies across different sectors are always evolving but it is generally accepted that greenhouse gas abatement in non-electricity sectors is more difficult (e.g. see page 81 of Treasury (2011)). However, on the positive side there is more abatement available in land use and as discussed above the light duty road transport sector can electrify (and even without electrification internal combustion transport can be made significantly more efficient). However, aviation, diesel based rail and the marine sectors have more limited options because of specialised fuel needs.

If we proposed that electricity generation did more than its share and halved its emission relative to 2005 and that the transport sector did its proportional share through deep cuts in the road sector, we would still need to find almost 100 $MtCO_2e$ of abatement from the remainder of the sectors of which direct combustion is the largest.

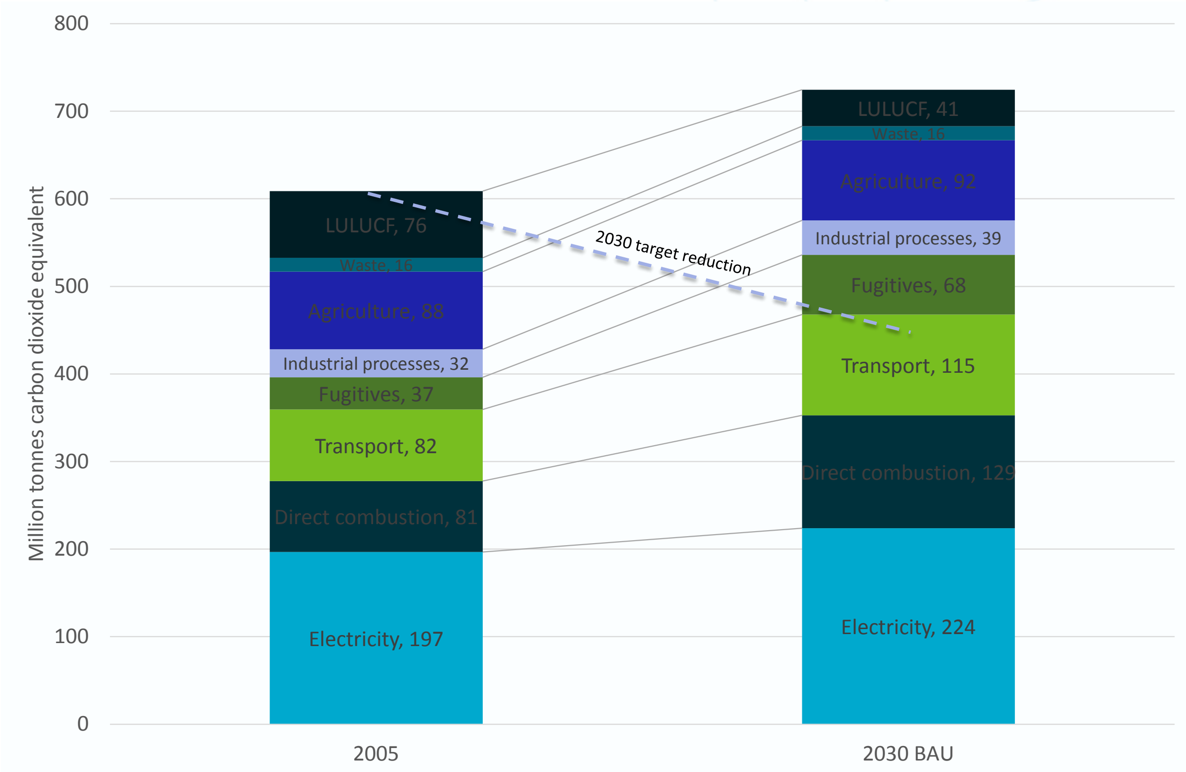

Figure 17: Australia's national greenhouse gas emissions by sector: 2005 and projected 2030 business as usual and target emission reduction trajectory, Source: DoE (2015).

Even if other sectors are able to provide the necessary abatement in 2030, there is another consideration which is that the Australian government has in principle signed up to the longer term climate goal of limiting the increase in the global mean temperature to 1.5-2 degrees Celsius. It is generally accepted that to do so will require developed countries to reach zero net emissions by around mid to late-century. Under such a target, there can be only three possibilities:

- Each sector of the economy achieves zero emissions
- Australia purchases sufficient emission credits from overseas to cover positive emission sectors
- Australia generates sufficient emission credits from domestic land use changes to cover positive emission sectors

Given that we would expect electricity generation to lead carbon abatement and become increasingly decarbonised and with the challenge of cross sectoral abatement in 2030 and 2050 in mind, we asked ClimateWorks Australia to review the *Pathways to Deep Decarbonisation in 2050* project, led by ClimateWorks Australia and the Australian National University in 2014, to outline the potential for electrification in the industrial sector, should it be required (ClimateWorks Australia, 2014).

The analysis indicates that across the industrial sectors reviewed in the 2014 study, electricity contributed between 8 to 33 percent of energy requirements. By 2050 it was estimated that using plausible technological changes, those industries could increase their share of electricity into the range of 34 to 60 percent with the remainder delivered by other sources such as coal, gas, biomass and petroleum fuels. This was an upper limit based on economically plausible steps that could be taken in the context of achieving zero net emission by 2050. This increase in the share of electricity in total energy consumption, if implemented would lead to a 90 percent increase in electricity demand for selected industrial sectors. Note that, ClimateWorks Australia and ANU (2014) use domestic land use credits (i.e. afforestation) to cover emissions from positive emissions sectors.

Such an increase in industrial electricity demand would be very significant indeed but of course needs to be understood in context under which the projection as made. We cannot place any confidence in this area until we better understand Australia’s 2050 emission targets (which are currently not agreed), the abatement potential of non-electricity sectors and the likely cost of domestic and international emission credits.