Boomerang Price Shocks in Electricity

Impact of asset write downs and regulatory suppression on price shocks in the network electricity sector

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DECLARATION

I, Zubin Meher-Homji, certify that the work in this thesis entitled "Boomerang Price Shocks in Electricity - Impact of asset write downs and regulatory suppression on price shocks in the network electricity sector" has not been submitted for a higher degree to any university or institution other than Macquarie University.

I also certify that the thesis is an original piece of research and it has been written by me. Any help and assistance that I have received has been acknowledged.

In addition, I certify that all information sources and literature used are indicated in the thesis.

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SUMMARY

Electricity prices doubled between 2007 and 2013 in most Australian capital cities (Mountain, 2020, p188). The network sector was the dominant driver of higher electricity prices (Australian Competition and Consumer Commission, 2018, piv). The prices of state-owned networks rose significantly higher than private peers (Australian Competition and Consumer Commission, 2018, pp10-23).

This empirical observation has led to duelling narratives. The *gold-plating* narrative contends that deficiencies in the regulatory framework incentivised state-owned networks to seek excessive expenditure and returns (Mountain, 2010, p5770; and Grattan Institute, 2012, p3). In contrast, the *keep the lights on* narrative argues that higher expenditure was required to address reliability and safety issues, following regulatory decisions in the previous decade that suppressed expenditure and 'wrote down' asset values (Ausgrid, 2008, p4).

This paper contributes to the literature by using a 'mechanistic' model to quantify price movements using variables identified in both narratives. The model has been adapted from the ecology field and has been fitted with data from the NSW distributor Ausgrid, the network with the largest price increase in the National Electricity Market.

Our key finding is that the *gold-plating* variables including stronger reliability targets, overstated demand forecasts, declining efficiency and higher rate of return contributed to about half of Ausgrid's price increase between 2009 to 2014. The variables identified by the *keep the lights on* narrative such as asset write downs, suppressed replacement and declining energy volumes accounted for the other half.

We contend that the lessons of the *keep the lights on* narrative have been ignored by policy makers. We identify key metrics of regulatory suppression to show that South Australian, Victorian, and Tasmanian distribution networks are at risk of price shocks in the future. The analysis presented in this paper shows that these networks have a significantly under-valued Regulatory Asset Base and replace assets below a sustainable rate. Together, our model suggests these metrics are a recipe for steeply rising prices in the future.

CONTENT

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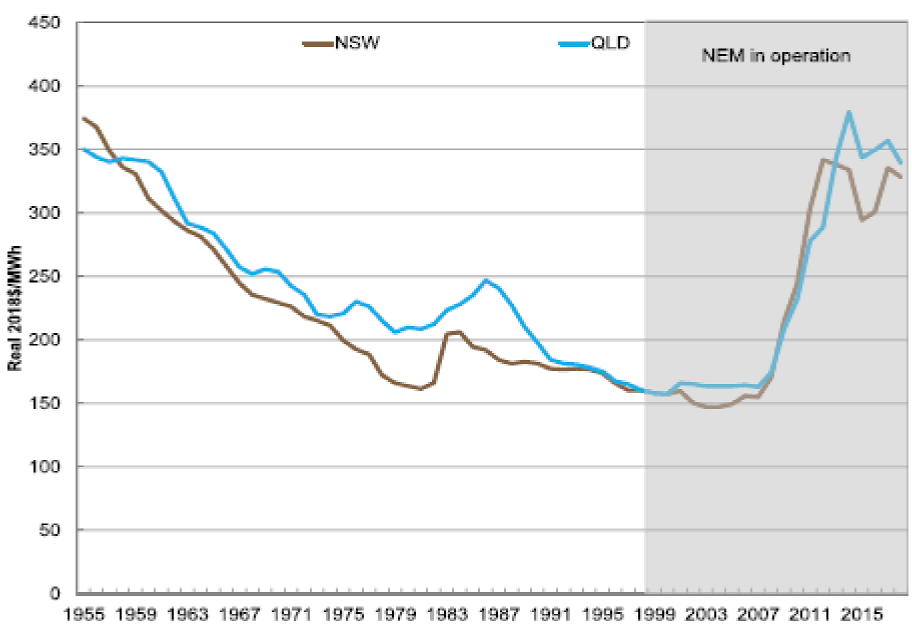
1. Introduction

There is consensus in the literature that Australian electricity prices increased significantly from 2007. In its 2018 Retail Electricity Pricing Inquiry, the Australian Competition and Consumer Commission (ACCC) found that residential prices increased by 56 per cent in real terms between 2007-08 and 2017-18 across the National Electricity Market (ACCC, 2018, pv). Using Australian Bureau of Statistics (ABS) data for a shorter period, Mountain (2014, p188) found that electricity costs doubled in Australia's main capital cities between 2007 and 2013.

There is limited data in the literature on price movements in Australia before 2007. Figure 1 is an extract from Rai and Nelson (2019, p3) which shows that NSW and Queensland residential prices fell in real terms between 1955 and 2006. From 2007 to 2015, prices rose by more than double, returning prices back to approximately 1955 levels in real terms.

Figure 1 - NSW and Queensland tariffs between 1955 and 2015 ($/MWh, real $2018)



Source: Rai and Nelson (2019, p3).

To supplement the literature on long term prices, we examined ABS data on electricity cost changes between 1980 and 2019[1] (ABS, 2020). Figure 2 identifies the annual (1 year) and 5 year rolling averages of electricity costs in real terms, excluding CPI. It shows that the maximum 5 year increase in real electricity costs was 75 per cent between September 2007 and September 2012. Figure 3 shows that the trend is similar across capital cities, except for Darwin. Figure 4 shows that a price shock in electricity was the fifth largest among price shocks across all 133 goods and services between 1980 and 2019.[2]

Figure 2 - – Real change in electricity costs in Australia between 1980 and 2019 (Annual and 5 year rolling average)

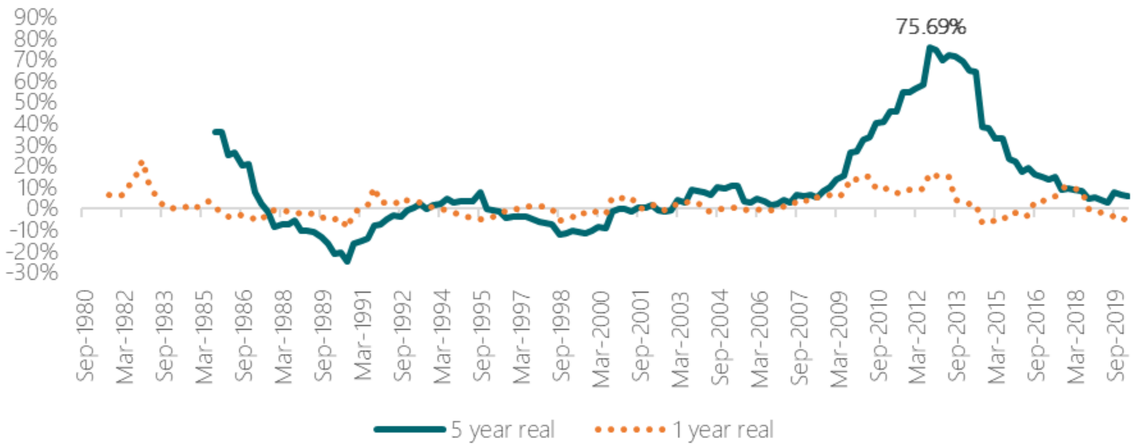
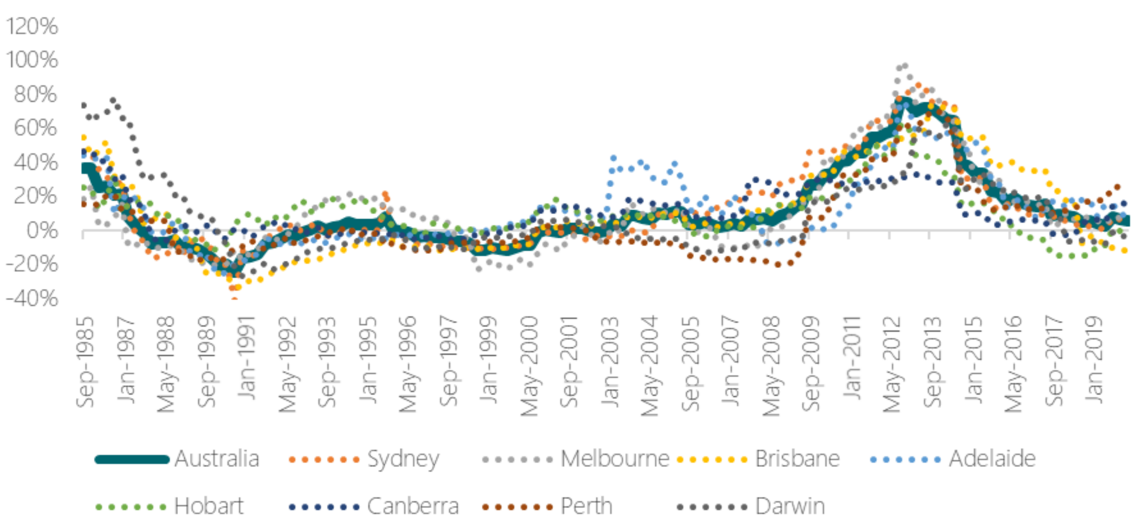


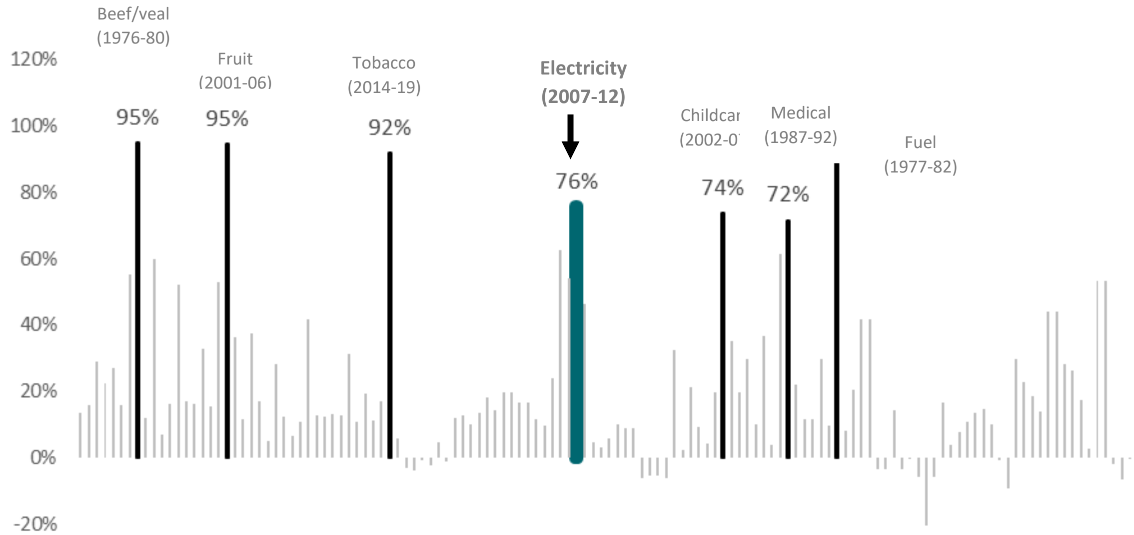
Figure 3 - Real change in electricity costs by capital city between 1980 and 2019 (Annual)



[1] Electricity costs were first published in the CPI series in 1980.

[2] The analysis and source data for Figures 2 to 4 can be found by clicking on "Analysis and Source Data - Figure 2 and 3 - Electricity Cost Increases" and " Analysis and Source Data - Figure 4 - Price shocks for all goods and services" at http://www.dynamicanalysis.com.au/research

Figure 4 - Maximum real increase in costs of Australian good and service types over 5 year periods, 1980-2019



1.1 Corrosive impacts of price shocks

Higher electricity prices sparked intense public concern, with media articles on electricity increasing by a factor of 6 to 7 over this period (Simshauser and Laochumnanvanit, 2012, p61). Below we briefly discuss three corrosive impacts of higher prices including higher rates of energy poverty, energy affordability concerns, and polarisation and inaction on climate change policy.

1.1.1 Energy poverty

There is clear evidence in the literature that energy poverty increased in Australia from 2007 onwards. Energy poverty is defined as the inability to connect to, or afford energy services (Churchill and Smyth, 2020, p1). This deprives a household of access to essential amenities such as heating, cooking and lighting (Chester and Morris, 2011, p436), and can extend to foregoing other essentials such as medicine or food (National Council of Social Services, 2017, p2).

The literature identifies two primary factors that drive energy poverty: high ratio of energy prices to income, and limited access to energy efficiency options (Churchill and Smyth, 2020, p1). Under this framework, a surge in energy prices places low income households in financial distress (Moore, 2012, p23), exacerbated by limited financial means to reduce energy use through alternative actions (Mattioli, Lucas and Marsden, 2017, p97).

On a range of measures, energy poverty increased in Australia from 2007 onwards. For example, a KPMG report (2016, p15) commissioned by the Energy Consumers Australia showed that disconnections for non-payment between 2010 and 2016 rose for all states. In Queensland, disconnections rose from 15,000 to about 28,000 between 2008-09 and 2014-15, a period which coincided with a price increase of 87 per cent (Chai et al, 2019, p7).

From an income perspective, electricity prices have grown at a faster rate than household income, particularly in the low- income quintile. Our analysis of ABS data shows that the mean equivalised disposable annual income of the lowest quintile of households in Australia grew from $20,800 to $22,516 between 2007-08 to 2017-18 (ABS, 2019)[3]. The ACCC inquiry found that electricity prices for a typical household increased from $1210 a year to $1636 a year over the same period (ACCC, 2018, pv). The ratio of electricity residential prices to disposable income for low income household therefore grew from 5.8 per cent to 7.3 per cent, an increase of 25 per cent.[4]

This analysis does not account for rising costs of other goods and services such as rent, or that some low income households faced fixed incomes. Saunders and Bedford (2017, p280) observe that the Newstart unemployment allowance in Australia has not kept pace with cost of living pressures, estimating a shortfall in budget of between $47 to $126 a week. Nelson, McCracken-Hewson, Sundstrom, and Hawthorne (2019, p263) suggest this has led to a rationing of essential services such as electricity and food. A 2017 National Council of Social Services report (2017, p2) draws out the visceral impacts on financially vulnerable Australians based on a survey of 440 people living below the poverty line:

> *"We heard about individuals, and even families with children, skipping meals, delaying health treatment or purchasing medication, not using hot water and going to bed early to save energy in order to pay their energy bills. Having reduced their energy usage below acceptable community standards, we heard*

[3] We have converted the weekly rate to an annual rate by multiplying by 52. We have used the equivalized rate in the ABS data for low income households.

[4] The analysis and source data can be found by clicking on "Analysis and Source Data - Section 1.1.1 - Income to Electricity Bill Analysis" at http://www.dynamicanalysis.com.au/research

> *about people then getting into debt, selling personal items, and going without a range of household essentials just to keep the lights on."*

1.1.2 Energy affordability concerns of households

There is mixed evidence to demonstrate that rising electricity prices placed significant financial stress on average-income Australian households. Simshauser and Nelson (2014, p13) use 2012 ABS data to show electricity was only 2.6% of the household budget, much lower than housing (18%), food and beverages (16.5%) and alcohol and tobacco (3.6%).

However, customer surveys show that electricity costs were a primary affordability concern of households during the price shock (CHOICE, 2013, p3). This could be explained by the low level of liquid savings in Australian households. The recent ME Bank survey data reports that only 37 per cent of people could raise $3000 without selling an asset (ME Bank, 2020, p45). This provides some insight into the pressure faced by households, and why a sudden shock in electricity prices became what Simshauser described as a "cost of living focus event for consumer groups and politicians" (2019, p27).

A further reason is that income may not necessarily reflect the ability of a household to meet the expense of an electricity bill. For instance, Nelson, McCracken-Hewson, Sundstrom, and Hawthorne (2019, p263) find that financial hardship factors include number of people in the household, young families, and high energy consumption.

1.1.3 Polarisation and inaction on climate change policy

A key hindrance to a coherent climate change policy in Australia is deep concern about its impact on higher electricity prices. The narrative first erupted in 2011 when the Federal Labor Government introduced a new carbon tax, at a time when electricity prices were spiking (Meng, Siriwardana, and McNeill , 2013, p313). The Coalition Opposition seized a political opportunity to tie Labor's carbon tax to energy prices in the minds of the electorate. The politics of climate change became brutal and toxic, with the Opposition leader Tony Abbott declaring (Australian Broadcasting Commission, 2011, p1)

> *"I am giving you the most definite commitment any politician can give that this tax will go. This is a pledge in blood: this tax will go."*

The legacy of a toxic debate on climate change resonates in Australian politics today, with no clear national framework to address climate change. This has arguably resulted in higher emissions than would have otherwise been achieved (NDEVR Environmental, 2020, p1) and a higher cost for each unit of emission (Garnaut, 2020).

1.2 Causes of price shocks

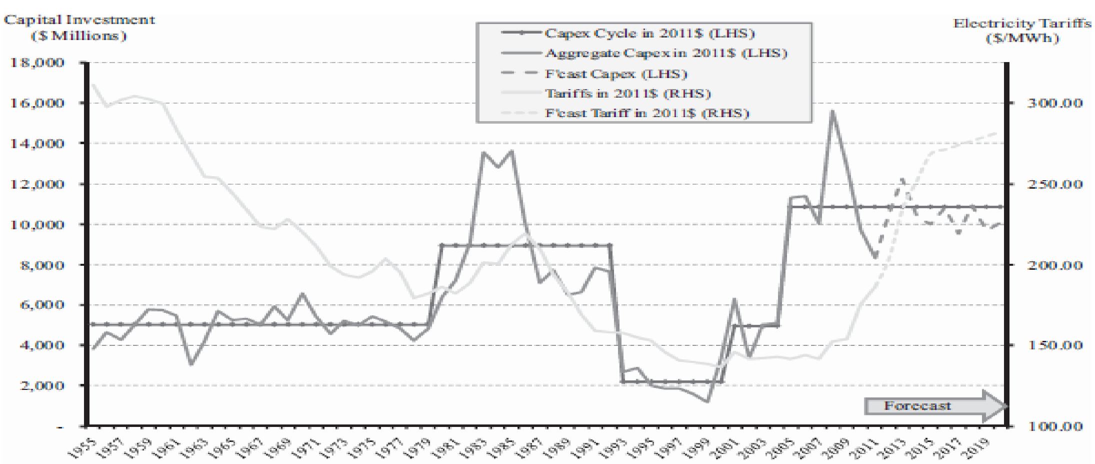
There is extensive interest in the literature on the causes of rising electricity prices over the last decade, reflecting public concern about energy affordability and climate change policy. We have identified two general approaches to examining the drivers of the price shock – what we term the *historical approach* and the *sector by sector approach*.

1.2.1 Historical approach

The *historical approach* seeks to draw out macro factors that explain electricity price movements since the 1950s. The analysis relies on an empirical observation that price movements are correlated with capital investment, and the latter relates to market and policy developments from 1955 onwards.

Figure 5 below is an extract from Simshauser and Catt (2012, p64) which shows 4 distinct periods in Queensland tariffs and capital expenditure since 1955. This forms the basis of the *historical approach* to explaining long term price trends in Queensland and other states.

Figure 5 - Queensland capital investment ($ millions, real 2011) and electricity tariffs ($/MWh, real 2011)



Source: Simshauser and Catt (2012, p64)

The drop in electricity tariffs between 1955 to 1980 is characterised by the *historical approach* as substantial economies of scale arising from rapid expansion (Rai and Nelson, 2019, p2). The increase in prices in the 1980s is described as a period of over-investment when new industrial loads did not eventuate as expected (Simshauser and Nelson, 2014, p17). The decline in prices in the 1990s to 2007 is explained by the Hilmer microeconomic recommendations implemented by state governments (Whiteman, 1999, p17) and by minimal need to invest due to spare capacity arising from over-investment in the 1980s (Simshauser, 2019, p3). From 2007 onwards, the increase in capital expenditure is explained by an investment 'megacycle' caused by growing demand outstripping capacity (Simshauser, Nelson and Doan, 2011, p73) and by excessive investment by networks, combined with generation shortages and retail market concentration (Rai and Nelson, 2019, p1).

1.2.2 Sector by sector approach

The *sector by sector approach* examines micro drivers of price increases in the generation, network and retail sectors of the electricity market, restricting analysis to the period of price shock. The ACCC adopted this method for its 2018 Retail Electricity Pricing Inquiry. The ACCC found network prices were the dominant driver of higher prices contributing 38 per cent of the price increase, followed by wholesale prices contributing 27 per cent, retailer costs and margins contributing 20 per cent and environmental policies contributing 20 per cent (ACCC, 2018, p7).

Researchers have found that higher generation prices can be explained by increased fuel costs (Grattan Institute, 2018(a), p14), disorderly transition to replace retiring generators (Rai and Nelson, 2019, p8) and unfair bidding practices by generators that inflate the spot price (Clements, Hurn and Li, 2016, p25). As discussed in more detail in chapter 2, higher network prices have been blamed on ineffective regulatory frameworks to curb excessive expenditure and returns (Mountain and Littlechild, 2010, p5770) or alternatively a rebound from unsustainable regulation in the prior decade (Ausgrid, 2008, p4). Higher retail prices have been blamed on the market dominance of major retailers (Finncorn Consulting, 2017, p6). Environmental policies such as over-generous feed in tariffs have been said to drive up retail prices (Poruschi et al, 2018, pp260-261 and Nelson, Simshauser, and Kelley, 2011, p113).

1.3 Where our paper contributes to the literature

In this paper, we analyse and contribute to the literature on the cause of higher prices in the regulated network sector of the electricity market. Network prices grew significantly between 2007-08 and 2017-18 in all Australian capital cities, however the increase in state-owned networks was far higher than private peers (ACCC, 2018, pp10-23).

Our thesis draws out a schism in the literature on the drivers of higher network prices based on competing narratives which we have termed *gold-plating* and *keep the lights on*. The *gold-plating* narrative argues that the cause of higher network prices was excess expenditure and regulatory gaming by state-owned networks. The *keep the lights on* narrative argues that a 'step up' in expenditure was required to address unsustainably low allowances and asset write downs of regulators in the decade before the price shock. The *gold-plating* narrative is dominant in the literature and government reports, while the *keep the lights on* narrative finds expression in the submissions of state-owned networks during the price shock, with muted support in the academic literature.

Our thesis seeks to contribute to the literature by developing a price movement model that quantifies the impact of variables in the respective narratives on annual price changes in the distribution network sector of the National Electricity Market (NEM). We have used a mechanistic model currently being used in contemporary ecology research (Porter and Kearney, 2009). We have fitted the model with published data from Ausgrid, the network which had the largest price increase.[5]

The model captures the *historical approach* to researching the causes of price shocks by examining changes in prices over a long time series from 1900 to 2050. It also reflects the *sector by sector approach* by focusing on the distribution networks in Australia's National Electricity Market (NEM).

This thesis is structured as follows. Chapter 2 provides a summary of the literature of the causes of network price increases, and how our model seeks to contribute to the literature. Chapter 3 describes our price movement model. Chapter 4 identifies the key findings of the model. Chapter 5 provides policy insights from the model's findings. We have included

[5] This is based on analysis we have undertaken in Chapter 2 of this thesis.

references and a glossary. Appendix 1 provides the link to a website where the spreadsheets for the model and all original data analysis presented in this thesis can be accessed.

2. Literature review – Network price shock

In this section, we explore the key narratives in the literature that seek to explain the causes of network price increases.

By way of background, the network sector typically accounts for about 40 per cent of a residential customer's electricity prices (AER, 2020, p17). There are 14 distribution networks and 6 transmission networks operating under the National Electricity Law (NEL) and National Electricity Rules (NER) framework (AER, 2020, pp119-120)[6].

The prices of networks are set by independent regulators due to their monopoly characteristics, including higher capital intensity (AER, 2020, p119). Australian regulators use a formula to derive the annual maximum revenue that a network can charge its customers for standard (control) services for a 5 year period.[7] Individual tariffs to collect the revenue from customers are approved by the AER on an annual basis.

Using ACCC data from its 2018 Retail Inquiry, Figure 6 shows the relative contribution of higher network charges to the overall increase in residential bills between Financial Year (FY) 2008 to FY2018 for each state in the NEM (ACCC, 2018, pp17-22). The ACCC's report found that network price rises were far higher in networks owned by state governments during this period including in NSW[8],Queensland, and Tasmania compared to privately owned networks in South Australia and Victoria. We have included smart meter related cost increases for Victoria, which is a different approach than the ACCC which excluded this cost.[9]

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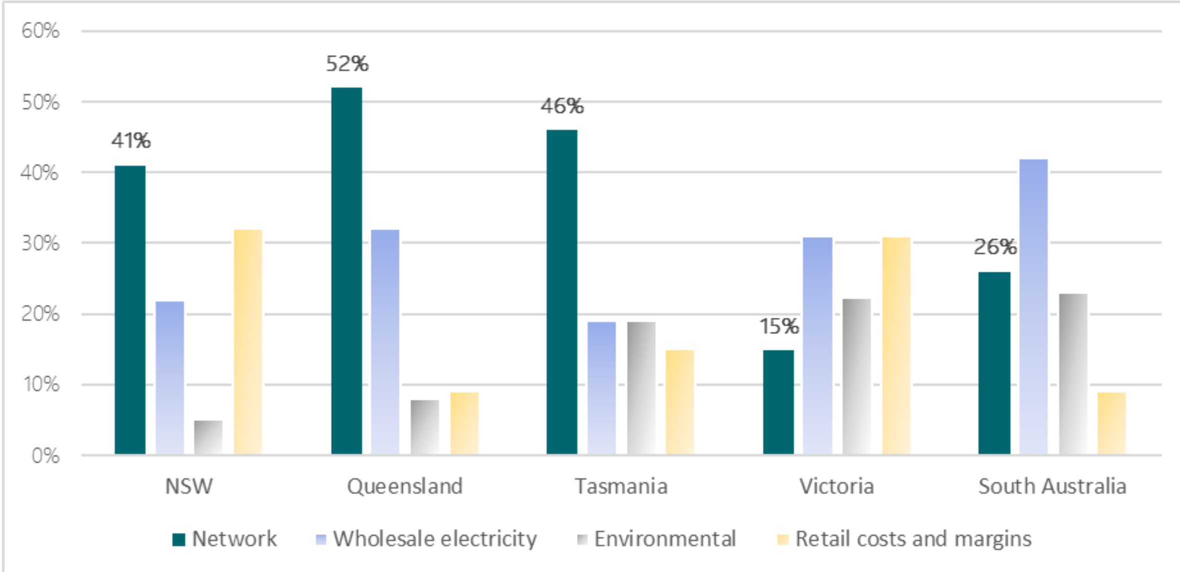
6 There are three distribution networks in NSW (Ausgrid, Endeavour Energy and Essential Energy) and one transmission network (Transgrid), two distribution networks in Queensland (Ergon Energy and Energex) and one transmission company (Powerlink), five distribution networks in Victoria (United Energy, Powercor, Citipower, Jemena, Ausnet) and one transmission network (Ausnet), one distribution and one transmission network in Tasmania (both TasNetworks), one distribution network in South Australia (SAPN) and one transmission network ElectraNet in South Australia, and a combined distribution and transmission network in the Northern Territory. These networks are all subject to economic regulation by the Australian Energy Regulator under the National Electricity Law and National Electricity Rules, but Northern Territory is not part of the National Electricity Market and operates under its own version of the National Electricity Rules. Western Australia is not part of the NEM, and the distribution and transmission networks are subject to economic regulation under a Western Australian regulator.

7 The AER also set individual (alternative control) charges for one-off services provided to individual customers such as meter testing.

8 Ausgrid and Endeavour in NSW were partially privatised in 2016 (Guardian, 2018).

9 The analysis and source data for Figures 2 to 4 can be found by clicking on "Analysis and Source Data - Figure 6 - Network price increases - ACCC adjusted for Victoria" at http://www.dynamicanalysis.com.au/research

Figure 6 - Contribution of network charges to increase in retail bill between 2007-08 and 2017-18



Source: ACCC, 2018, pp17-22 (Adjustments to Victoria data to include smart meter revenue)

The ACCC's Inquiry focuses on residential prices at two points in time, providing a limited understanding of price movement trends across all customers and on a yearly basis. We have undertaken additional detailed analysis on price movements for each of the 14 distribution networks operating under the National Electricity Law and Rules framework.[10] Our approach has been to use a public dataset provided by the distributors to the AER which identifies actual revenue and energy consumption from FY2006 to F20Y19.[11]

This provides a cents per kilowatt hour measure for each network that is widely used in the literature for benchmarking the price of networks (Nepal, Menezes, and Jamasb, 2014, p13). The advantage of this approach is that it abstracts from tariff complexities to provide an average measure of price movements for all customers.

Figure 7 identifies the real network prices in cents per kilowatt hour (cents/kWh) of the 14 distribution networks between FY2006 and FY2019. The thick lines represent the private

[10] The AER commenced economic regulation of Power and Water Corporation electricity network services in the 2019-24 regulatory determination under the Northern Territory National Electricity Rules. Prior to this, the services were regulated by the Northern Territory Utilities Commission.

[11] The AER requires distribution networks it regulates to respond to Regulatory Information Notices (RINs) which are then published on the AER's website. We have used the responses to the Economic Benchmarking RINs of each network including the following years of responses: FY2006-13, FY2014, FY2015, FY2016, FY2017, FY2018, and FY2019. A link to the source documents is provided in our references under: Australian Energy Regulator, 2006-20, Responses to Economic Benchmarking RIN", Accessed on 24 August 2020 at: https://www.aer.gov.au/site-search/Response%20to%20RIN?f%5B0%5D=type%3Aaccc_aer_performance_report

companies while the dashed lines represent the state-owned networks, noting that Ausgrid changed from public to part privatised ownership in FY2016 (Gaurdian, 2018). The data shows that state-owned companies had very large price increases between the FY2008 to FY2015 periods, compared to private companies. However, the gap significantly decreased between FY2016 to FY2019 as the price of state-owned networks fell.

Figure 8 provides the data on an indexed basis with all prices normalised to 100 in 2006. The purpose of this analysis is to draw out the relative change in price without the 'noise' of the starting price in FY2006. The data more clearly brings out the large increase in price of state-owned networks between FY2009 to FY2015 periods compared to private companies, with a trend back to equalisation between FY2016 to FY2019. Figure 9 compares private networks with public networks using the sum of data for these companies. The data shows that price increases in state-owned networks were far higher than private networks between FY2007 to FY2015 on an aggregate basis.

Figure 10 identifies the 5 year maximum price increase for each network between FY2006 to FY2019. This shows that Ausgrid had the highest real price increase of 136 per cent on a cents per kilowatt hour basis, and other state-owned networks such as Essential Energy also experienced price increases approaching 100 per cent.[12]

[12] The analysis and source data can be found by clicking on "Analysis and Source Data - Figure 7 to 10, and 35 - Cents per kWh and Revenue" at http://www.dynamicanalysis.com.au/research

Figure 7– Cents per KWh for each distribution network - FY2006 to FY2019 (real $2006)

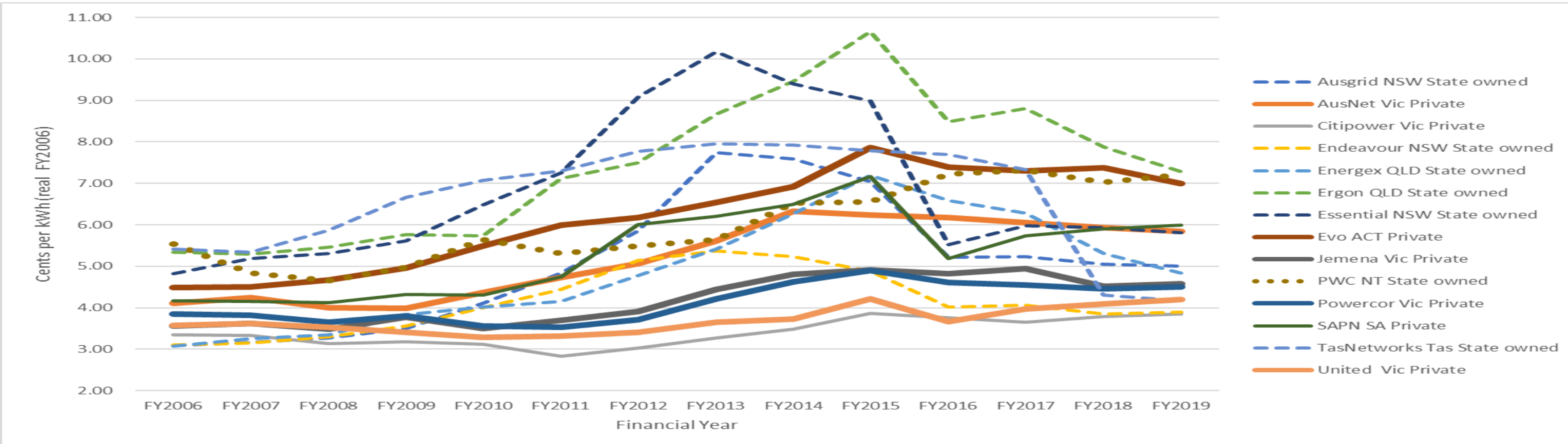


Figure 8– Cents per kWh, indexed (normalised) to 100 in 2006 - FY2006 to FY2019 (cents per kWh, real $2006)

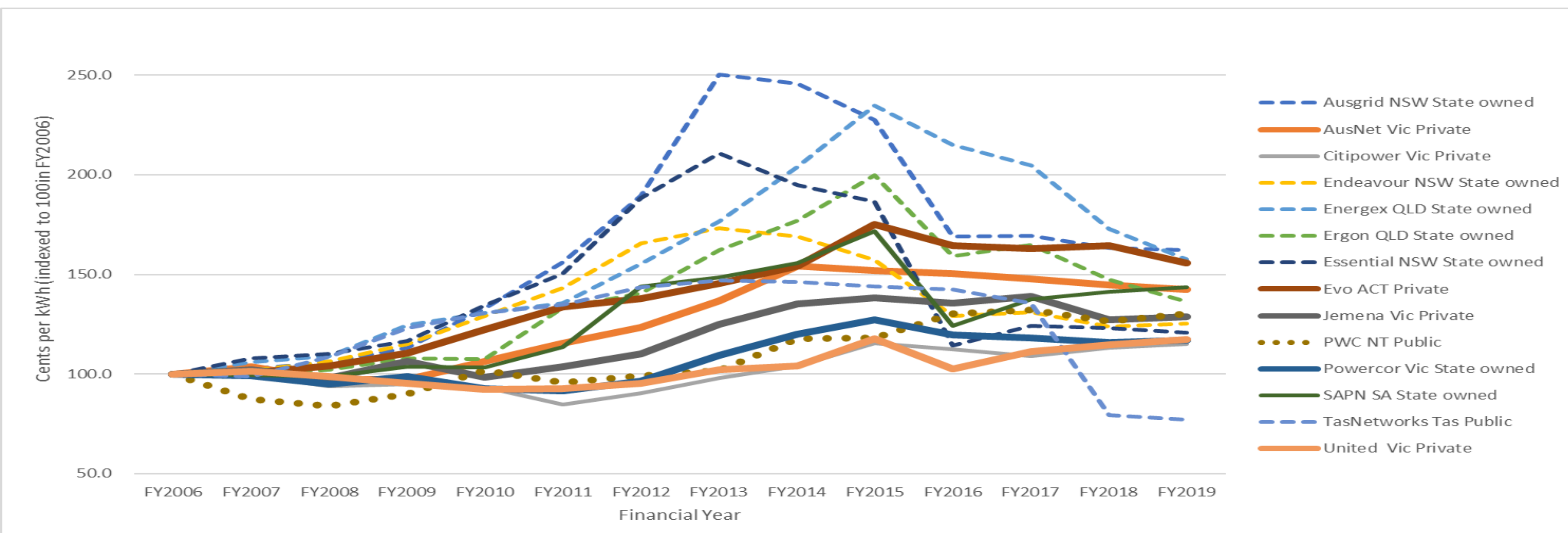


Figure 9- Change in real price FY2006 to FY2019 - State-owned vs private networks, indexed normalised to 100 in 2006 (cents per kWh, real $2006)

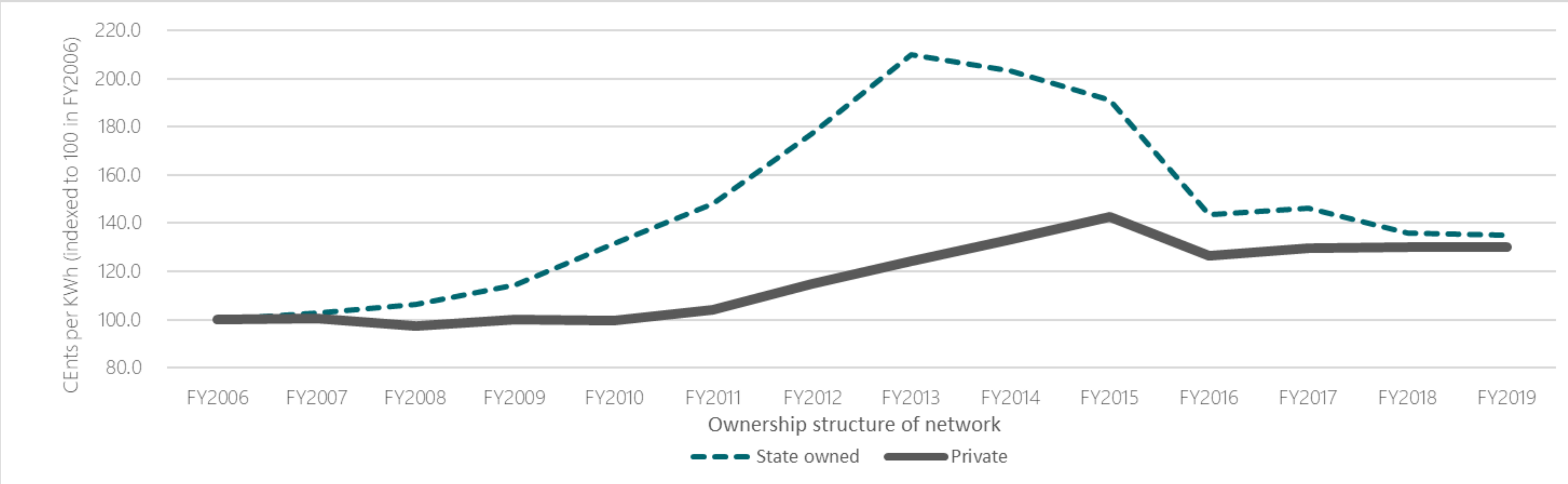
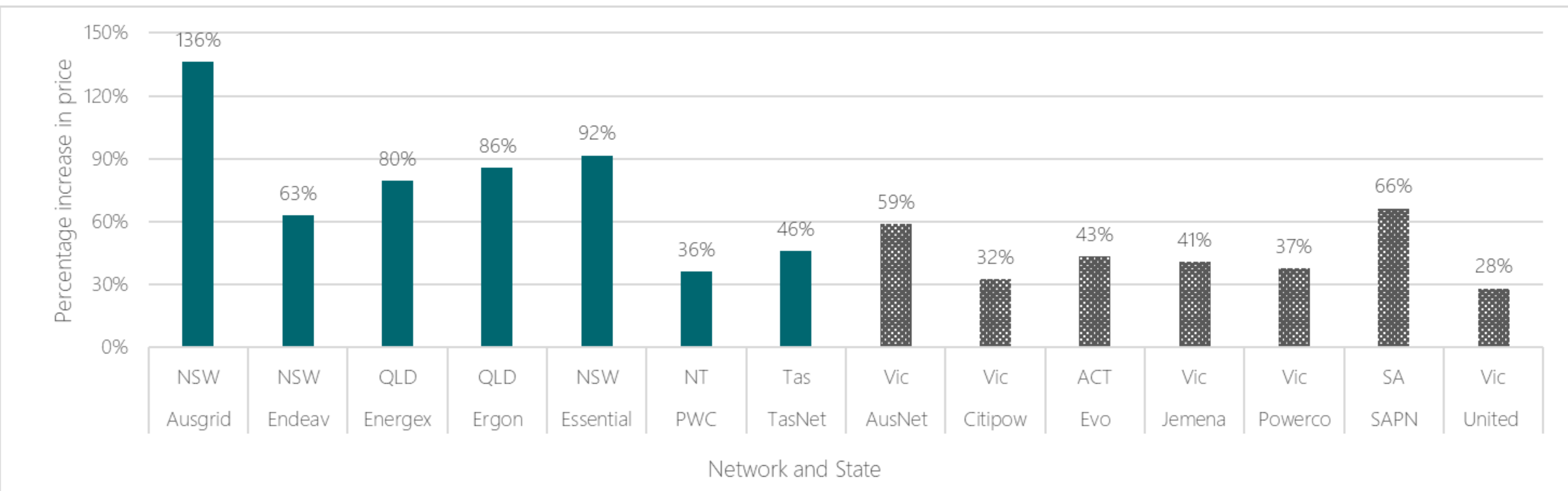


Figure 10 - Maximum 5 year price increase between FY2006 and FY2019 (cents per kWh, real $2006)



2.1 The *gold-plating* narrative

The *gold-plating* narrative argues that inefficient state-owned networks sought excessive expenditure and rates of return between FY2009 and FY2015, utilising weaknesses in the regulatory framework. In the sections below, we first examine the origins of the *gold-plating* narrative before identifying government reports and other literature that supports this contention. We also draw out the policy recommendations that follow from the *gold-plating* narrative.

2.1.1 Origins of the *gold-plating* narrative – Mountain and Littlechild article

Mountain and Littlechild published a seminal article in 2010 that first raised the idea that state ownership was a key driver of network price shocks in New South Wales. The analysis utilised benchmarking metrics to show that revenue per customer was four times higher in New South Wales than private United Kingdom networks, and that operating expenditure was 3.5 times higher (Mountain and Littlechild, 2010, pp5771-5772). The article also found that the state-owned networks in New South Wales had become less efficient over time compared to the private Victorian networks in terms of per customer operating expenditure, capital expenditure, regulatory asset base and cost of capital.

A key contention of Mountain and Littlechild was that state-owned networks are inherently less efficient than private networks. The analysis draws on economic literature in the 1970s which identifies why private firms respond better to efficiency incentives. This includes that private firms have greater profit motivation, reduced bureaucracy, and that interest groups such as unions and government have less influence on decision making (De Allesi, 1974, p3; and Pollitt 1997, pp13-18).

A second premise of the Mountain and Littlechild paper was that government ownership had led to a regulatory framework 'stacked' in favour of the networks. In 2014, Mountain expanded on this point by stating (Mountain, 2014, p88):

> *"… government ownership has undermined the authority and independence of economic regulation"*

Mountain and Littlechild's 2010 article identified the following elements of the regulatory framework that dampened the powers of the regulator: placing the onus of proof on the regulator to reject proposals; limiting the regulator's ability to rely on benchmarking analysis in its decisions; and an appeals framework that allowed networks to 'cherry-pick'[13] unfavourable elements of the regulator's decision (Mountain and Littlechild, 2010, p5774-75). According to this view, a weak regulatory framework had sown the seed for state-owned networks to seek excessive revenue and returns from the regulator. The ensuing result was a large increase in expenditure and returns that led to a price shock.

2.1.2 Government reports support the *gold-plating* narrative

In the wake of media and political scrutiny on higher electricity prices, Government agencies undertook reviews and inquiries into the causes of the steep network price rises. The findings of reports supported the *gold-plating* narrative.

In 2011, the Garnaut updates on its 2008 report into climate change sought to show that steep electricity price increases were solely related to increases in network prices. The update considered there were incentives for *gold-plating* the network including a high return on investment by leveraging lower borrowing costs, and that Government firms are more prone to increase reliability standards based on political concerns (Garnuat, 2011, p2).

The Productivity Commission (2013) considered that the rise in electricity prices was partly driven by inefficiencies in the industry and flaws in the regulatory environment. The Productivity Commission considered that the change in reliability licence conditions had been the main cause of higher prices in New South Wales, and that customers were paying for a higher level of reliability than they value (Productivity Commission, 2013, pp 113-114).

[13] This is a term commonly used in the literature to characterise the perceived behaviour of networks to only appeal the elements of the AER's decision that are unfavourable to its interest, while not contesting elements of the decision which are favourable.

The ACCC's retail enquiry (2018, piv) also found that the regulatory framework was a driver of higher prices:

> *"In networks, the framework that governs regulation of monopoly infrastructure was loosened, leaving the regulator with limited ability to constrain excess spending by network owners."*

The ACCC also noted that reliability standards were set too high and were in excess of what customers were willing to pay (ACCC, 2018, piv). They noted that this had led to a significant increase in capital expenditure that had resulted in higher asset base values in networks that had been state-owned at the time of the price shock (ACCC, 2018, p159).

2.1.3 Broad consensus in the literature to support *gold-plating* narrative

The literature has also tended to conclude there was at least a degree of *gold-plating* enabled by a weak regulatory regime. Nepal, Menezes, and Jamasb (2014, p13) compared the domestic cost of electricity of Norway, United Kingdom and Australia. They found prices in Australia were considerably higher and this was largely related to increases in network costs since 2010. They also noted that institutional and regulatory arrangements at the time explained the observed differences including the lack of resources and independence of the AER, and limited use of benchmarking in regulatory decisions (Nepal, Menezes, and Jamasb, 2014, pp15-18). However, Newbery found that there was great variation in the network component of prices among European countries (Newbery, 2018, p8) suggesting that direct comparison of price may reflect inherent operating and regulatory differences.

Rai and Nelson (2019, p1) noted that sustained increases in distribution network expenditures was a key reason for higher prices since the 2000s and this was related to 'excessive tightening' in reliability conditions and 'over-estimated' demand forecasts. Rai and Nelson also note the higher rates of return associated with the GFC, as amplifying the price increase (2019, p9) such as by increased cost of borrowing.

Simshauser (2019, p22) notes that 'hard-wiring' of the regulatory framework reduced the ability of the regulator to reject the proposed capital expenditure and rates of return of state-owned networks. The author suggested that ‘hard wiring’ had been a response of state governments who were anxious about the potential for adverse decisions by a new independent national regulator.

2.1.4 Policy implications of the *gold-plating* narrative

The *gold-plating* narrative gave rise to three policy prescriptions to address price shocks – strengthening the regulatory framework; privatisation, and asset write downs to immediately reduce prices.

The *gold-plating* narrative emphasised the need to strengthen the regulatory framework to provide the AER with more powers to reject excessive expenditure of networks. For instance Nepal, Menezes, and Jamasb (2014, p21) argued that the AER should be provided with greater resources and discretion. Mountain and Littlechild questioned whether the regulator should have prescribed restrictions on their powers (Mountain and Littlechild, p5781). Mountain and Littlechild also considered that the appeal process in the United Kingdom led to less ‘cherry-picking’ of elements of the decisions that were unfavourable to the regulator.

In response, the economic regulation framework has altered substantively. In 2012, the Australian Energy Regulator successfully sought a change to the National Electricity Rules (NER). The Australian Energy Market Commission (AEMC) in assessing the Rule change found that the regulator should be provided with more strength and flexibility to make decisions (AEMC, 2012, pi). The Rule changes commenced in 2013, which has led to a significant fall in the AER’s allowed revenue for state-owned networks (AER, 2020, p137).

Further, the ability of a network to seek ‘limited merits review’ (LMR)[14] of the AER’s decision was abolished in 2017 (Mountain, 2019, p3). This was a decision of the Council of Australian Governments with the Minister for Energy (at the time) Josh Frydenberg, explaining the decision in a second reading speech in Parliament (Hansard, 2017):

[14] Limited merits review allows a network to seek review of the AER’s decision from the Australian Competition Tribunal based on limited grounds for review. It is a term used in the legislation.

> *"The COAG Energy Council determined that the LMR regime was still failing to meet its policy intent with the consequence of higher prices for consumers. In the face of escalating energy prices the government is taking action to stop energy networks using the LMR to extract monopoly rents from consumers."*

The *gold-plating* narrative also gives rise to privatisation as a policy cure for price spikes. This is because privatised firms perform better on efficiency (Mountain and Littlechild, 2010, p5781) and privatisation leads to a clearer demarcation between regulators appointed by governments and the network (Mountain, 2014, p188). The Productivity Commission also recommended that state-owned networks should be privatised noting that conflicting objectives in these businesses had reduced their efficiency (Productivity Commission, 2013, pp 257-60). Further, international literature emphasises that privatisation creates 'hard budget' constraints and lessens the incentives to pursue actions that are politically opportunistic (Joskow, 2008, p9).

Acting in part on these recommendations, the NSW and Queensland Liberal Governments both went to state elections with a pledge to privatise their networks. The urban distribution networks in NSW were privatised in part in 2016 upon the successful election of the Liberal Government in NSW, but privatisation was not implemented in Queensland following election of the opposition state Labor Government who had contested privatisation during the elections.

The other substantive policy prescription of the *gold-plating* narrative is to "write down" the value of state-owned networks to bring about an immediate reduction in electricity prices. The ACCC recommended an asset value write down to 'correct' for past over-investment (ACCC, 2018, p162). The Grattan Institute also recommended writing down the asset value of networks that remained in state ownership (Grattan, 2018, p3)[15].

Simshauser provided a more nuanced view of the rationale for asset write downs, noting the decline in energy consumption may lead to stranded assets that in a competitive environment would be written down by the business (Simshauser, 2017, p385). The

[15] The Grattan Institute found that asset write downs should not be applied to networks which were subsequently privatised as "..reversing those sales transactions to force an asset write-down raises too many other problems" (2018, p3).

regulatory framework has to date not included any asset write downs related to past price shocks. This argument was expanded by Simshauser and Akimov (2019, p117) where they proposed a system where assets can be 'parked' (excluded from the RAB) until such point that they move from stranded to providing a service.

2.2 The *keep the lights on* narrative

The *keep the lights on* narrative claims that state-owned networks required a substantial increase in expenditure and returns to safeguard the reliability and safety of the network. (Ausgrid, 2008, p3). The narrative predominantly finds expression in the submissions of the state-owned networks at the time of the price shock, with only muted support in the literature.

The key argument is that capital expenditure had been low in the 1990s and early 2000s, but that a step up in capital infrastructure was required to meet increasing peak demand, secure the network, and replace aged assets (Ausgrid, 2008, p4). Further, that the rates of return on investment needed to be higher to reflect higher cost of equity and debt during the global financial crisis that occurred in 2008 (Integral Energy, 2009, p57).

Below we draw out the evidence and arguments put forward in submissions by the state-owned networks, and then discuss the support for these claims in the literature.

2.2.1 Submissions of the state-owned networks

The state-owned networks were the dominant 'voice' for the *keep the lights on* narrative. The key argument was that state regulators had artificially reduced prices in the 1990s to mid 2000s, by reducing the value of the asset base and insufficient allowances.

In their 2008 regulatory proposals to the AER, the three NSW distributors identified primary drivers of higher revenue in the 2009-14 period including: an increase in need for capital expenditure which significantly increased the value of the asset base, an associated increase in operating expenditure, and an increase in the rate of return (AER, 2008, p. xv).

Ausgrid[16] positioned these arguments within a narrative that blamed previous regulatory decisions (2008, p10)

> *"The result of the past distribution regulatory regime is that pricing has not kept pace with both capital and operating expenditure requirements ... a price adjustment is necessary just to rectify the legacy of previous regulatory decisions."*

Ausgrid noted that a driver of higher capital was a need to improve the reliability of the NSW networks, consistent with the NSW Government's reliability licence conditions. The conditions imposed onerous security of supply conditions following an outage, together with minimum reliability targets (NSW Government, 2007, p2). Ausgrid portrayed the licence conditions as a 'regulatory bargain' following the 'shortcomings' of regulatory decisions in the past which had left the network unable to cope with increasing peak demand from air conditioners, falling reliability, and an ageing asset base (Ausgrid, 2008, p4). In particular, Ausgrid noted that replacement allowances had not kept pace with the ageing of the asset base, resulting in about 10 per cent of assets older than their technical life (Ausgrid, 2008, p4).

The two other NSW distributors, Country Energy and Integral Energy[17], did not raise issues with previous regulation, but emphasised that growing increase in air conditioning was driving the need for additional capital expenditure (Integral Energy, 2008, p3).

In a later submission in 2012, Ausgrid provided further analysis on the drivers of the price change in 2009-14. A key new argument was that the value of its Regulatory Asset Base (RAB) had initially been set by its state regulator, Independent Pricing and Regulatory Tribunal (IPART), in 1998 at a value significantly less than the replacement value of the network. Relevantly, Ausgrid stated (Ausgrid, 2012, p24):

> *"The value of Ausgrid's RAB (Regulatory Asset Base) in 2004-09 was significantly depreciated compared to its modern day value of $30 billion.*

[16] Ausgrid changed its name from EnergyAustralia in 2012 following separation from its retail business. For continuity, we have referred to the submissions made by EnergyAustralia as "Ausgrid" and continued this protocol in our referencing.
[17] Country Energy is now called Essential Energy. Integral Energy is now called Endeavour Energy.

IPART forecast that the RAB at 2008-09 would be $5710 million, less than 20% of the modern day costs of building the network."

The import of Ausgrid's argument was that an initial undervalued asset base had led to a significant increase in the value of the RAB in percentage terms when new capital expenditure was required. This had led to a higher price increase than would have occurred had the asset base been set by regulators at its proper value in 1998.

Ausgrid's report also identified falling energy sales (system consumption) between 2009 and 2012 as driving higher average prices for customers (Ausgrid, 2012, p30). It noted that energy conservation measures and higher electricity prices had driven lower energy sales during this period.

The Queensland networks identified similar drivers of higher prices to NSW networks including new security conditions, increasing peak demand, and ageing assets. Unlike New South Wales, Queensland had undergone a major reliability event in 2004 when storms and hot weather resulted in 120,000 customers losing power in South East Queensland (Somerville, 2004, p191).

The outages sparked a major review of the network by an independent panel chaired by Sommerville in 2004. The panel found the network was highly utilised and managed with a high degree of risk that lent itself to supply outages (Somerville, 2004, p14-15). Its recommendation was for the networks to apply a more stringent reliability security standard (Somerville, 2004, p15).

2.2.2 Support in academic literature for the 'keep the lights on' narrative

There is muted support in the academic literature for this narrative put forward by the networks at the time. Simshauser and Laochumnanvanit (2012) provide an analytical framework that gives theoretical support to the idea that price suppression can cause a price shock (p61):

"... when an overregulated tariff is eventually restored to long-run efficient levels, it typically occurs quickly, and can result in bill shock."

However, this falls short of supporting the premise that state regulators suppressed the price of state-owned networks in the 1990s to mid 2000s.

The literature notes that peak demand increased significantly in the late 1990s and early 2000s (Simshauser, Nelson and Doan, 2011, p73; Simshauser and Catt, 2012, p64; and Simshauser and Laochumnanvanit 2012, p51). However, the researchers also note that there was spare capacity in the network to meet growing demand (Simshauser, 2019, p3), and that demand was over-stated by the NSW networks in the 2009-14 period (Rai and Nelson, 2019, p3).

There is also some data in the literature which would support the network's arguments to increase replacement levels for past 'lumpy investment'. For instance, Rai and Nelson (2019, p2) demonstrate that installed generation capacity increased by 250 per cent between 1965 and 1980, which arguably would translate to a proportionate increase in network infrastructure during this period. Simshauser and Catt (2012, p64) also note that 'aging system infrastructure' was a primary driver of the investment megacycle in the industry, but do not discuss the network sector.

There is little support in the literature to suggest that the initial value of Ausgrid's network was understated or written down by IPART (the NSW state regulator) in 1998. In fact, researchers at the time considered that the valuation methodology used by IPART provided for higher returns than warranted (Johnstone, 2003, p4). The reasoning proffered was that IPART did not adequately adjust the historical value for likely asset stranding. However, primary material at the time of IPART's decision suggests that the initial valuation of NSW networks was in part due to the Government's desire to ensure a 20 per cent real reduction in electricity prices (IPART, 1999, p51). We discuss this in more detail in our description of the model and key results.

2.2.3 Policy implications of the *keep the lights on* narrative

The policy implications of the *keep the lights on* narrative have not been fully drawn out in the literature as researchers have tended not to investigate past regulatory decisions as a reason for the price shock.

However, the narrative paints a cautionary tale against regulatory intervention to keep prices low. The import of the argument is that asset write downs and expenditure suppression result in a boomerang price rise when 'catch up' investment is eventually required to maintain the health of the network.

2.3 Our contribution to the literature

This thesis seeks to build on the existing literature on network price shocks in Australia. We have focused on Australia to narrow the research question, and to reflect the unique regulatory framework and circumstances in Australia. In particular, we note that international benchmarking demonstrates great variation in network prices even within regions such as Europe which are likely to exhibit similar regulation (Newbery, 2018, p9). In this case, a more precise research design is to undertake a narrow case study of networks in Australia, rather than over-extend the analysis to other countries. However, the research method could be extended to the experience of other countries in future research.

Our key contribution is to develop a model that quantitatively tests the sensitivity of price movements to each of the variables identified by the *gold-plating* and *keep the lights on* narratives.

In the sections below we identify the extent of the quantitative gap in the literature, explain why this relates to limitations in traditional modelling techniques, describe how we have addressed this limitation by relying on a mechanistic modelling approach, and then identify how we have adapted and fitted our model.

2.3.1 Gap in literature – quantitative testing of narratives

The *gold-plating* narrative relies primarily on benchmarking analysis to demonstrate that expenditure and returns were far higher in state-owned networks relative to private networks (Nepal, Menezes, and Jamasb, 2014, pp15-18; and Mountain and Littlechild p5780).

Researchers also successfully draw out the values of some of the key variables that are said to have caused the price shock. For instance, Mountain and Littlechild (2010, p5771-5772) focus on the material uplift in capital expenditure and the rate of return in the FY2009 to FY2014 period compared to the previous decade. The Grattan Institute (2018, p13) likewise show the uplift in capital expenditure and asset base trends for state owned networks. These researchers also identify that the change in reliability conditions was a driver of higher capital expenditure.

However, the *gold-plating* narrative does not demonstrate how each individual variable contributed to price movements over this time. Further there is limited granularity on the contribution of tighter reliability conditions contributed to higher capital expenditure in NSW and Queensland as compared to other drivers such as replacement capital expenditure.

The *keep the lights on* narrative similarly provides data on individual variables. For example, Ausgrid provide data on capital expenditure over time, information on peak demand over a decade, some data on undervaluation of the asset base, and data on declining energy sales (Ausgrid, 2008, p3-7; and Ausgrid, 2012, pp25-30). However, the narrative also does not show how each of these variables contributed quantitatively to the price shock.

2.3.2 Barriers to modelling price shocks

A key barrier for researchers in monopoly regulation is that traditional modelling approaches are not readily available to test price shock hypotheses.

In a competitive market, prices organically arise from the natural forces of supply and demand. For this reason, the literature concerning electricity prices in the competitive wholesale sector of the market have relied on supply and demand models (Clements, 2016, p3; and Houston Kemp, 2019, p5) to explain changes in prices over time.

An alternative approach is to develop an econometric regression model that can test the sensitivity of prices to variables using empirical data. Under this statistical approach, a change in prices would be dependent on a range of explanatory variables such as expenditure, peak demand, asset value, and rates of return.

There are advantages to applying a statistical approach such as well developed techniques for handling and testing data, with results explained by reference to accepted statistical outputs such as goodness of fit and correlation (Kendall et al, 1999, p1790). A key drawback however is that statistical analysis is agnostic to the underlying system of variables (Kendall et al, 1999, p1790). For example, the *keep the lights on* narrative emphasise a chain of related events to explain the price shock such as higher 'catch up' investment after replacement suppression, leading to a large increase in the value of the RAB caused by a one-off asset write down. This system of events is hard to fit within a statistical time series model, where an implicit assumption is independence of explanatory variables.

A further alternative is to use a 'machine learning' technique such as Monte Carlo simulations to assess price shocks based on multiple iterations of values of variables. This approach is possible given that the calculation of revenue and prices is known in advance, based on input variables such as expenditure and customer growth. The Monte Carlo approach would draw out instances where a price shock has occurred, and the analyst could examine the cluster of variables that occurred. The key weakness with the approach is that it does not focus on a combination of values that occurred in reality, so it is difficult to isolate and test the *gold-plating* and *keep the lights on* narratives in the context of actual data.

2.3.3 Mechanistic modelling approach

In our thesis, we have sought to overcome the modelling barriers by relying on a 'mechanistic' modelling approach which quantifies the impact of variables on price movements in a regulatory setting. The model allows us to input a cluster of dynamic input variables over a long time series, and identify the outcome on annual price changes.

Mechanistic models originated in ecology and climate change research where the model predicts the survival of species under changing climate conditions (Porter et al, 1994, p126). The models rely on theoretical thermo-dynamic equations to model animal outputs such as metabolic rate (Porter and Kearney, 2009, p19671).

A mechanistic model is well suited to quantitative testing of the hypotheses of drivers of network price increases. This is because there is strong knowledge of the underlying system of variables such as the interaction of expenditure, financial, revenue and pricing variables.

In the case of our research question, the input parameters are the customer demand, reliability targets and asset life, unit costs, financial parameters and regulatory intervention variables that impact annual expenditure levels. The known relationships are the formulaic calculation of revenue and prices used by regulators in Australia based on the values of expenditure. The model can test price sensitivity of scenarios (clusters of variables) that align with data pertaining to the *gold-plating* and *keep the lights on* narratives.

2.3.4 How we have adapted and fitted the mechanistic model

We have fitted the model using the current calculations of the Australian Energy Regulator to estimate annual prices based on a set of expenditure and financial parameters.

To simplify the exercise, we have focused on collecting quantitative data from only one distribution network in NSW. Ausgrid is the largest electricity distributor in Australia by customer size and energy delivered to customers (AER, 2020, p121). Ausgrid's average price as measured by cents per kWh increased by 136 per cent in real terms between FY2009 and FY2014, the largest price increase of any network in Australia. Ausgrid is also a good case study given available data on previous regulatory decisions in the 1990s and mid 2000s. We discuss the construction of the model in greater detail in the next section.

3. Description of price movement model

The purpose of this section is to summarise and justify the parameters of the price movement model developed for this thesis. Section 3.1 provides a simple explanation of the model schema and key assumptions; section 3.2 provides details on the expenditure calculations; section 3.3 summarises the revenue calculations; and section 3.4 describes the outputs of the model including prices and price movements. The model can be accessed as a spreadsheet by clicking "The Price Movement Model" at:

http://www.dynamicanalysis.com.au/research

3.1 Model schema and assumptions

The model calculates annual prices based on dynamic inputs, as discussed in section 3.1.1 below. Section 3.1.2 draws out the key assumptions in the model's construction and why they are appropriate for the research purpose.

3.1.1 Big picture of model

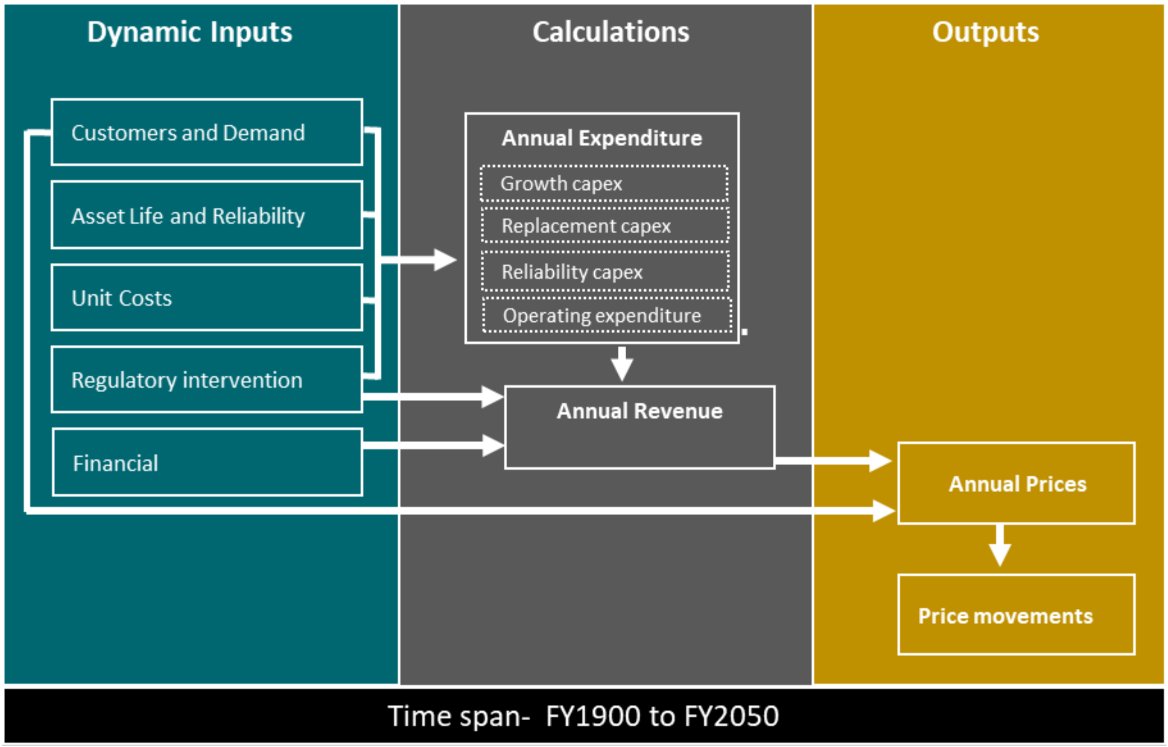
The model estimates prices from 1900 to 2050. The time period captures the growth of the Ausgrid network from its inception in FY1900 to the price shock period of FY2009-14 and beyond to FY2050.[18] We consider such a long-term approach is consistent with the historical approach in the literature, and appropriate for assets with long lives. It also provides for an intuitive 'organic' understanding of cost and revenue build up that gives context to the results.

Figure 11 provides a schema of the model in a simplified form. The dynamic inputs are variables that impact annual capital and operating expenditure including customer growth, peak demand and energy use; asset health and reliability targets; unit costs for capital and operating expenditure, regulatory intervention such as expenditure suppression and asset

[18] We have extended the model to 2050 so that we can show that the price shock was not due to an inevitable peak pricing period, but rather an aberration that would correct itself over time. A long lived model is also well suited to the long lives of network assets.

write downs, and financial parameters such as rate of return, inflation, and financial life of assets.

Figure 11 - Simple schema of price movement model

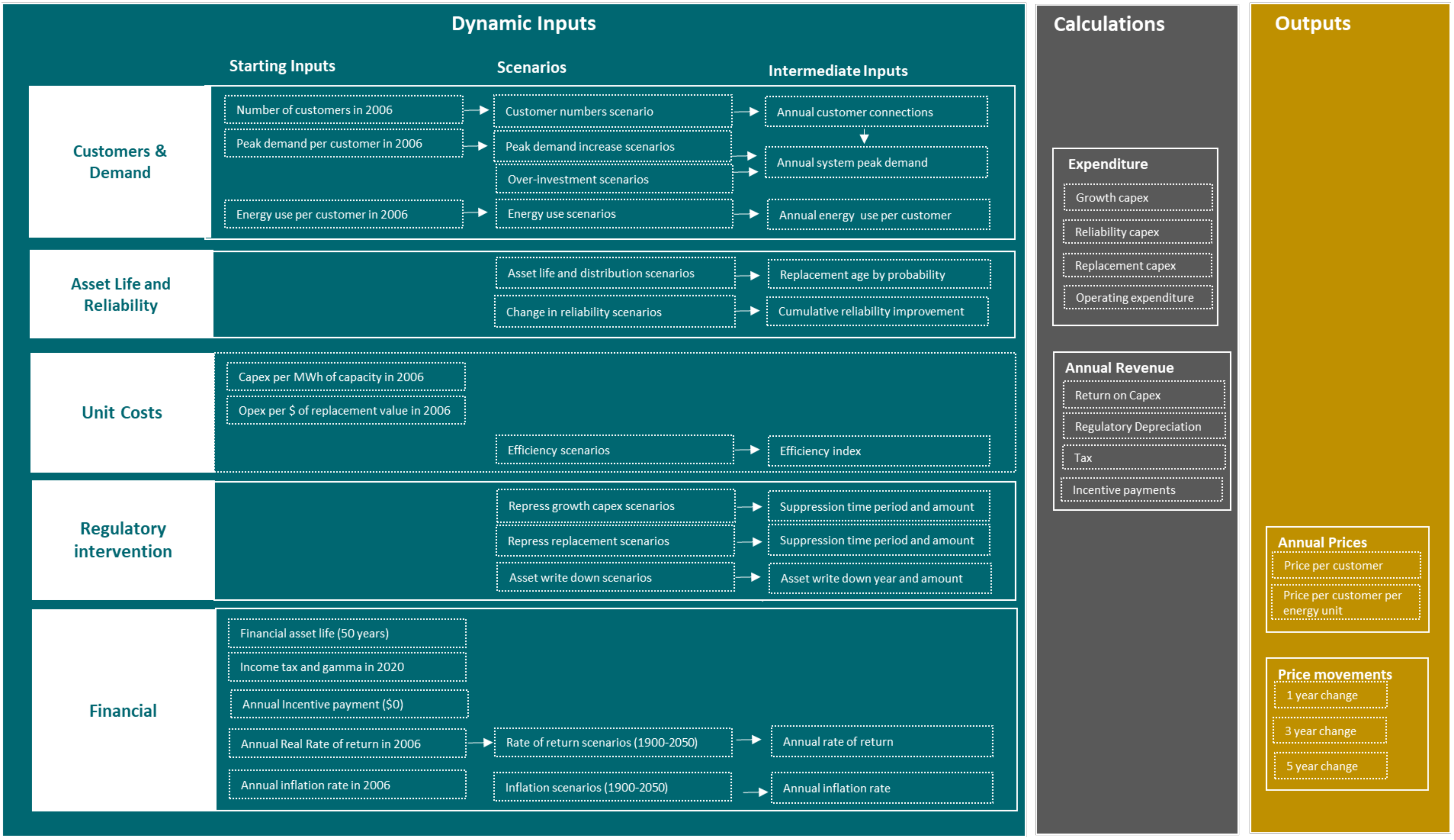


The annual revenue is based on AER's current calculation method which uses capital and operating expenditure as inputs, and financial parameters such as rate of return, inflation, financial asset life. Annual prices are in cents per kilowatt hour delivered by the network. The model then calculates price movements over 1, 3 and 5 years based on the change in cents per kilowatt hour measure.

The model expresses financial information in 2006 dollars (termed "real $2006") and in the dollar of the day (termed "nominal $"). However, the model results in this thesis are expressed in real $2006 dollars.

Figure 12 provides a more complex schema of the model, which we draw to explain the inputs into each of the expenditure and revenue calculations in sections 3.2 and 3.3; and outputs in section 3.4.

Figure 12 - Complex schema of price movement model



3.1.2 Key assumptions

In building the model, we have made four key assumptions. Firstly, the model uses a single asset class to derive price calculations. An asset class is a group of assets that have broadly similar characteristics, and an equal life expectancy such as poles, underground cables or zone substations (AER, 2018(a), p22). Networks have several asset classes for the purpose of calculating revenue, often with varying financial lives depending on their expected years in service (Advisian, 2015, p17).

Our view is that a single asset class provides greater insight on the drivers of higher prices relative to a model with many classes. We note that while the model can be expanded in future to include multiple asset classes, this would create complexity in the analysis and would be difficult to use in practice.

A second assumption is that all capital expenditure is on network asset such as “poles and wires” which are generally characterised by long asset lives. In reality, networks spend capital expenditure on shorter lived assets such as IT, fleet, property, together with assets that have infinite life such as land (AER, 2018, p25). Theoretically, the model can input shorter lives for these types of assets, and generate similar results underlying price shocks. We have chosen this assumption as system assets comprise more than 90 per cent of historic investment (IPART, 1999, p69).[19]

A third assumption of the model is that each customer shares identical characteristics in respect of energy and demand. Individual customers have very different consumption and demand characteristics which flow into the price they pay for electricity. The assumption however does not impact the analysis and findings. The final measure of price movements is cents per kilowatt hour, which is not based on customer numbers, but rather total energy consumption.

A final assumption is the use of Ausgrid data to fit the model, including published data on customers, energy and peak demand in 2010 and the average unit costs for capital and

[19] IPART estimated that non-system assets only comprise $237 million of a total valuation of $3.7 billion in 1998.

operating expenditure. Networks in practice differ in topology, density, operating conditions and scope of services (AER, 2014, p17). The model can be expanded in the future to fit any electricity network in Australia. A key advantage of using actual data from Ausgrid is that we are more closely able to quantify the impact of variables on the price shock experienced by a network. Ausgrid also had the largest increase in network prices over the FY2006 to FY2020 period.

3.2 Expenditure calculations

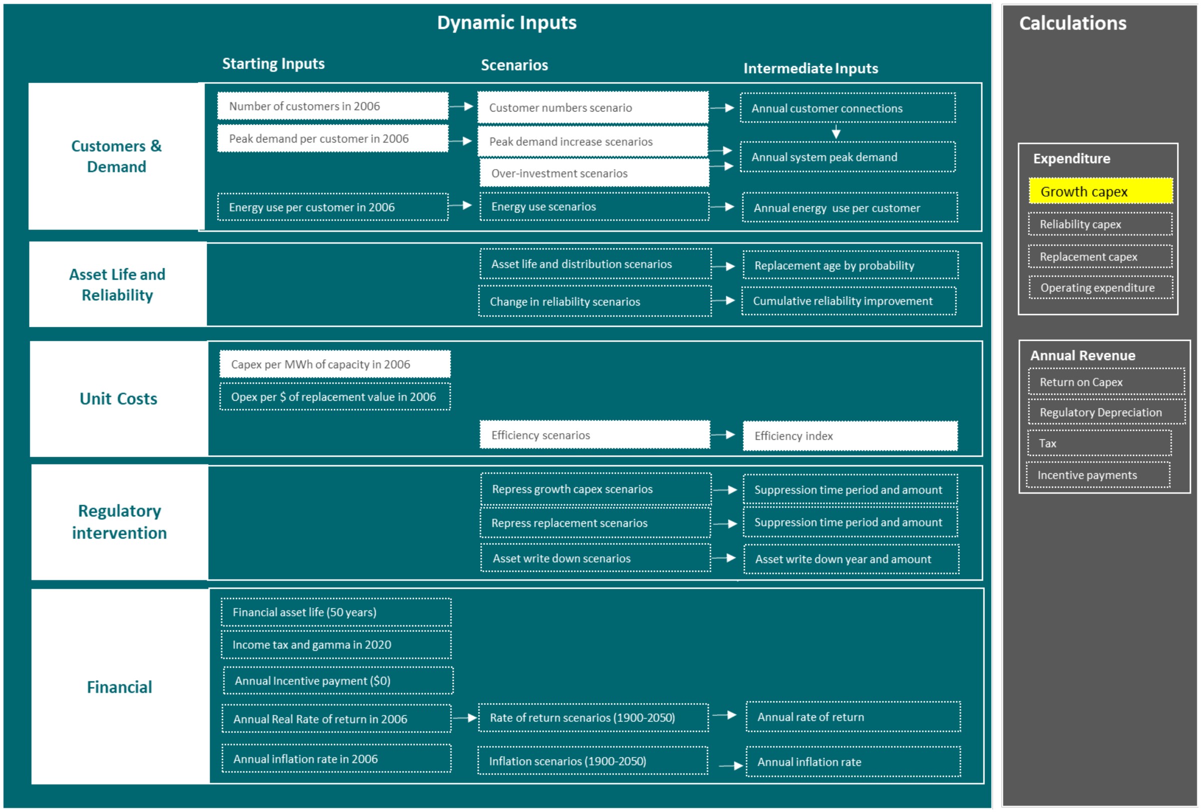
Capital expenditure (capex) and operating expenditure (opex) are key determinants of the AER's calculation of revenue, and the resultant price path. For the model we have assumed that there are three categories of capital expenditure – growth capex, reliability improvement capex, and replacement capex. We have assumed that opex is a single category. This broadly reflects the AER's assessment process where it tends to undertake a category assessment of capex, and a total review of operating expenditure (AER, 2013, pp17-25).

3.2.1 Growth capex

Growth capex relates to investment in new system assets to meet growing demand from customers. This includes the costs of directly connecting a new customer to the grid, which is termed 'connections capex' (AER, 2013, p20). It also includes 'augmentation capex' which is the additional capacity to meet the peak demand of new and existing customers (AER, 2013, p19).

Figure 13 identifies the key variables (small white rectangles) that impact the calculation of growth capex (yellow rectangle) which we explain in more detail below.

Figure 13- Variables that impact the calculation of growth capex in the price movement model



The model calculates annual growth capex as the annual change in capacity (MW) of the network multiplied by the unit cost of delivering an additional MW. The change in capacity volumes is determined by three variables – new customers, over investment in capacity, and growing peak demand per customer.

We have assumed that a network needs to expand capacity to connect a new customer. We used public data from 2006 to calculate the average capacity (3.4 kW) required to serve a single customer (Ausgrid, 2013, tab 5). We then develop two scenarios to trace how Ausgrid connected customers to the network between 1900 and 2050. Both scenarios rely on published data showing Ausgrid had 1.55 million customers in 2006 (Ausgrid, 2013, tab 2 5) The first scenario is a hypothetical scenario where customers connect evenly over time. The second scenario seeks to estimate Ausgrid's actual customer connections based on published data and historical accounts of capacity in NSW.

Capacity volumes are also impacted by changes in peak demand per customer over time. The 'no change' scenario assumes that peak demand per customers stays at 3.4 kWh from 1900 to 2050. We have then developed a scenario which assumes that peak demand increases per customer after FY1998 to FY2013 by 1.12 per cent per annum. This is based on the literature which shows that increasing air conditioning installations resulted in significant growth in peak demand per customer between FY1998 and FY2013. (Simshauser, Nelson and Doan, 2010, p73), and that demand forecasts were overstated by networks between FY2009 to FY2013 (Rai and Nelson, 2019, p5).

The model also assumes that capacity volumes are impacted by periods of over-investment and spare capacity. The model has two scenarios for over-investment, the first of which assumes that the network does not over-invest in capacity. The second scenario relies on data in the literature which suggests that there was significant over-investment in the network in the 1980 to 1990 period (Rai and Nelson, 2019, p3) followed by spare capacity until 2008. The implication of this scenario is that the growth in peak demand between FY1998 and FY2008 could be met through over-investment in the 1980s. It is only when networks over-state demand from FY2008 to FY2013, that additional growth capacity was invested in Ausgrid's network despite the demand not eventuating. This scenario is discussed in more detail in the key results.

We have derived a unit cost per capacity delivered (MWh) by dividing the estimated cost to build the network over time by the total system peak demand of Ausgrid's network in 2006. The system peak demand in 2006 was over 5222 MWh (Ausgrid, 2013, tab 5) We have used source material from Ausgrid's 2008 regulatory proposal (Ausgrid, 2008, p3) to estimate that it would have cost $23.5 billion to replace Ausgrid's system assets in 2006. Combining this data we have estimated that the cost of installing 1 MW of peak demand is $4.5 million (real $2006).

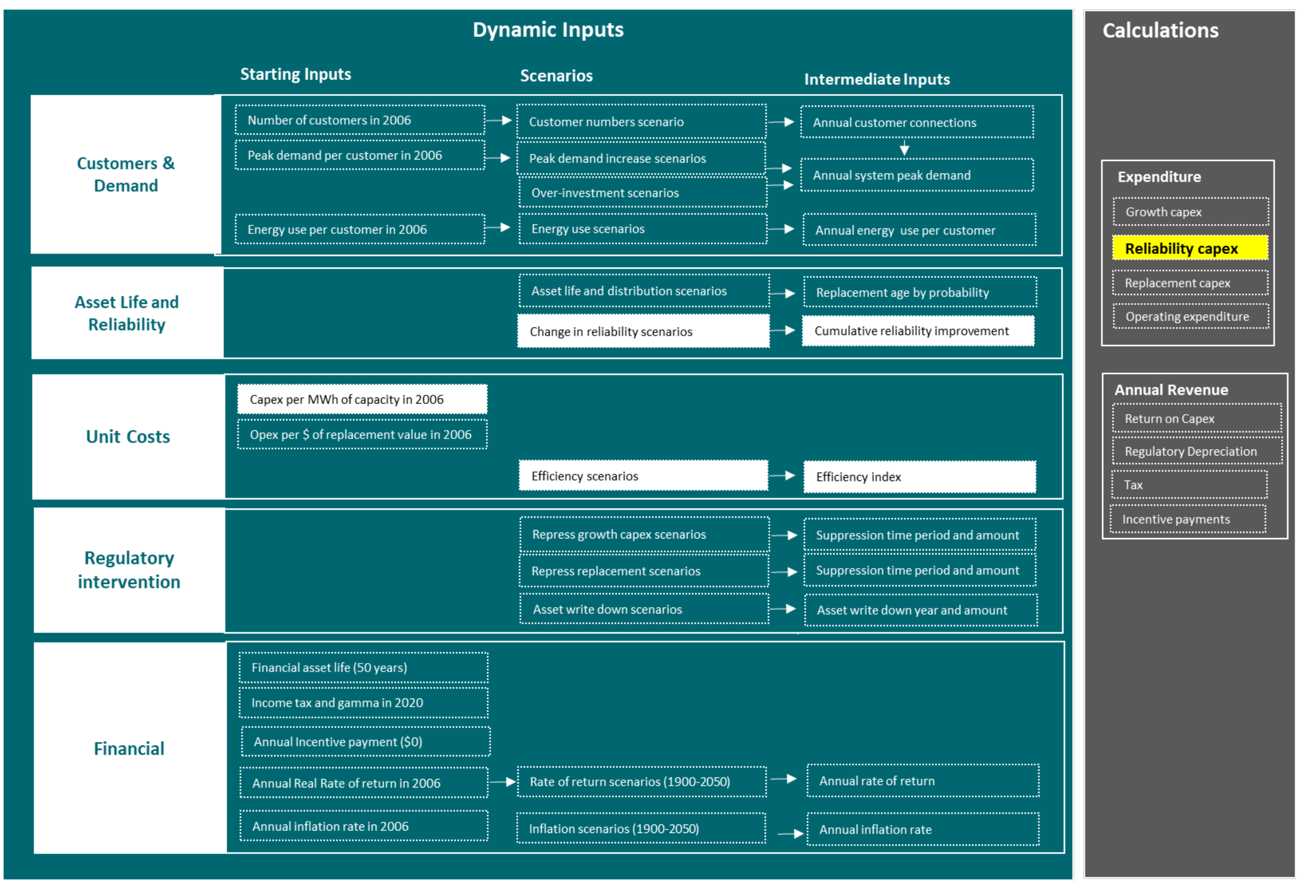
The unit cost per MWh capacity is impacted by efficiency improvements or declines over time based on efficiency scenarios in the model. This includes a 'no change' scenario where unit costs stay the same in real terms from FY1900 to FY2050. The alternative scenario is where unit costs increase by 2.5 per cent annually between FY2007 and FY2014 based on AER benchmarking data (AER, 2014(a), p31) which we discuss in more detail in section 4 of this thesis.

3.2.2 Reliability capex

Reliability capex is directed at reducing the frequency and duration of outages experienced by customers (AER, 2020, p30). Power outages occur when a system asset fails in service, or where this is insufficient capacity to meet the simultaneous demand of customers (Adoghe, 2013, p429). In general, reliability capex is a response to government directions, such as the NSW Government mandated reliability conditions (NSW Government, 2007, p2).

Figure 14 shows how the input variables relate to the calculation of reliability capex. Our model assumes that the network is designed to deliver a reliability target of less than 100 minutes of outages per customer, which is within the range of most networks in Australia (AER, 2020, p168).

Figure 14 - Variables that impact the calculation of reliability capex in the price movement model



From a mechanical perspective, the model assumes that a 1 per cent improvement in reliability is the equivalent of a 1 per cent expansion in the capacity of the network at that time. This is the number of customers multiplied by the peak demand per customer multiplied by the unit rate multiplied by the percentage improvement in reliability.

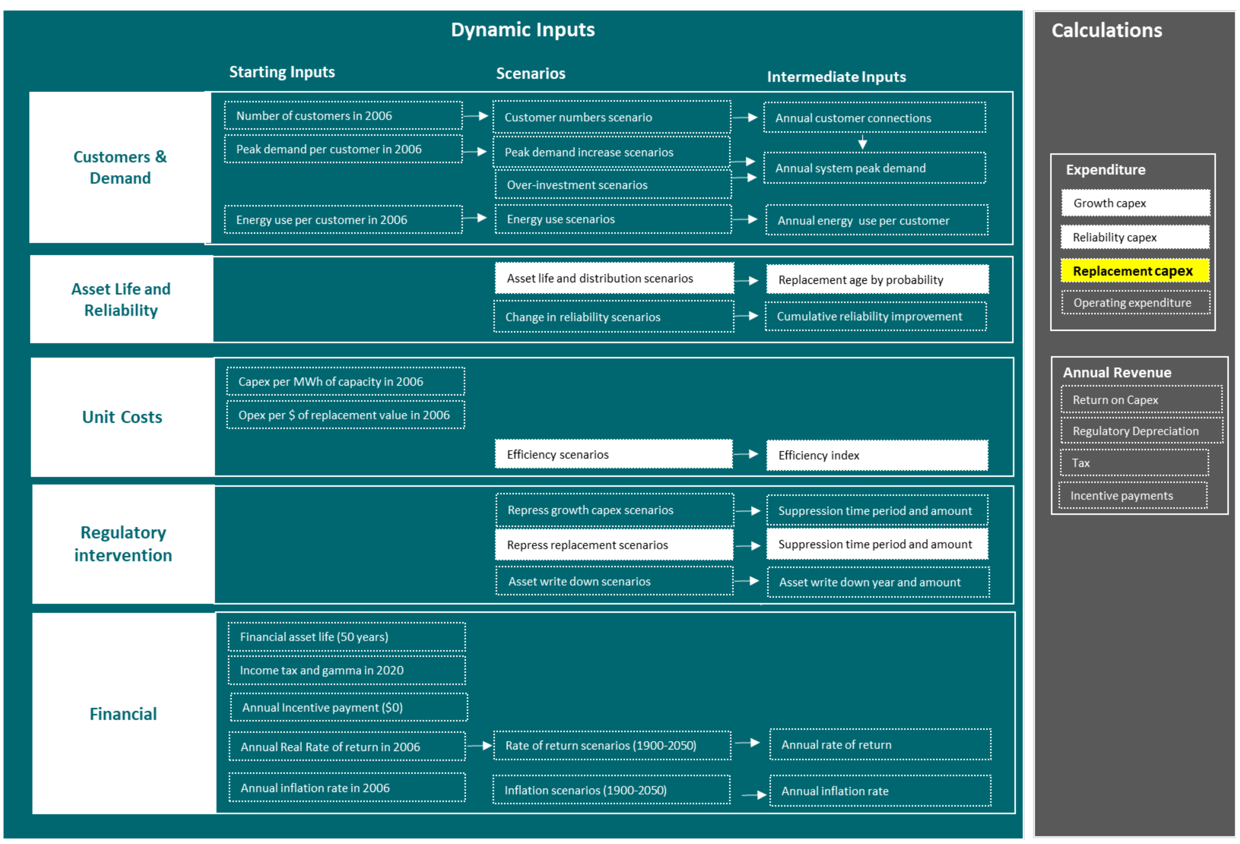
Our model includes a 'no change' scenario where networks do not invest in any additional reliability works. The second scenario relates to actual data which showed that Ausgrid spent $1.2 billion between FY2006 and FY2014 in response to new reliability licence conditions (Wilson Cook, 2008, p38 and Ausgrid, 2005, p4).

Unit costs are the same as growth capex with 1MW of capacity equal to about $4.5 million, adjusted for any efficiency improvements or decline.

3.2.3 Replacement capex

Electricity assets such as poles and wires generally have a lifespan of 40 to 60 years (Advisian, 2015, p17). Replacement capex is required to replace or significantly remediate an asset at its point of failure, or in advance due to a known deterioration issue (AER, 2013, p18). Figure 15 shows which variables impact the calculation of replacement capex.

Figure 15 - Variables that impact the calculation of replacement capex in the price movement model



In the model we have assumed that capital investment will need to be replaced at the end of their life. For the model we have assumed that life expectancy is equal to 50 years, and that there is an equal probability of replacement between 41 and 59 years. The cost of replacement is the same as the initial investment in real terms, adjusted for any efficiency improvements over time.

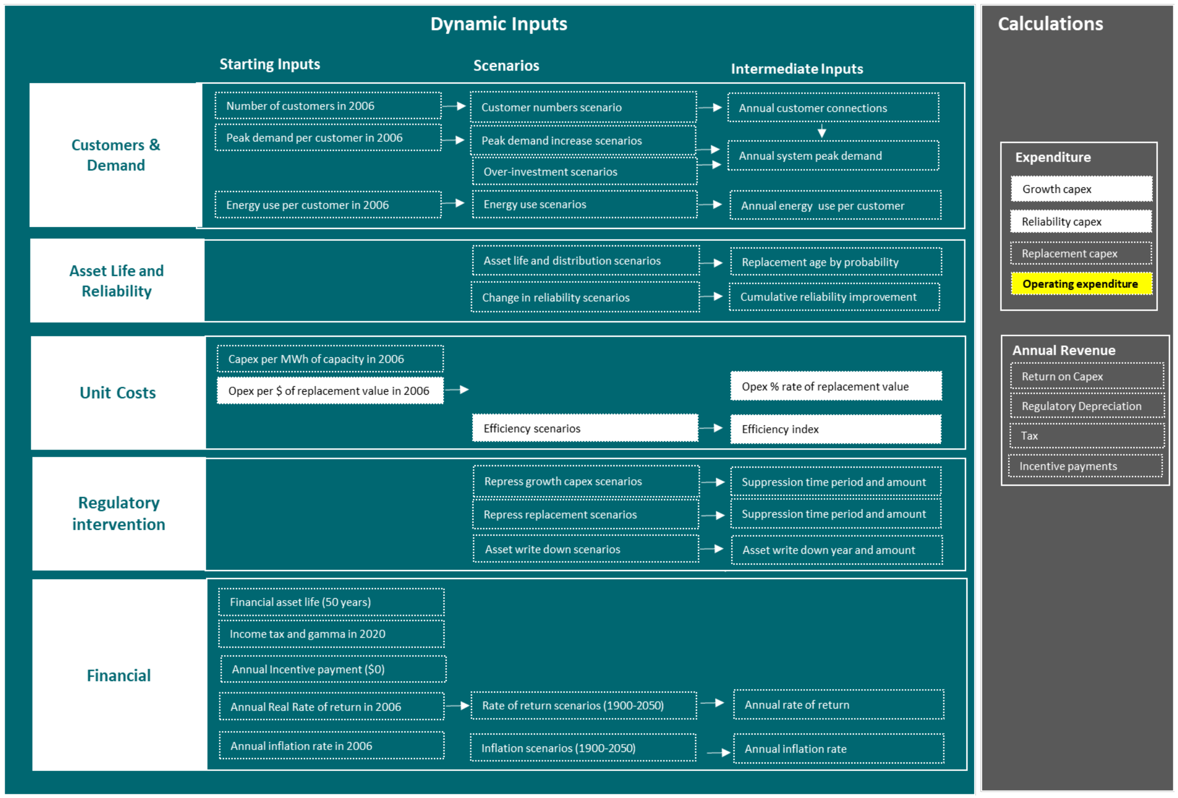
The model constructs an alternative replacement scenario based on the *keep the lights on* narrative where replacement is suppressed by 50 per cent between FY1998 and FY2008, before an eventual catch up in the FY2009 to FY2014 period.

The calculations for replacement capex each year is set out in a separate tab of the model due to their complexity, and is then integrated back into the model calculations.

3.2.4 Operating expenditure

The model assumes that operating expenditure (opex) is a function of the size of physical assets installed on the network. This captures the fact that asset maintenance increases with the number of assets due to greater volume of inspections, routine repair, and storm repairs (AER, 2013, p29) Opex is also required for customer service and corporate functions (AER, 2013, p30) which we have assumed would grow with the physical size of the network, given more customer service would be required. Figure 16 shows the key variables that impact opex.

Figure 16 - Variables that impact the calculation of operating expenditure in the price movement model



In the model, we have calculated opex as a fixed percentage of the replacement value of the asset base in any given year, which relates to the sum of new assets (i.e. growth and reliability capex) that have been installed over time. We have relied on Ausgrid data from 2006 which shows standard control opex was about $380 million in 2006 (Ausgrid, 2013, tab 3) of a replacement value of $23.5 billion, which results in a value of 1.65 per cent. The fixed percentage means that operating expenditure grows in line with the capacity of the network.

The model also allows for efficiency scenarios where the unit cost declines or improves with enduring changes in efficiency of the network.

3.3 Revenue calculations

Under the 'building block method' codified in the National Electricity Rules (NER), the AER must calculate the annual maximum revenue based on expenditure and financial parameters (AEMC, 2020, p783). The AER has developed a "Post Tax Revenue Model" (PTRM) which sets out the calculations of revenue consistent with the NER (AER, 2018(a), p6). Our model replicates the AER's calculations in the PTRM, based on expenditure calculations and financial parameter inputs. In some cases, however, we have adopted simplifications such as for tax and incentive payments.

In principle, the AER is seeking to provide the networks with a market return on the equity and debt required to fund capital expenditure, together with a pass through of operating, tax and incentive payments. We discuss each in turn.

3.3.1 Returns and depreciation for capital expenditure

Capital returns compensate a network for the costs of financing investments over the expected life of an asset (ACCC, 2006, p22). It assumes that a network seeks funding from debt and equity holders, and must make payments to the holders to maintain the financial capital (Economic Insights, 2009, p21)

The AER aggregates annual capital expenditure into an asset class (AER, 2018(a), p14). The asset class concept is a way of 'bucketing' all investments of a similar life expectancy (Advisian, 2015, p16). For our model we have assumed there is only one asset class comprised of network assets.

The regulator provides an annual revenue stream for depreciation and 'return on' assets. Depreciation is a similar concept to paying back the principle of a loan. The regulatory framework seeks to provide a steady revenue stream (in real terms) over the financial life of the asset which equals the cost of the initial investment. The total depreciation allowance is the sum of depreciation accruing to each year of the investment. In our model, this is the sum of growth capex, reliability, and replacement capex in each year (net capex) for all previous years divided by the asset life, until the value is completely depreciated. The depreciation calculations are set out in a separate tab of the model, with the values incorporated back into the body of the model.[20]

The 'return on' allowance is akin to repaying interest on a loan. The regulator is seeking to compensate a network for the returns they must pay out to debt and equity holders for the

[20] We have used a method termed 'year on year' depreciation, which is currently used by the Queensland and South Australian networks. Other approaches such as weighted average life would produce slightly different outcomes, and would be useful in future versions of the model.

costs of raising finance for capital expenditure. In mechanical terms, the annual 'return on' allowance is the value of the regulated asset base (RAB) multiplied by the nominal rate of return applying to that year.

The RAB is the undepreciated value of past capital expenditure (Simshauser and Akimov, 2019, p124). In the model, we assume that the RAB is zero at the commencement of the model in FY1900. The asset base reflects the sum of growth, reliability and replacement capex (net capex) in prior years but is reduced by the sum of depreciation paid out in previous years.

The rate of return calculation used by Australian regulators is based on the capital asset pricing model theory (Truong et al, 2008, p95). The regulator uses observed data of comparable competitive businesses in the industry to calculate a return on debt and a return on equity (AER, 2018(c), p3). The annual cost of capital reflects underlying conditions in financial and equity markets, and structural changes that the AER makes from time to time that impact values and calculations (AER, 2018(c), p4). In our model we have developed a scenario where the rate of return applying to all years is equal to Ausgrid's rate in 2006. The alternative scenario is where the rate of return increases between FY2009 and FY2014 to reflect Ausgrid's actual experience during the price shock period.

The model also calculates the impact of asset write downs on both the depreciation and return on allowances. We have developed a scenario that applies an asset write down in 1998, based on evidence of under-valuation by the regulator at that time. Mechanically this reduces the amount of depreciation for all investment prior to 1998, and the value of the asset base in 1998 by the level of asset write down.

3.3.2 Operating expenditure, tax and incentive payments

The AER provides a 'pass through' of revenue for operating expenditure incurred in a year, reflecting that the network does not need additional compensation for ongoing financial capital maintenance (ACCC, 2006, p22). For this reason, our model's calculation of revenue includes a line item that equals the operating expenditure incurred in that year.

The AER recognises that the network incurs a tax liability for profit margins that arise from capital returns provided to equity holders (ACCC, 2006, p22). The AER's calculates a tax allowance to provide compensation for tax liabilities which is based on the corporate income tax rate applying to taxable revenue, adjusted for the value of franked dividends available to equity holders (AER, 2018(b), p4). In general, taxation accounts for about 5 per cent of total revenue of distribution networks' total annual revenue (ACCC, 2020, p123).

In our model, we have made some simplifications to calculate the tax allowance. We have assumed that taxable revenue includes a deduction for regulatory depreciation, when in reality this is based on tax depreciation which are often based on different financial asset lives to the regulatory framework (AER, 2018(b), p1). We have used the corporate income tax rate as applied by the AER, and included a value for the implied benefit of franking credits[21] (gamma) of 0.4 consistent with the AER's most recent decisions (AER, 2019(b), p7-5).

The AER's regulatory framework is incentive-based, meaning that networks can earn or lose additional revenue based on efficiency, service performance, or innovations such as demand management (AER, 2013, p7). In this model, we have assumed that the value of incentive payments is zero, although this can be modified in the future.

3.4 Outputs – Prices and price movements

The AER does not prescribe individual prices that a customer pays. Rather it calculates an "X-factor" which denotes the annual percentage movement in allowed revenue from one year to the next, and has a light-handed role in approving tariffs set by the network each year (AER, 2018(a), p7).

Section 3.4.1 sets out the model's calculations of annual prices, and section 3.4.2 sets out the price movement calculations for three scenarios of 1, 3 and 5 years.

3.4.1 Annual prices

Our model calculates two measures of annual prices. The first is the average price paid for by a customer, which is total revenue divided by total customers. This is relatively simple

[21] The regulatory framework recognises there are taxation benefits to equity holders that can utilise franked dividends.

in the model as the customer is assumed to be homogenous, with the same average consumption and peak demand in any given year.

However, the price per customer metric does not consider change in the units delivered to the customer. For instance, a customer may pay the same price as the previous year but may have consumed less, effectively getting less value for money.

For this reason, the key output metric we have used for the model is cents per kilowatt hour (cents/KWh) each year, which is annual total revenue (in cents) divided by total annual energy consumption (in kWh). Cents per kilowatt hour provides the best indication of average price movements, and is widely used for comparisons of network prices (Simshauser, 2019, p23).

3.4.2 Price movements

We calculate annual price movements as the percentage change in the price per energy unit delivered (cents/KWh) from one year to the next. Similarly, we measure 3 year, and 5 year movements using a similar approach.

The model calculates the maximum annual, 3 year and 5 year price movement over the total lifespan of the model, and during the FY2009 to FY2014 period where the price shock occurred at Ausgrid.

4. Key findings from model

For this thesis, we have developed four case studies for the price movement model that provide insight on the variables that caused the FY2009 toFY2014 Ausgrid price shock. The first case study is based on stable inputs that we hypothesise would produce minimal price movements over time. The other three case studies relate to the *gold-plating*, *keep the lights on*, and a combination of the narratives.

4.1 Steady variables over time - Case Study 1

Case study 1 tests if price movements are minimised under stable conditions over time. Regulatory frameworks have a "common emphasis on price stability" (Biggar, 2009, p2) and therefore we would expect minimal volatility under stable conditions. This is also a threshold question before examining the *gold-plating* and *keep the lights on* narratives, as we first need to demonstrate that the regulatory framework does not produce unexplainable price movements in a steady state.

Case Study 1 assumes that the same number of customers connect evenly to Ausgrid's network from 1900 to 2050, that peak demand and energy per customer stays constant over time, that reliability standards are unchanged, that unit costs stay consistent in real terms, that the rate of return and inflation are at the same levels for 150 years, and there is no other regulatory intervention.

Figure 17 shows that the maximum annual price increase in Case Study 1 is less than 1 per cent, with a 5 year maximum increase of less than 1.5 per cent. The results show that prices do not fluctuate under stable conditions.

Figure 17- Maximum price rise between FY1900 to 2050 (real, $2006)

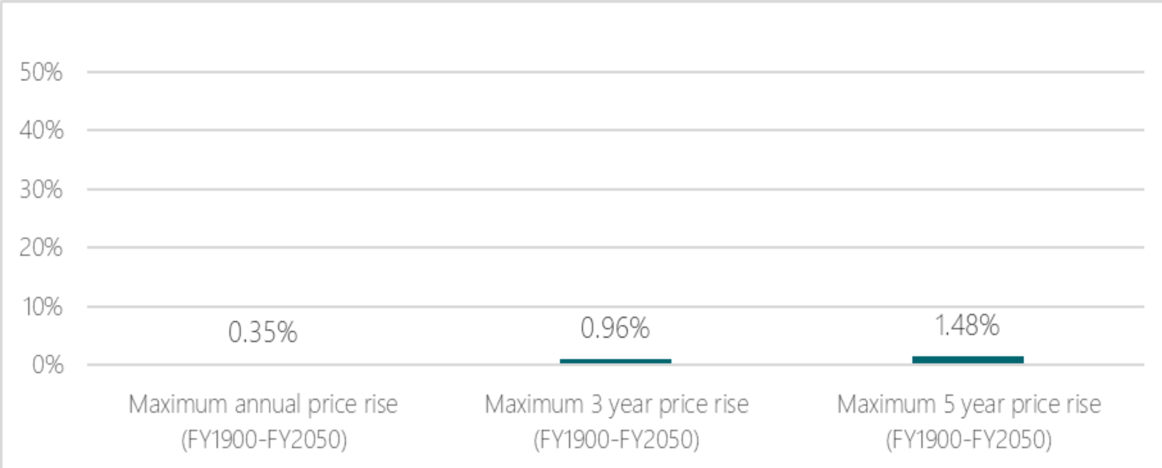
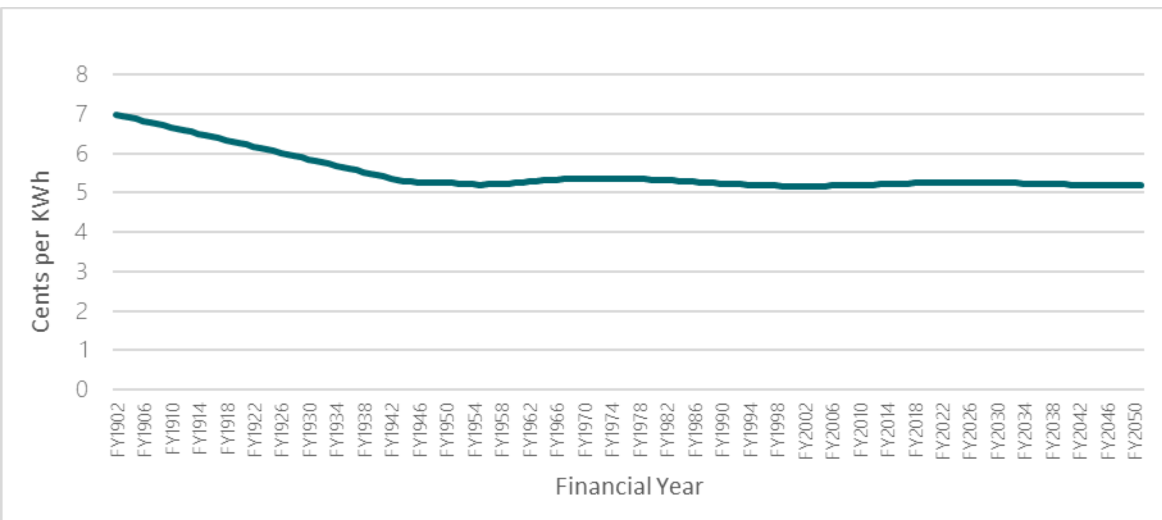


Figure 18 shows the price path in terms of cents per kilowatt hour between 1900 and 2050 under this case study. The price path is smooth, with an initial decline in prices until replacement first occurs in 1940. From here prices remain relatively flat for the next 110 years.

Figure 18- Price path under Case Study 1 (cents per kWh, real, 2006)



We consider Scenario 1 demonstrates the inherent stability of the regulatory framework, showing that annual price movements are marginal when underlying variables such as customer growth, costs, and rates of return are constant over time.

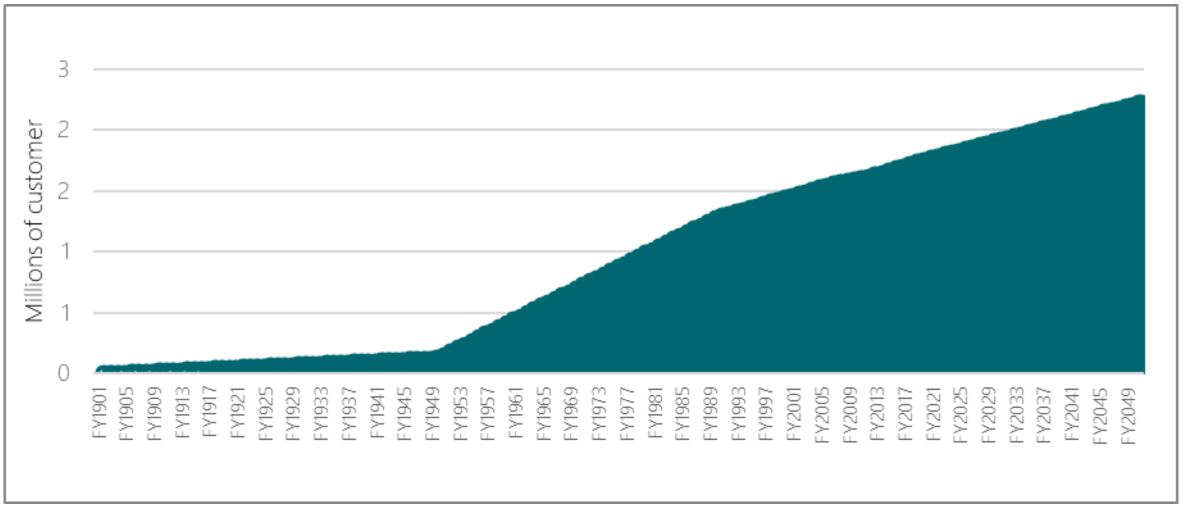
4.1.1 Variant of Case Study 1 – Lumpiness in growth of the network

The base case for Case study 1 assumes that connections and peak demand per customer are steady each year, leading to an even growth in growth capex. As a variant to this case study, we relax this assumption by generating a connection scenario that mimics the development of Ausgrid's network over time.

The literature demonstrates that growth capex was uneven on Ausgrid's network from FY1900 to FY2020, resulting in 'lumpy' network investment. Ausgrid's network expanded relatively slowly between 1900 to 1950 (Wilkenfeld and Spearrritt, 2004, p3). Between 1950 to 1995, generation capacity in NSW increased by ten-fold (Rai and Nelson 2019, p3). Ausgrid note a coinciding increase in the size of its network in this period caused by the rapid expansion of Sydney's suburbs in the 1960s and 1970s (Ausgrid, 2008, p3). From 1995 to 2005, expansion slowed in Ausgrid's network due to excessive capacity installed in the 1980s (Simshauser, 2019, p4).

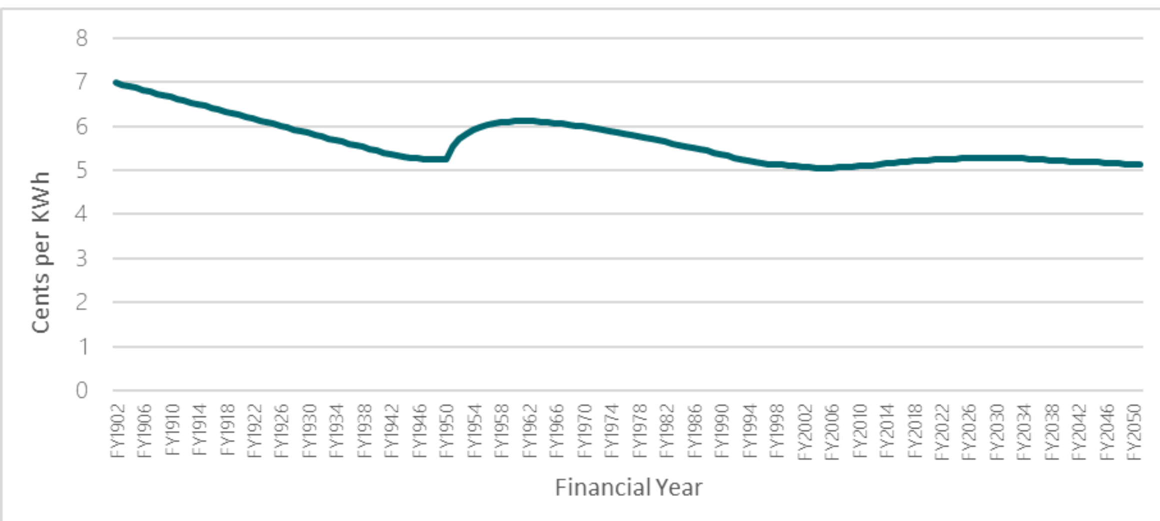
Our method to estimate data on Ausgrid's network expansion relied on public data and the literature. We used actual published data from FY2006 to FY2019 (AER, 2006-19, tab 5). We used the average growth rate over this period to extrapolate customer numbers to FY2050. We then utilised published data on Ausgrid's connections in 1996 to extrapolate an even annual connection of customers to FY2006. Using Rai and Nelson's analysis, we have estimated that customer connections would have been a tenth of FY1996 values in FY1950, and used this as a basis for deriving an annual growth rate from FY1950 to FY1995. We have then estimated that customers connected evenly between 1900 to 1950. Figure 19 depicts Ausgrid's actual connections from 1900 to 2050 based on the above method.

Figure 19 - Estimate of Ausgrid's actual customer connections over time in variant of case study 1



The model results suggest that 'lumpy growth' of the network can lead to minor price rises over time, particularly in periods of strong customer growth. However, for the purposes of our research question, lumpy capital expenditure does not seem to explain price shocks that occurred in the FY2009 to FY2014 period in isolation as seen in Figure 20.

Figure 20 - Cents per kwh by year for variant of case study 1 (real $, 2006)



In Case Studies 2 to 4, we have incorporated Ausgrid's actual connections, given its flow-on impact to growth in capital expenditure and replacement capital expenditure over time.

4.2 The *gold-plating* narrative (Case study 2)

The purpose of Case Study 2 is to test the sensitivity of variables identified by the *gold-plating* narrative as the root cause of the FY2009 to FY2014 price shock, using actual public data from Ausgrid. We have modelled the four key variables identified in the literature: increase in reliability capex from new licence conditions, increase in growth capex from overstated demand forecasts, higher unit costs for capex and opex due to a decline in efficiency, and an increase in the rate of return.

Figure 21 shows that the *gold-plating* variables considerably increased the prices paid by Ausgrid's customers between FY2009-14. The results indicate that the combination of the factors led to a 47 per cent increase in prices over 5 years.

Figure 21- Increase in prices between FY2009-14 (real, $2006) – *gold-plating* Narrative

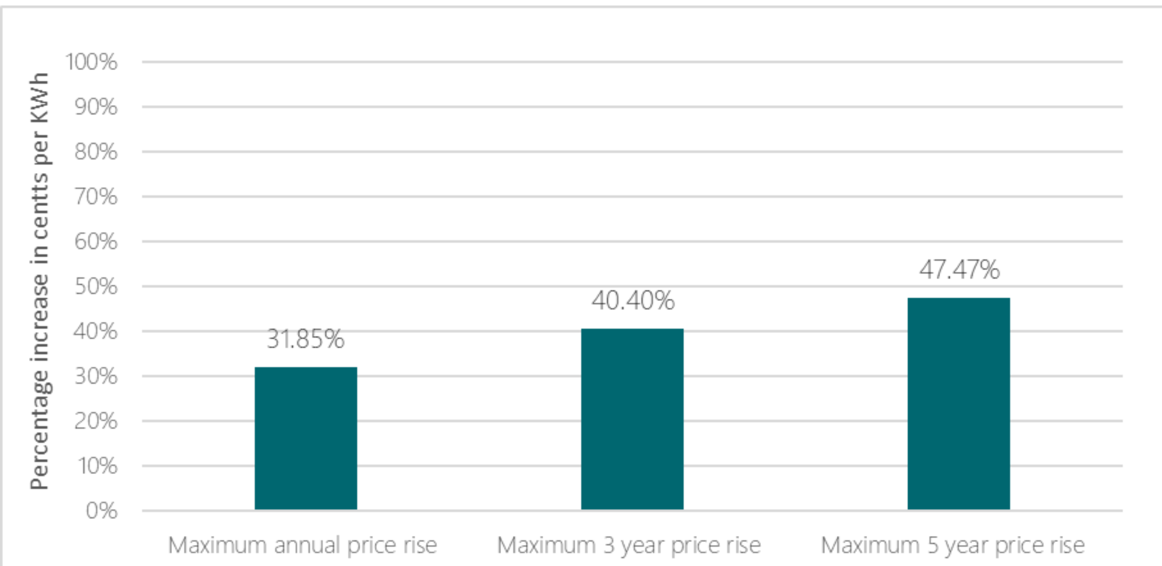


Figure 22 shows the price path between FY1900 to FY2050 for Case Study 2. The average price per customer increases sharply between FY2009 and FY2014.

Figure 22- Cents per kWh (real $, 2006) – Goldplating Narrative

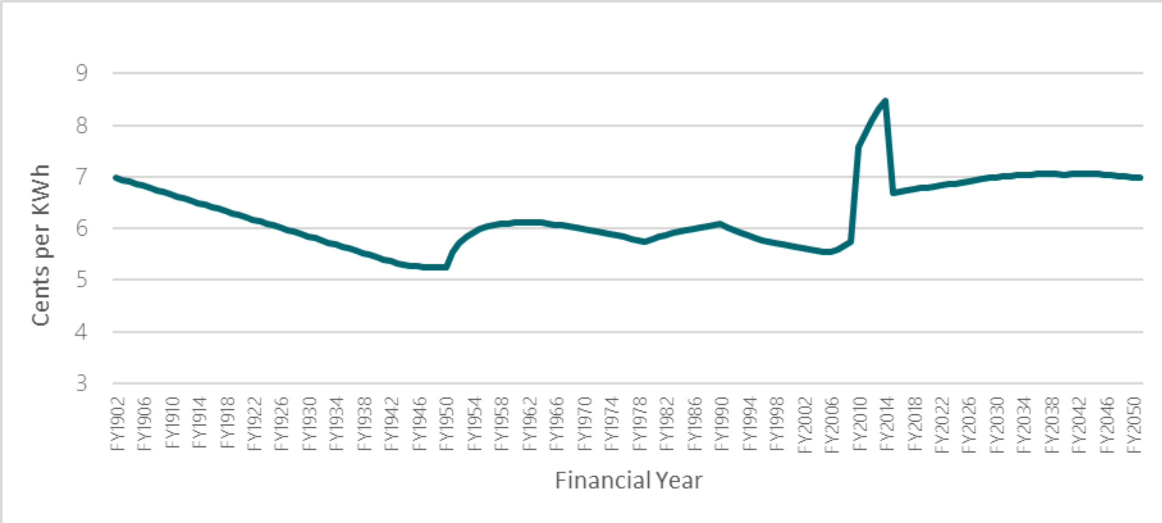
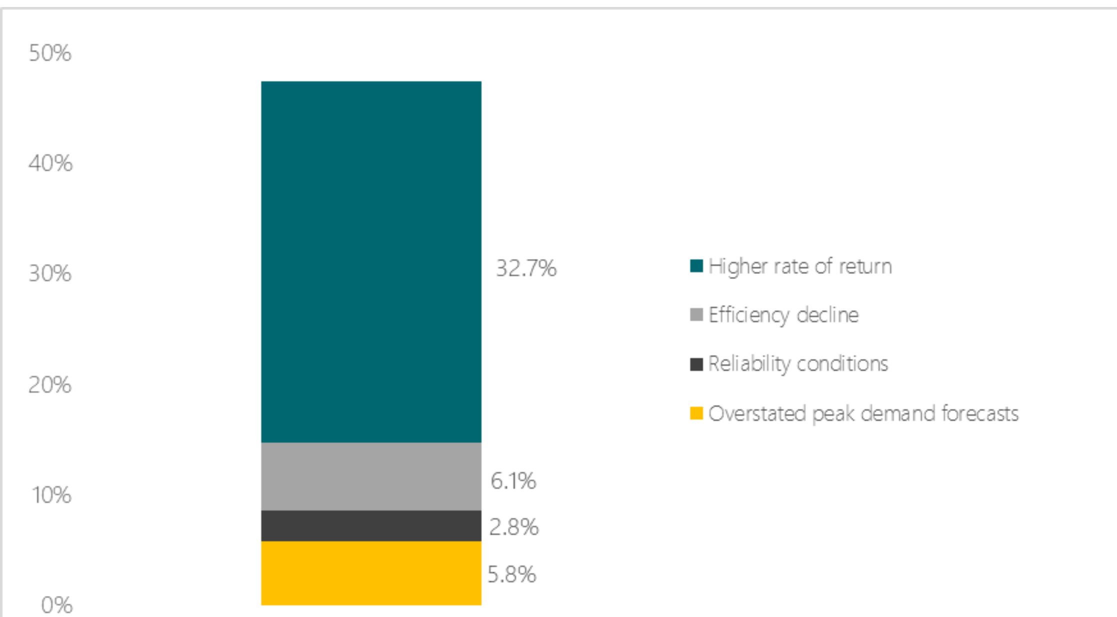


Figure 23 demonstrates that that the rate of return is the largest contributor to higher prices under the *gold-plating* case study , accounting for 32 percentage points of the 47 per cent increase in prices over 5 years.

Figure 23– Contribution of each gold-plating narrative to Ausgrid price increase between FY2009-14 (percentage points)



In the following sections, we provide more detail on each variable including our method to establish the values of each parameter.

4.2.1 Growth capex – Impact of overstated demand forecasts

Ausgrid's growth capex was relatively low in the 1998 to 2008 period at an annual average of $150 million between FY1998 and FY2008 (IPART, 2004, p35).

During the FY1998 to FY2008 period, peak demand grew by about 1.12 per cent per annum, in response to a surge in air conditioner installations (IPART, 2004, p243). The *gold-plating* narrative argues that low growth capex during this period was justified based on spare capacity on the network. Utilities significantly over-invested in the capacity of the NSW network between 1980 to 1990 (Rai and Nelson, 2019). Simshauser (2019, p3) suggests that this period of over-investment provided almost 20 years of spare capacity on the network.

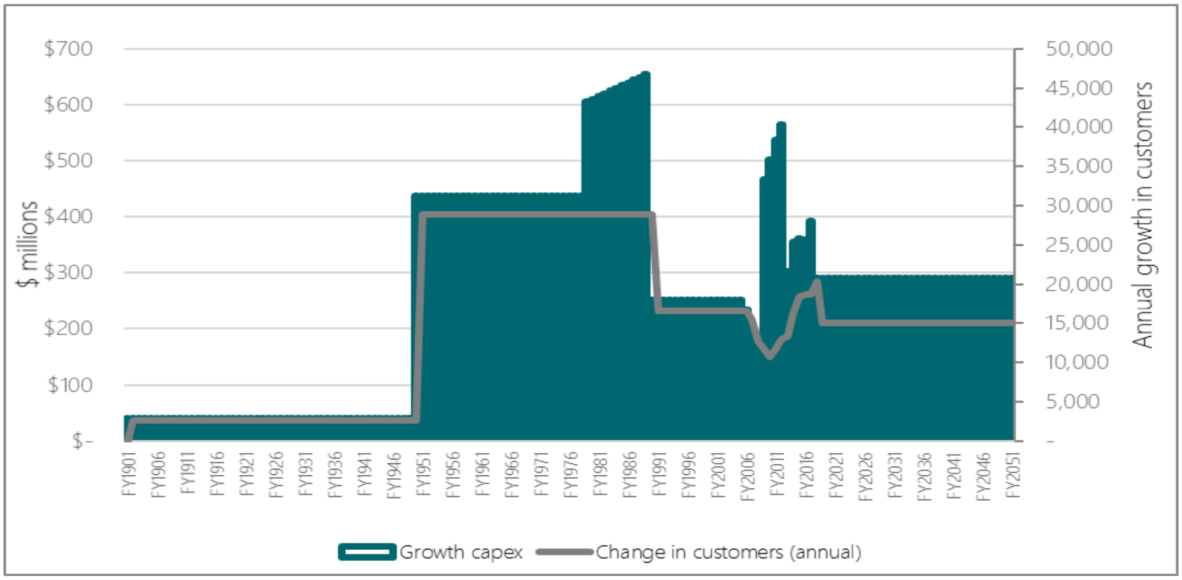
The model captures this version of events through a scenario where Ausgrid over-invests in the network between 1980 and 1990. We then estimate that the growth in peak demand per customer could be met by spare capacity between 1999 and 2008. This means that the network only incurs growth related capex to meet the capacity of new connections between FY1998 and FY2008.

From FY2009 to FY2014, Ausgrid's growth capex increased four-fold to $600 million per annum (Wilson Cook, 2008, p38). In its regulatory proposal, Ausgrid forecast that peak demand would continue at the same level as the FY1998 to FY2008 period (Ausgrid, 2008, p43). Further, they sought to show that new capacity investment would be required given that all spare capacity had been exhausted between FY1998 to FY2008 (Ausgrid, 2012, p34).

The *gold-plating* narrative argues that the demand forecasts were overstated. Our analysis of public data supports the view that Ausgrid overstated its peak demand forecasts resulting in over-investment in growth capex in FY2009 to FY2014. Ausgrid forecast for peak demand growth per customer during the 2009 to 2014 period to grow at the same annual levels as 1999 to 2008 (Ausgrid, 2008, p43) of about 1.1 per cent. Actual data however revealed that peak demand was close to flat at 0.13 per cent (Ausgrid, 2013, tab 3.1). The model includes the overstatement of demand as a scenario.

The impact of running the combined scenarios is seen in Figure 24, which shows growth capex (green columns) compared to new customers connecting to Ausgrid's network (grey line). Under the scenarios, growth capex keeps pace with customer connections until the 1980s, before rising above these levels when the network overinvests in capacity. From the 1990s to 2008, growth capex keeps pace with customer connections with the spare capacity of the 1980 sufficient to meet the growth in peak demand from FY1998 to FY208. From 2009 onwards growth capex increases at a higher rate than customer connections as the network overestimate peak demand.

Figure 24- Comparison of growth capex to customer connections ($m, real 2006, customer numbers)



The impact of the surge in growth capex has the effect of increasing Ausgrid's prices by 5.8 per cent during the FY2009-14 period.

4.2.2 Reliability capex – impact of new licence conditions

In 2005, the NSW Government changed the reliability licence conditions for NSW networks and subsequently updated the conditions again in 2007 (Ausgrid, 2008, p39). The licence conditions required NSW networks to deliver stringent new security criteria and meet reliability targets on individual feeders (NSW Government, 2007, p3). The *gold-plating* narrative has focused on the change in reliability standards as a key driver of excessive capital expenditure by NSW networks during the price shock period (Grattan Institute, 2012, p3).

Before the change to licence conditions, Ausgrid had spent $6 million capex annually on improving reliability for customers from FY1999 to FY 2005 (IPART, 2004, p35). In FY2006, Ausgrid received a pass through to spend $608 million of capex over 4 years to meet the new licence standards (Ausgrid, 2005, p4). Between FY2009 to FY2014, Ausgrid proposed a further $538 million to meet the updated licence conditions (Wilson Cook, 2008, p38).[22] Based on these estimates, we have calculated that Ausgrid spent $1.2 billion of reliability capex to meet the new licence conditions evenly between the years FY2006 and FY2014.

From a mechanical viewpoint, the model has generated this result by estimating the level of reliability improvement that would be associated with $1.2 billion of capex between 2006 and 2014. We assume that 1 per cent reliability improvement results in a 1 per cent increase in capacity of the network. Between the period 2006 to 2014, this is the equivalent of a 5 per cent improvement in reliability for all customers.

Reliability capex in the 2009-14 period only contributes an additional 2.8 per cent to Ausgrid's prices during the price shock period. The lower sensitivity reflects that reliability capex was significantly lower than growth and replacement capex during the 2009 to 2014 period.[23]

4.2.3 Unit cost increases – impact of declining efficiency

The *gold-plating* narrative successfully uses benchmarking analysis to demonstrate a decline in the efficiency of state-owned networks during the price shock period. For instance, Mountain and Littlechild (2010, p5780) show that capital and operating costs per customer increased substantially in NSW while falling in privatised networks in Victoria.

In this thesis we have used AER published benchmarking analysis to identify the extent of the efficiency decline experienced by Ausgrid . We have used AER benchmarking analysis on multi-factor productivity between 2006 and 2014 to estimate the level of efficiency decline in Ausgrid. The data suggests that Ausgrid's efficiency fell by about 20 per cent

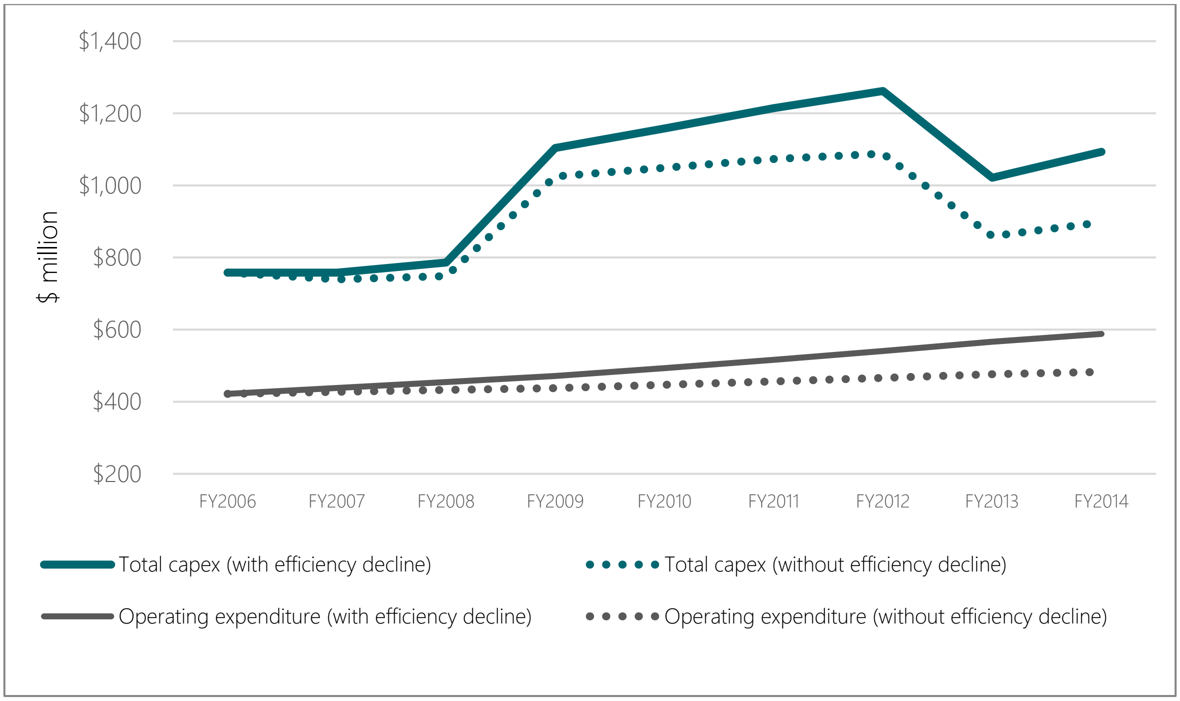
[22] This may understate the capex that was spend on licence conditions, as some of the growth-related capital expenditure may also relate to new reliability standards (Energy Australia, 2008, p43).

[23] We note that re-ordering the sequence of growth and reliability capex does not impact the results in aggregate (ie: the combined impact of growth and reliability capex is to add 8.61% increase to prices between 2009-14). However, an interesting finding is that the relative impact changes when we re-order the sequence. In this case, the relative impact of reliability and growth capex are the same, which does not seem intuitive given growth capex is significantly higher than reliability capex. While beyond the scope of this thesis, our initial analysis suggests that price increases at a decreasing rate with a change in capex. We consider this has to do with the percentage change in the RAB, but have not been able to investigate further as part of this thesis.

between FY2006 and FY2014, which we have estimated as a 2.5 per cent decline annually during this period (AER, 2014, p31).

Our model captures the decline in capital and operating unit costs through an efficiency scenario where the cost of capital and operating inputs increase by 2.5 per cent annually between FY2006 and FY2014. The impact of efficiency decline on expenditure can be seen in Figure 25, which looks at the with and without results.

Figure 25- Capex and opex - with and without efficiency decline ($m, real 2006)



While significant in terms of capital and operating expenditure, the decline in efficiency only contributes an additional 6.1 per cent to prices in the FY2009 to FY2014 period.

4.2.4 Rate of return – impact of excessive returns in the GFC

The *gold-plating* narrative focus on deficiencies in the regulatory framework that allowed state-owned networks to receive an excessively high rate of return. This included the prescribed calculations in the National Electricity Rules, which allowed networks to 'lock in' an excessive rate of return for 5 years based on temporary abnormal market conditions during the global financial crisis. The narrative also observed the deficiencies in the appeals, noting that NSW networks were allowed to 'cherry-pick' a review of the AER's rate of return decision, without opening up other elements where the AER had made a favourable decision (Mountain and Littlechild, 2010, p5775).

Our model seeks to input the data on the real rate of return to estimate its impact on prices during FY2009 to FY2014. In FY2005 to FY2009, the jurisdictional regulator (IPART) set a real rate of return within a band of 3.5 to 4.5 per cent (IPART, 2004, p61). In FY2010 to 2014, the AER was directed by the Australian Competition Tribunal upon review of the decision to set a real rate of return of 7.55 per cent (AER, 2009, p2). We have used the top of IPART's FY2005 to FY2009 band to estimate that the change in the real rate of return was 68 per cent when transitioning to the following regulatory period.

The model shows that the higher rate of return significantly and materially caused higher prices in the 2009-14 period, accounting for an additional 32.7 per cent of the price shock.

So why does new capex have a relatively minor impact on prices compared to the rate of return? The model reveals the underlying difference in how capital expenditure and rate of return impact price movements.

The surge in new growth and reliability capex increases the value of the regulatory asset base (RAB) resulting in additional return on capital and depreciation revenue. The additional revenue (roughly speaking) is equivalent to the percentage change in the RAB caused by the new capital expenditure. In the *gold-plating* narrative, capital expenditure increases by about $600 million a year in FY2009-14 compared to FY2008 representing a relatively low fraction of the non-written down value of RAB of $18 billion by 2013-14.

The rate of return impacts the return on capital revenue stream. This is the dominant driver of capital returns accounting for about 80 per cent of capital revenue under the AER's calculations. However, the higher rate of return is applied to the total RAB, including the new capital expenditure. The significant increase in the rate of return of 68 per cent therefore has a much more material impact on capital returns.

4.3 The *keep the lights on* narrative (Case study 3)

The *keep the lights on* narrative seeks to explain the price shock in terms of past regulatory decisions that suppressed price, together with an emphasis on falling energy sales. We have identified three variables in the literature to test within the model context – a write down of the true value of the asset base in FY1998; suppression of replacement allowances between FY1998 to FY2008 which necessitated a 'catch up' in FY2009 to FY2014; and a decline in energy consumed per customer between FY2006 and FY2013 (Ausgrid, 2012, pp25-27)

Figure 26 below shows that the variables estimated in the *keep the lights on* scenario increased prices by 47.9 per cent during the 5 year period of FY2009 to FY2014. The results are set out in the figure below. This indicates that the variables in the keep the lights on narrative have a similar impact to variables in the *gold-plating* narrative on causing the price shock.

Figure 26- Increase in prices between FY2009-14 (real, $2006) – *keep the lights on* narrative

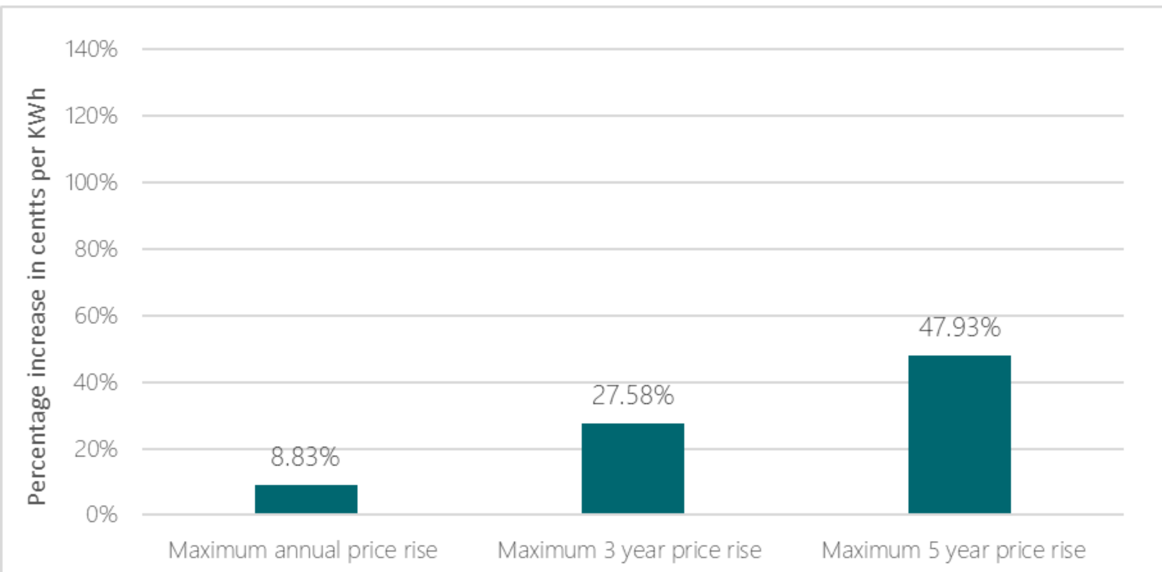


Figure 27 shows the annual price path per customer under the *keep the lights on* case study. The interesting feature is the reduction in prices in 1998 associated with the asset write down, followed by a rapid rebound in price in the 2009 to 2014 period.

Figure 27- Cents per kWh (real $, 2006) – *keep the lights on* narrative

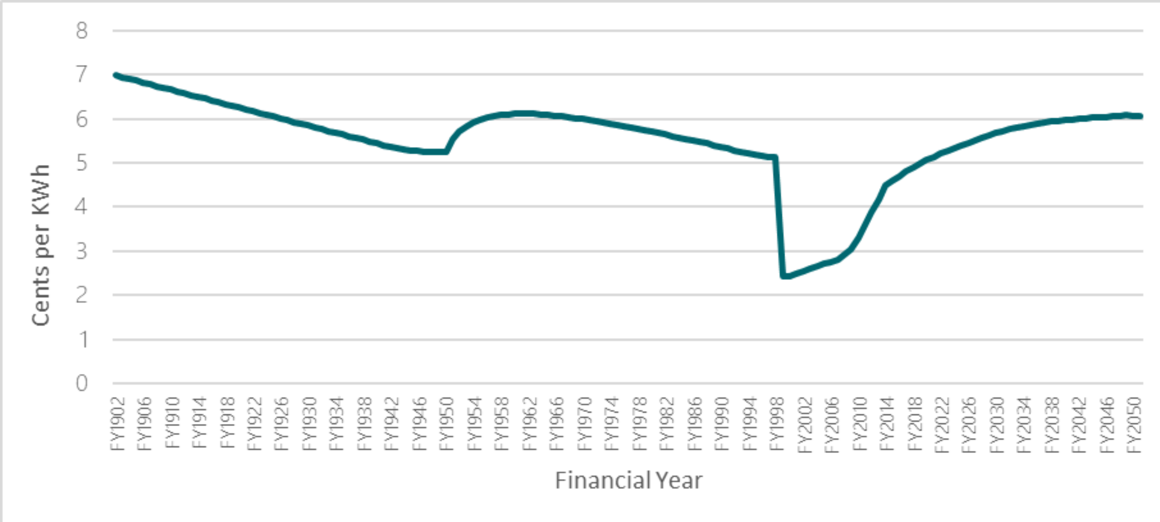
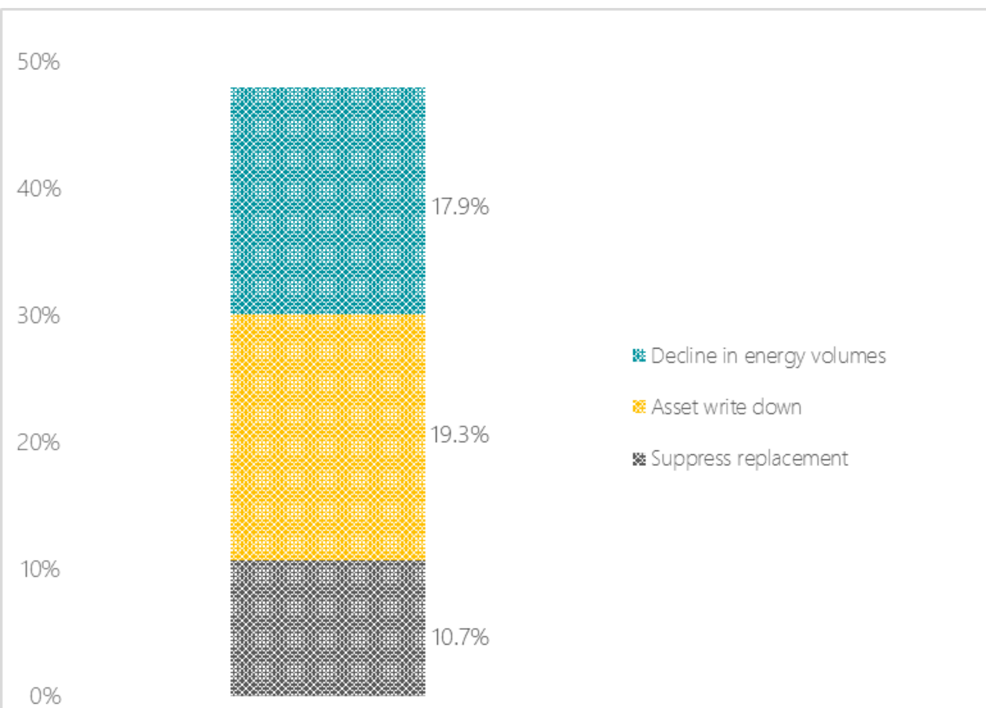


Figure 28 shows the contribution of each variable to the price shock. The asset write down is most material at 19.3 basis points of the 47.9 per cent increase, followed by decline in energy volume at 17.9 basis points, and suppression of replacement at 10.7 basis points.

Figure 28- Contribution to 5 year price increases between FY2009-14 – *keep the lights on* narrative (basis points)



In the sections below we describe how the values underlying each of the variables was derived.

4.3.1 Allowance suppression – impact of constraining replacement

A key contention of the keep the lights on narrative is that replacement allowances were below sustainable levels in the 1998 to 2008 period, and this resulted in deterioration in the condition of assets. We have sought to assess the evidence of suppression of replacement allowances.[24]

Ausgrid's proposed replacement program increased from about $100 million on average between 1998 to 2008 (IPART, 2004, p35) to about $800 million per annum between FY2009 to FY2014, an eight-fold increase. Ausgrid noted that its 2009-14 replacement expenditure sought a 'reversal in the ageing trend' through a catch-up program, given over 10 per cent of its assets were over their expected age (Ausgrid, 2008, p6).

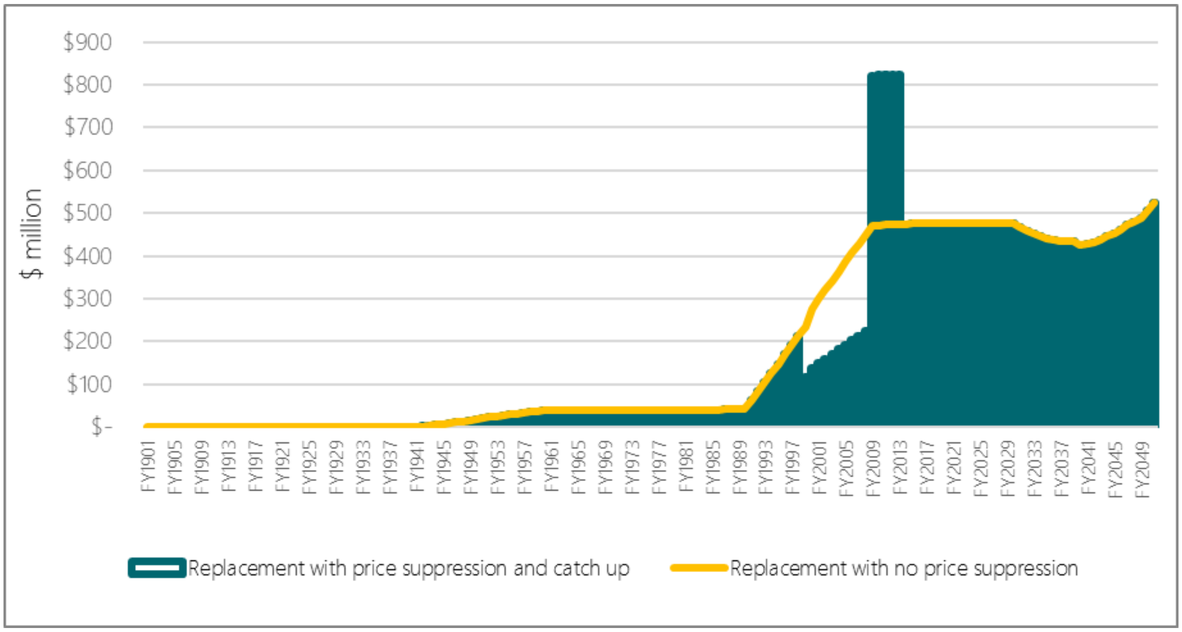
In our model, we have traced the likely replacement program based on our estimate of Ausgrid's network expansion over time, assuming no regulatory interventions. Under our primary scenario, initial capex is eventually replaced at a median age of 50 years, with an even distribution between 40 to 60 years around the mean age.[25] This means that replacement generally follows the pattern of new capital expenditure.

From here we develop a regulatory intervention scenario to approximate the observed expenditure between 1998 and 2013. This involves the regulator providing 60 per cent less than the predictions of the model for FY1998 to 2008, and then a period of catch up for the delayed replacement between FY2009 and FY2013. This results in the profile of replacement expenditure in Figure 29, which closely resembles the actual allowances of Ausgrid during this period.

[24] We also considered a scenario which examines the idea that growth capex was suppressed in the 1998 to 2008 period. However, we consider the *gold-plating* narrative provides a more compelling case to show that there was spare capacity in the network to meet growing peak demand on the network, and that the increase in growth capex between 2009-14 was to meet further demand on the network that did not eventuate.

[25] In the *keep the lights on* scenarios we do not consider inefficiencies in unit costs.

Figure 29- Replacement capex - with and without suppression ($m, real 2006)



The model finds that the suppression of allowances increased prices by 10.7 per cent between FY2009 to FY2014. The relatively high contribution compared to reliability and growth capex reflects that replacement capex was the dominant driver of higher capex in the 2009-14 period accounting for close to 60 per cent of capex increases (Wilson Cook, p11).

4.3.2 Asset write down – impact of asset undervaluation in 1998

Ausgrid noted that a key driver of the price shock was a severe undervaluation of its asset base in 1998, which was subsequently rolled forward in successive determinations (Ausgrid, 2012, p26). The claim has not been examined in detail in the literature.

Prior to 1998, prices for Ausgrid's network were set by the NSW Government without a rigorous framework. In response to productivity reform in the 1990s, the Government required the NSW state regulator (IPART) to set prices for NSW networks from 1996 onwards.

In December 1998, the National Code and National Electricity Law came into effect in NSW. The Code provided guidance on how revenue and price paths should be set by state regulators. IPART (1999, p. i) included a building block approach that relied on a valuation of the asset base. IPART's 1999 to 2004 determination was therefore the first decision where an asset value was established for Ausgrid.

IPART's determination noted that Ausgrid's network value in 1996 was about $2.5 billion, which rolled forward to include capital expenditure was $2.75 billion by 1998. IPART considered this value to be a lower bound in its determination on Ausgrid's asset value. IPART's reasoning was that the 1996 value was primarily aimed at achieving a price reduction rather than reflecting the value of the network: (IPART, 1999, p51)

> *"The 1996 asset value of the DNSPs was based on a public exchange of correspondence between the Tribunal and the Government, in which the Tribunal set electricity prices having regard to, among other things, an average 20 per cent real price reduction target for the industry as a whole"*

IPART used an alternative method termed "depreciated optimised replacement cost" (DORC) to provide an upper bound value of the asset value. This method involves estimating the optimised replacement costs (ORC) which reflects the original cost of past investments adjusted for inflation, and subtracting the value of stranded assets. From there the value is deducted for depreciation already provided in revenues (Johnstone, 2003, p3). IPART determined a value was $3.647 billion in 1998 dollars for system assets, which comprised only a small deduction of $0.011 million for stranded assets. IPART chose a value of $3.53 billion for system assets which was closer to the upper bound DORC value (IPART, 1999, p53 and 69).

Our analysis to estimate the level of undervaluation in 1998 was to compare the ORC determined in IPART's 1998 decision with our estimates of the true value in 1998 based on public material on population of assets in service at that time.

There is limited public data available on how IPART estimated the DORC value. We understand that the value of assets was based on NSW Treasury values on costs of electricity assets (IPART, 1999, p54) and that the quantity was based on a count of existing assets in service. We have been unable to source how much depreciation was deducted from the ORC to derive the DORC. We have used Ausgrid asset age profile in 2001 (Meritec, 2003, p101) on the relative age of assets of Ausgrid in 1996 to derive an estimate of depreciation paid out to Ausgrid in the past. The data shows Ausgrid had a relatively young fleet of assets in 1996.[26] Based on this analysis we have conservatively estimated that IPART valued the ORC at $5.3 billion in 1998 (nominal $) implying depreciation of $1.8 billion or in other words depreciation was 33 per cent of the ORC.

Public data suggests that IPART's calculation of ORC was significantly lower than the true ORC in 1998. In 2008, Ausgrid estimated that the ORC at that time was between $30 to $35 billion in nominal dollars (Ausgrid, 2008, p3).[27]

We have estimated that Ausgrid's valuation may have had some level of overstatement.[28] Conservatively, we have estimated a value of $25 billion as our starting value for the ORC in 2008 and reduced this amount for new capital expenditure during the 1998 to 2008 period of approximately $1 billion (IPART, 2004, p34). We have then deflated the value by inflation over the 1998 to 2008 period by 35% (ABS, 2020) to obtain an estimate of the true ORC value of $18.4 billion in 1998 dollars.

This suggests that IPART's valuation of Ausgrid's ORC of $5.3 billion was 30 per cent of its true value of $18.4 billion, equating to a 70 per cent write down in the true value of the asset base at that time.

In the model, we simulate IPART's under-valuation in 1998 via a scenario where we devalue the capital expenditure rolling into the RAB and the depreciation by 70 per cent prior to 1998. Figure 30 shows the difference in the RAB with and without an asset write down in 1998.

Our model shows the price shock was amplified by an under-valued RAB, accounting for 19.3 per cent of the increase in network prices customers experienced between FY2009 and FY2014. The mechanics are explained in more detail in section 5.2. From a

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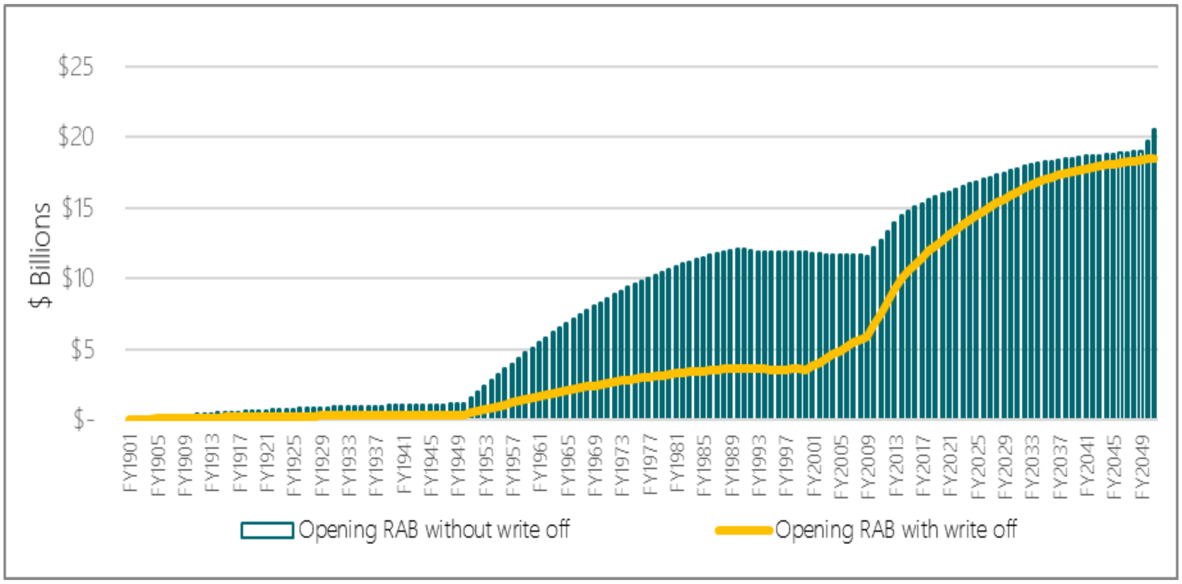
[26] About 67% of Ausgrid's assets between 1945 to 1995 were installed between 1970 to 1995, with 33 per cent installed between 1945 to 1970.

[27] We examined Ausgrid's replacement data and implied unit costs over four years from 2014-15 to 2017-18 which show widely varying values. The average of the 4 years is $33 billion. However, the lowest value was in 2018 of $26 billion. To be conservative, we have placed greater weight on this value.

[28] Our analysis from network's public responses to AER Category Analysis Regulatory Information Notices suggests that unit costs vary significantly across networks for similar assets. While this may be due to data reporting inconsistencies and operating and environmental differences, our general observation was that Ausgrid's unit cost appeared higher than peers such as Energex.

mathematical perspective, adding higher capital expenditure on a low value of the RAB has a large impact on prices relative to adding the same capital expenditure on a high RAB.

Figure 30- Opening RAB - with and without 1998 write down ($billions, real 2006)



4.3 Declining energy sales

The *keep the lights on* narrative emphasise that a decline in energy sales amplified the FY2009-14 price shock. Researchers have noted that the decline in energy sales in Australia related to higher prices, despite relatively inelastic prices in Australia (Doojav and Kalirajan, 2019, p204).[29] Falling energy sales was also associated with increased solar consumption from 2010 onwards when generous feed in tariffs were introduced by the NSW Government (Nelson, Simshauser and Kelley, 2012, p114), although it is also unclear the extent to which higher prices played its part in consumer decisions to install solar.

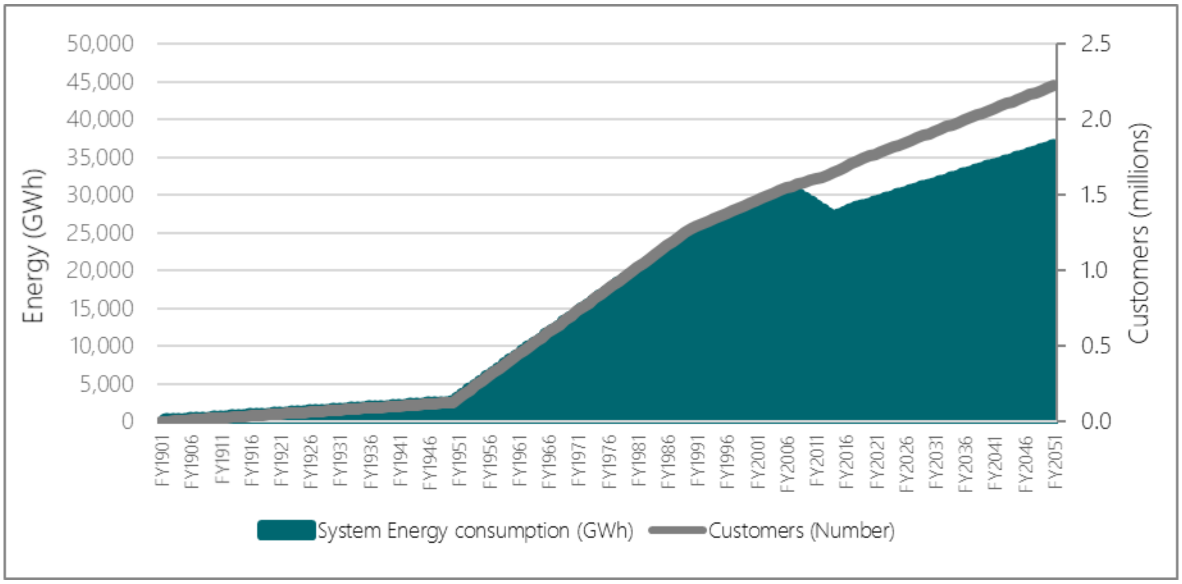
Our analysis of Ausgrid's public data shows that energy consumption fell from 30,120GWh to 25,523GWh between FY2006 to FY2014 (Ausgrid, 2014, tab 5). At the same time, customer numbers increased from 1.55 million to 1.65 million, suggesting that energy per customer declined rapidly over this period (Ausgrid, 2014, tab 5).

For the model we have used this data to create a scenario where Ausgrid's energy per customer declines by 2.31 per cent per annum between FY2007 to FY2014. Figure 31 shows

[29] Doojav and Kalirajan estimate that price elasticity in NSW was -0.17 to-0.37 between 1991 and 2013.

that in this scenario, energy consumption (green column) keeps pace with customer numbers (grey line) until FY2007, when a decline occurs until FY2014.

Figure 31- Energy consumption (Gwh) compared to customer numbers (millions) - FY1900 to FY2050



The decline in energy sales impacts the cents per kilowatt hour metric through its impact on reducing kilowatt hours. This means that customers are getting less value for money. Our model calculates that falling energy volumes increased prices by 17.9 per cent over the FY2009 to FY2014 period.

4.4 Combining the narratives – Case Study 4

Case study 4 combines the narratives. We note that this case study helps to understand how contributing variables amplify the impact on prices. For example, the price increase from a higher rate of return is compounded by increasing capital expenditure. Similarly, the price increase associated with the asset write down in 1998 is compounded by increasing capital expenditure and the rate of return.

For this reason, we have carefully considered the order of variables in terms of expenditure, rate of return, and asset write downs.[30] While re-ordering the sequence yields the same

[30] The exact order is as follows: capital expenditure (*gold-plating*), peak demand capex (*gold-plating*), replacement suppression (Keep the lights on), declining efficiency (*gold-plating*), the rate of return (*gold-plating*), asset write down (Keep the lights on) and declining energy volumes (Keep the lights on)..

total price increase, it will provide a different view of the relative impact of each variable to the outcome.

Figure 32 shows that the maximum 5 year price increase between FY2006 and FY2016 is 118.2 per cent in real terms. The model results are slightly lower than the actual price shock experienced by Ausgrid customers of 136 per cent in real terms, but still within a reasonable band. This provides us with a level of confidence that the model scenarios are providing plausible results.

Figure 32- Increase in prices between FY2009-14 (real, $2006) – Combined narratives

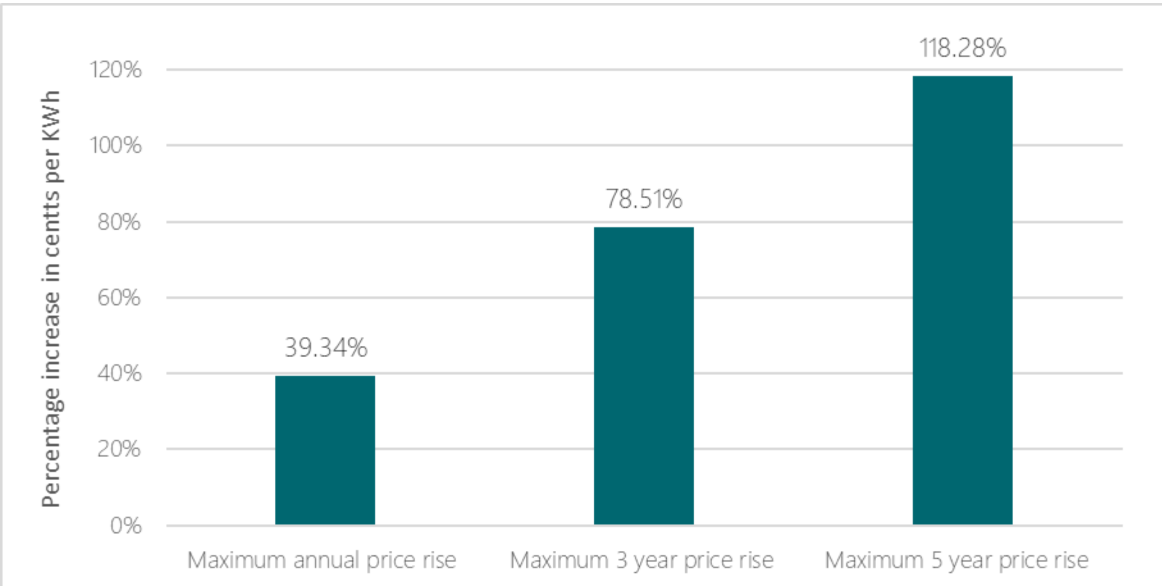
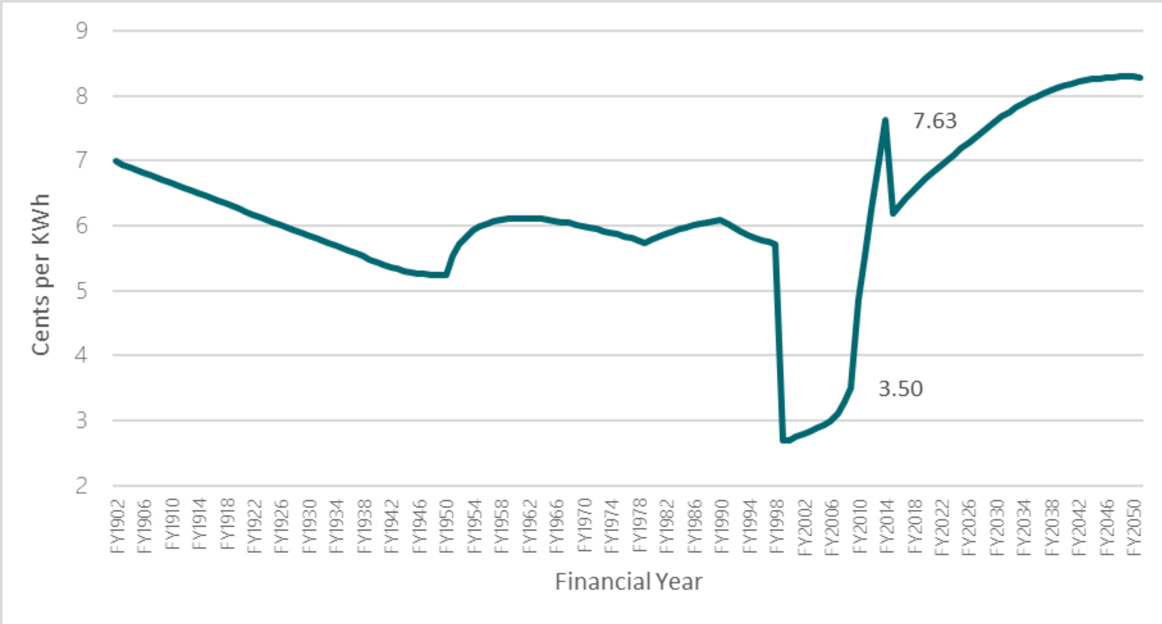


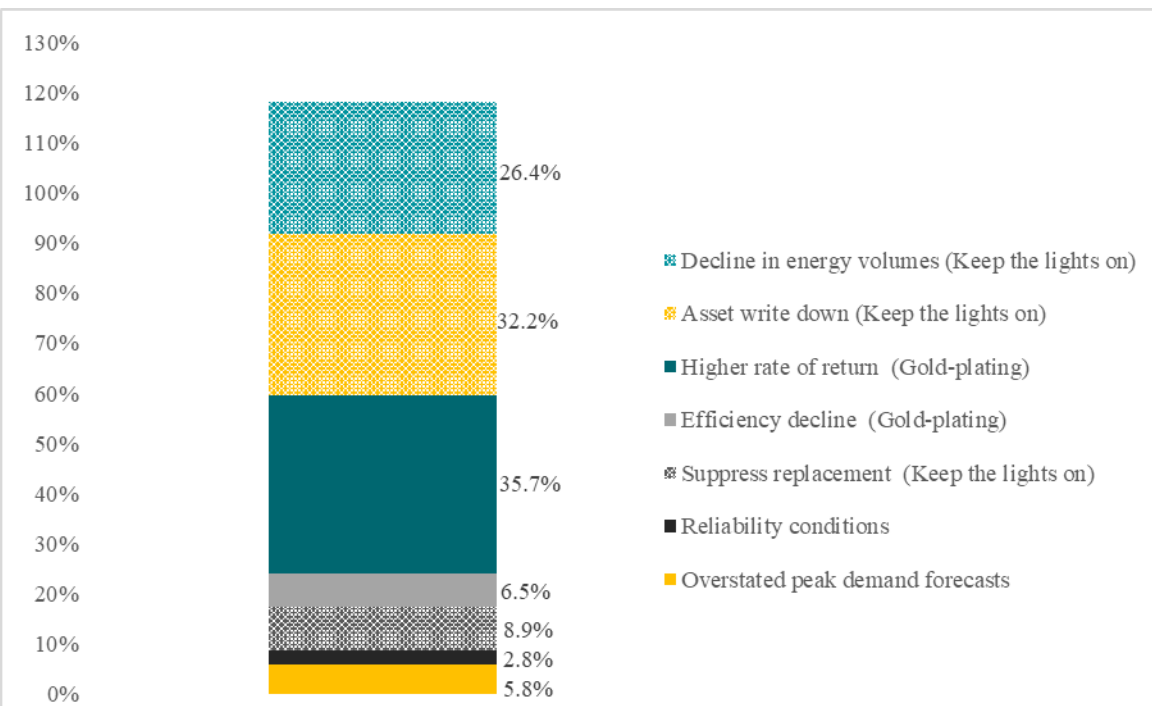
Figure 33 shows the magnitude of the price increase on a cents per KWh basis. This shows very similar results to Ausgrid's actual experience where cents per customer increased from 3.50 cents to 7.594 cents per kilowatt hour.

Figure 33- Cents per kWh (real $, 2006) - Combined narratives



In terms of the sensitivity of the variables, Figure 34 shows that the increase in the rate of return and the asset write down in 1998 were the largest drivers of higher prices, followed by the decline in energy sales.

Figure 34- Contribution to 5 year price increases between FY2009-14 - Combined narratives (basis points)



Case Study 4 shows that both narratives are important for explaining the magnitude of price shocks experienced by Ausgrid customers between FY2009 to FY2014. An interesting finding is how variables feed on each other to amplify the price shock. For example, the sum of the price increases of each narrative in isolation is 95.4 per cent, while the combination of the two narratives lead to a price increase of 118.3 per cent.

The big picture observation is that Ausgrid's price shock was a 'perfect storm' – a series of coinciding factors that amplified the magnitude of the price shock. For example, the global financial crisis was unexpected, occurring at just the time that networks increased their capital expenditure from very low levels. The higher prices then impacted on energy sales through a price elasticity effect, magnifying the price shock.

The implication is that price shocks of the magnitude experienced in NSW and Queensland are likely to be rare, and that simplistic narratives are unlikely to tell the whole story. However, as we discuss in the following chapter, there are many lessons to be learned from understanding the mechanics at play to prevent minor price shocks in the future.

5. Policy implications

The objective of this thesis was to understand the mechanics of the price shock in state-owned networks between FY2009 and FY2014, with the aim of identifying policy changes that could prevent price shocks in the future.

Our model findings show that both narratives provide a strong explanation for the price shock that occurred in the Ausgrid network. Policymakers have responded to the remedies identified in the *gold-plating* narrative but have not actively considered the implications of the *keep the lights on* narrative. The risk is that we do not learn the lessons from the NSW and Queensland price shocks in FY2009 to FY2014, and are blindsided when price shocks emerge in the future.

5.1 Acting on policy conclusions of *gold-plating* narrative

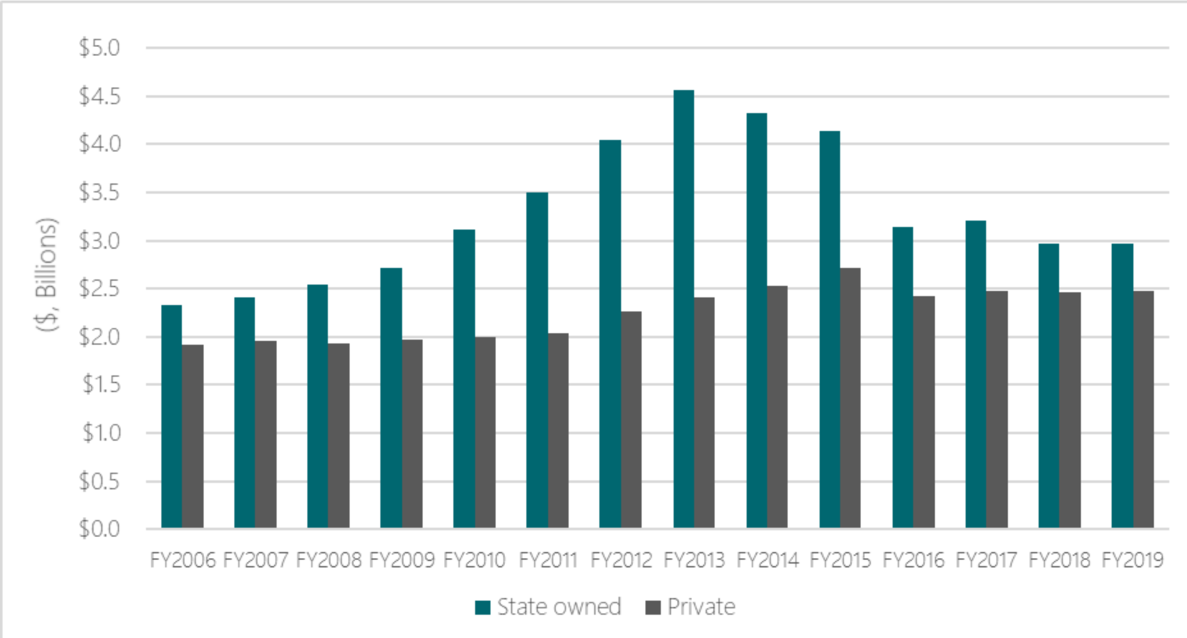
As discussed in section 2.1, the dominance of the *gold-plating* narrative has led to policy changes that strengthen the power of regulators to reject excessive proposals of networks (AEMC, 2012, p. vii), and remove the rights of a network to seek appeal review of the AER's decision (Mountain, 2019, p3).

This has emboldened the AER to make regulatory decisions that have significantly reduced the revenue of state-owned networks, as can be seen in Figure 35 below. The revenue reduction for state owned networks between FY2013 and FY2018 was 35 per cent compared to private networks which had a 2 per cent increase in revenue over the same period. Figure 35 also shows that the gap between state-owned and private networks has reduced to FY2006 levels.[31]

Viewed from this lens, the *gold-plating* period was an unnecessary shock to customers, reigned back in when the regulatory framework was fixed. As we argue in section 5.2, the *keep the lights on* narrative would argue that regulators may not have learned the lessons of the past, and could be simply suppressing the price by reducing expenditure below sustainable levels.

[31] The analysis and source data can be found by clicking on "Analysis and Source Data - Figure 7 to 10, and 35 - Cents per kWh and Revenue" at http://www.dynamicanalysis.com.au/research

Figure 35 - Revenue between FY2006-19 - Comparison of state-owned to private networks ($, billion, real 2006)



The *gold-plating* narrative has also provided the policy rationale for privatisation, with 2 of the 7 previously state-owned networks being privatised since the price shock. The *gold-plating* narrative would argue that further privatisation is required to improve efficiency incentives and ensure independence of regulation. Mountain (2019, p7) for instance provides empirical evidence from 235 international networks between 2002 and 2013 to show that private networks have lower revenue and RABs than state-owned networks.

The *gold-plating* narrative also holds open the possibility of reducing RABs of state-owned networks (Grattan Institute, 2018, p16). The key argument is that excess capital expenditure in the price shock period was 'locked in' under the regulatory framework. Advocates for asset write downs claim that customers should not pay for past 'over-investment'. The ACCC (2018, p167) for instance recommended asset write downs relating to the price shock period stating:

> *"Currently, consumers are effectively paying for any overvaluation of network assets—that is, the higher RAB leads to higher prices. The case from an affordability point of view for write downs is, in one sense, fairly simple. A lower network asset base leads, all else being equal, to lower revenues, which in turn lead to lower prices for consumers."*

While write-downs have not been implemented to date, the fact that the ACCC have recommended such action to reduce prices, demonstrates the dominance of the *gold-plating* narrative in policy making.

5.2 Ignoring the lessons of *keep the lights on* narrative

Our model shows that past regulatory practices to suppress prices can have a boomerang impact on prices in a later period. In the case of Ausgrid, under-valuation of the regulatory asset base in 1998 and a decade of unsustainable replacement allowances were the tinder that unleashed an unexpected price shock.

However, the simplicity and intuitive appeal of the *gold-plating* narrative has meant that the 'regulatory suppression' aspect of the NSW price shock has largely been ignored by the literature and policy makers. Indeed, the *gold-plating* narrative suggest that the asset value should be once again written down for NSW and Queensland networks. Further, it has led to decisions from the regulator to markedly lower expenditure allowances for NSW and Queensland networks. Arguably such actions may just lead to a boom-bust cycle of higher and lower prices for consumers, the antithesis of the underlying goal of price stability of regulation.

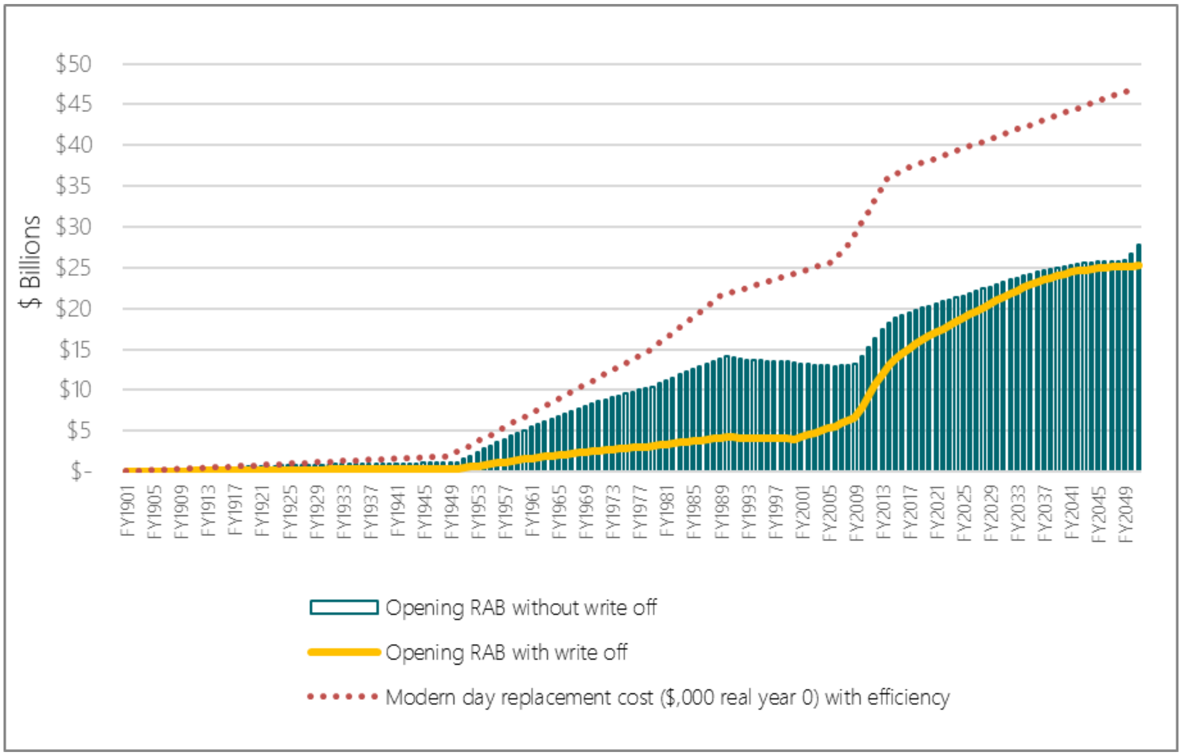
A notable contribution of the model is that it allows us to develop metrics that may provide some indication of unsustainable regulation, and to identify conditions when a price shock may emerge in the future.

5.2.1 Metrics for diagnosing under-valuation of RAB

In our model, we have developed a metric termed the 'modern day replacement cost of the network', which provides a view on how much it would cost to replace the network in any year. A key marker of asset under-valuation is when the RAB is significantly below the replacement cost.

This is seen in Case Study 4 of the model where we create a scenario where Ausgrid's RAB is written down to 30 per cent of its value in 1998. In Figure 36 below, the yellow line represents the written down value of the RAB based on this scenario. The green columns represent the RAB if there had been no write down. The red dotted line in the modern-day replacement cost. The yellow line catches up to the green column in the FY2009 to FY2014 period when there is an injection of capex. The yellow line then moves closer to the green columns by 2050, albeit in a more gradual way.

Figure 36- RAB and Replacement Cost - Impact of write downs (Real, $2006)



The underlying mechanics at play is that the write down of the asset base produces an immediate reduction in price. The impact of the write down is not felt until 2008, when capital expenditure expands rapidly. The yellow line RAB now includes a significant proportion of assets that have not been written down, boosting it closer to the green columns. This has the effect of amplifying the price shock compared to a scenario where the asset value is not written down. Eventually, more new capital expenditure 'washes away' the older assets which progressively become fully depreciated.

The analysis demonstrates that the one-off reduction in prices is eventually balanced by higher prices in the outer years, under the assumption that assets are not stranded.[32]

[32] Our model assumes there are no stranded assets from excessive investment or changes in technology that make the asset redundant. As noted by Simshauser and Akimov (2019, p118), asset write downs may be a reasonable policy in the event of stranded assets. In this case, the asset does not get replaced at its full value. In effect the green columns and modern-day replacement cost would fall.

However, this may be a long burn of gradually higher prices rather than a price shock if there is no accompanying surge in capital expenditure.

The above analysis provides a useful diagnostic tool to indicate if the value of the assets have been written down in the past. The model shows that the RAB generally stays within a band of 50 per cent or more of the replacement cost when assets are not written down. It follows that undervaluation is present when the regulatory asset base is significantly less than 50 per cent of the replacement cost of the network.

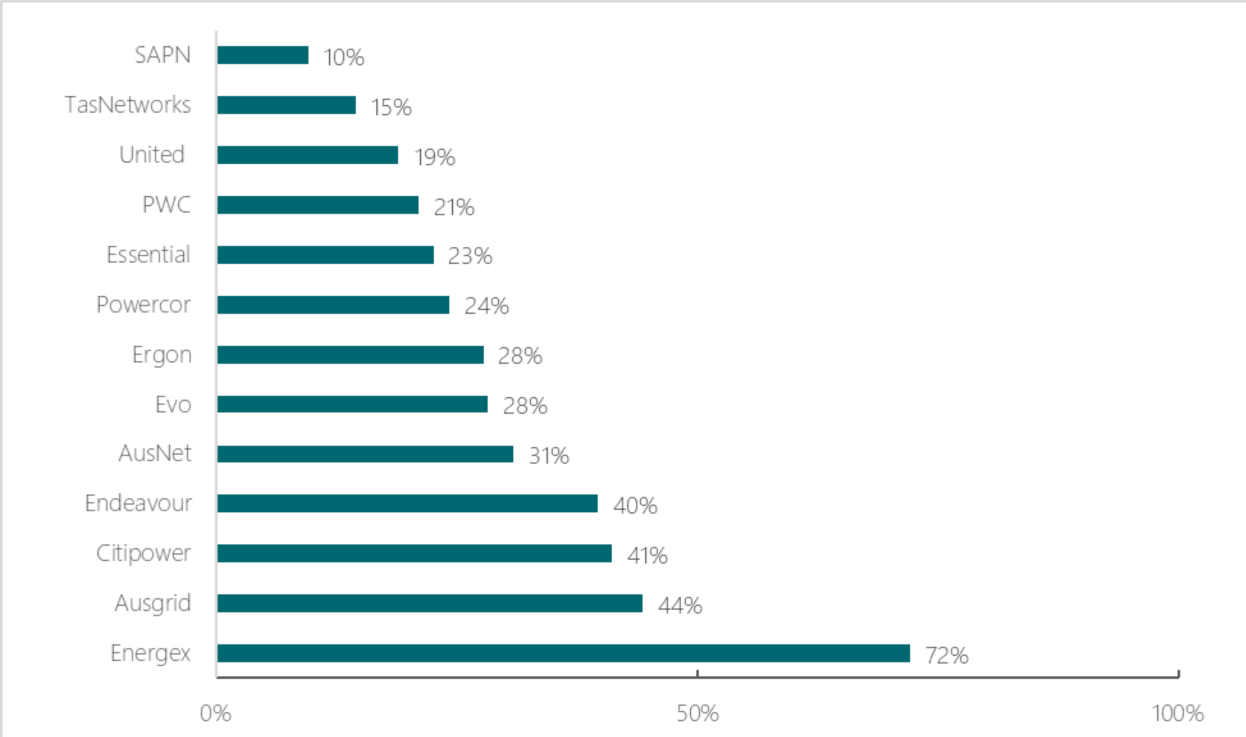
With this in mind, we undertook analysis of the replacement value of 13 networks and compared this to their Regulatory Asset Base value.[33] The replacement value is not readily reported but the system value can be implied by the audited information provided by networks to the AER on replacement age profiles and unit costs (AER, 2015-18, tab 2.1 and 5.2)[34] The ratio of the RAB to Replacement Cost. We have used the value of the RAB of each network in 2018 as stated in the AER's State of the Energy Market (AER, 2019(d), p136). The ratio of RAB as a proportion of replacement cost is set out in Figure 37.

On the face of it, the data suggests that many of the networks RABs are well below the 50 per cent metric. This may indicate that the replacement cost data including unit costs is overstated, or it may indicate that the value of assets is well below the replacement rate. This raises the prospect of significantly rising prices sometime in the future, with the prospect of a price shock dependent on the extent to which capex surges in a short period.

[33] We have excluded Jemena from the analysis as they have not provided unit cost data in their Regulatory Information Notices to the AER. The analysis and source data can be found by clicking on "Analysis and Source Data - Figure 36 to 40 - Replacement Cost , RAB, Replacement Value and Asset Age" at http://www.dynamicanalysis.com.au/research

[34] In this respect, we note that there may be reporting differences by networks that could explain the benchmark comparisons. However we note that the AER provide a high level of prescription in how information must be presented, and require audits and statutory declarations. In this context, reported data is expected to be of high quality. We have used data provided to the AER from the networks in the Category Analysis Regulatory Information Notices for the period FY15 to FY18 data. Tab 2.1 includes information on total costs and total volumes of replacement by asset category, which we have used to derive an implied unit cost. Tab 5.2 provides the asset population profile by year by the same asset category, with the sum enabling a calculation of population of each asset. We have then multiplied the unit cost by the population to derive the Replacement Cost of a network at a point in time. We have used the average of 4 years of data for NSW, ACT, Queensland, SA, Tasmania and NT networks, and 3 years for Victorian networks. The category analysis data is part of our references: Australian Energy Regulator (AER), 2015-18, "Responses to Category Analysis RINs", Tabs 2.1 and 5.2. Accessed on 24 August 2020 at: https://www.aer.gov.au/site-search/Response%20to%20RIN?f%5B0%5D=type%3Aaccc_aer_performance_report

Figure 37- RAB as a proportion of Replacement Cost



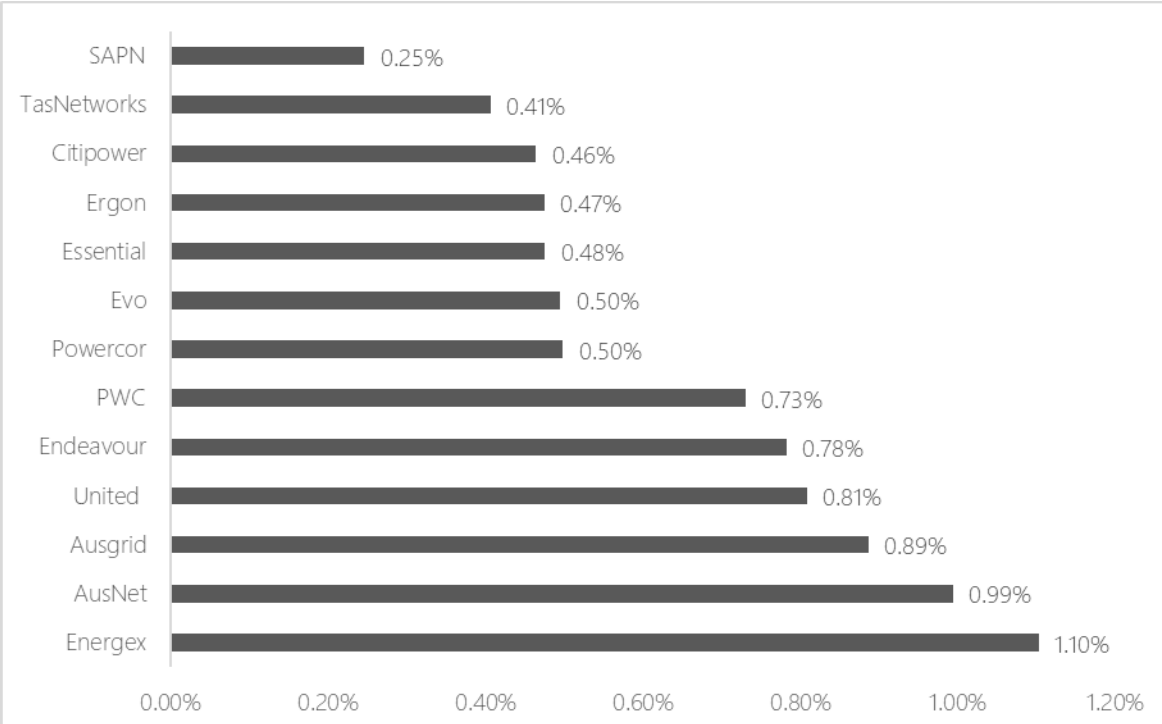
5.2.2 Metrics for unsustainable replacement

Our analysis demonstrated that Ausgrid's replacement capex was significantly lower in the FY1998 to FY2008 period than a sustainable level. The regulator has provided Ausgrid with an allowance of about $100 million per annum. To put this into context $100 million of a $25 billion replacement cost is 0.4 per cent a year. For this to be sustainable, the average life of an asset would be 250 years. Ausgrid subsequently increased its replacement capital expenditure to catch up on under-investment, and this added to the magnitude of the price shock.

We undertook analysis of recent network data to understand if current replacement is at sustainable levels. We would expect a sustainable annual rate of replacement to be about 2 per cent of the replacement cost of a network, which would mean the network is fully refreshed about every 50 years.

We examined the average annual replacement capex of the 13 distribution networks between 2015 to 2018 (AER, 2015-18, tab 2.1). We divided this by the replacement cost of each network as used in the analysis in section 5.2.1. The results are set out in Figure 38 below, which shows that all networks have been replacing assets well below the 2 per cent rate. Some networks were replacing assets below the rates of Ausgrid in the FY1998 to FY 2008 period.

Figure 38- Annual replacement capex as a percentage of Replacement Cost



A potential reason for such low rates of investment could be due to a low proportion of older assets in service. Figure 39 demonstrate that this is not the case for most distribution networks where there are a significant proportion of assets aged 50 and over. Further, Figure 40 demonstrates that networks with the lowest replacement rates also have the highest proportion of assets over 50 and 60, such as SAPN who have more than 23 per cent of assets over 50.

Figure 39- Value of assets installed by age ($billions, $FY2016)

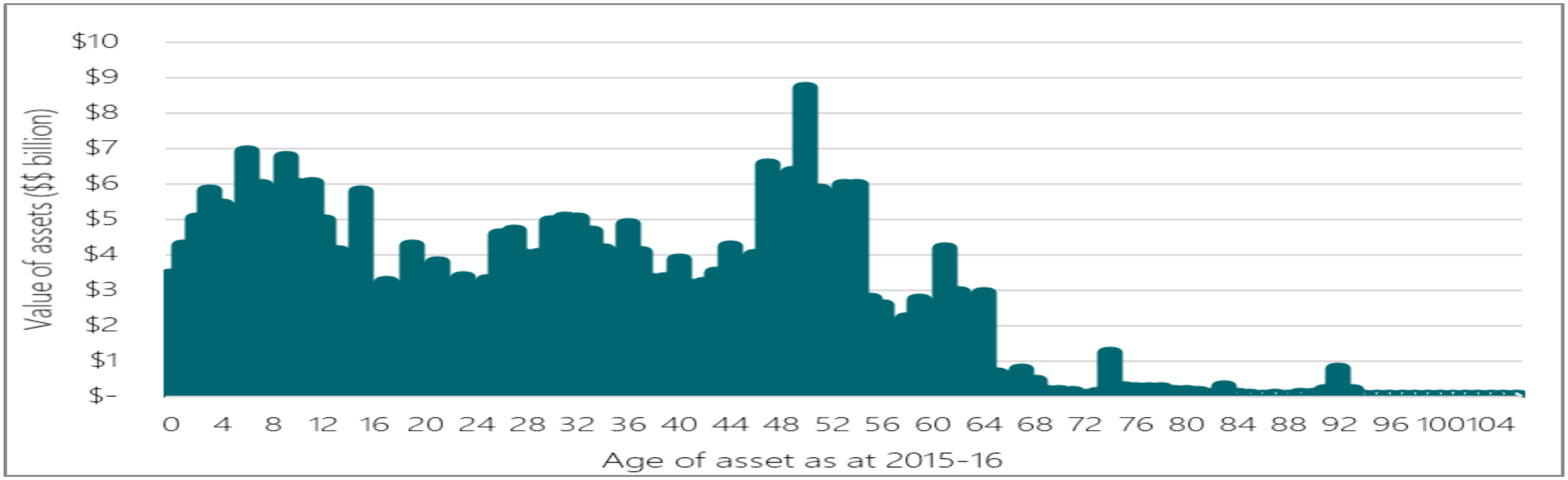
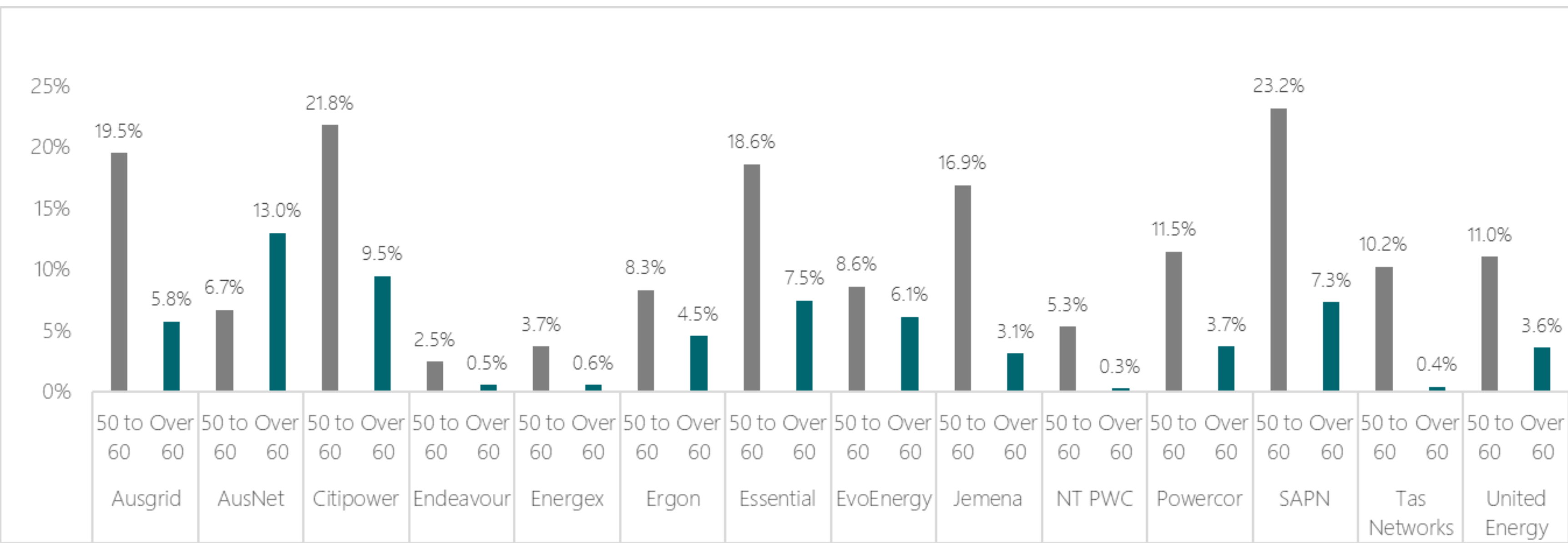


Figure 40- Asset aged over 50 and 60 (% of total assets)



There is increasing recognition that contemporary asset management practices and improved risk methods are enabling networks to keep assets in service far longer than their financial life. This is particularly the case for underground cables and steel poles such as those found in South Australia.

However, even if all assets can live for 100 years (which would still be highly improbable for most assets), the current level of replacement of networks is well below sustainable rates. This indicates that there is likely to be a significant 'catch up' in replacement capex in the future, that may lead to a surge in capex.

5.2.3 Networks most at risk of price shocks based on metrics

The magnitude of the NSW and Queensland price shocks were a 'perfect storm' of coinciding factors – a change in the regulatory framework allowing networks to push through their excessive proposals, a decade of air-conditioning straining the capacity of the network, governments imposing deterministic standards, a global financial crisis increasing the rate of return, previous write downs and unsustainable capital expenditure, and falling energy volumes. The compounding impact of these factors resulted in a once in a century increase in network prices.

Our view is that such a large price shock is unlikely in the future, particularly given the changes to the regulatory framework in response to the *gold-plating* narrative. However, we consider some networks face an upward battle to stem rising prices in the future, and in a worse case, may result in short periods of steep price increases.

In particular, we note that the SAPN, Citipower, and TasNetworks have very low RAB to replacement values, together with very low rates of replacement and a reasonable proportion of assets over the age of 50. Given these conditions, it is likely that prices will rise in the future when replacement capex increases from current levels, prompting a supercharged percentage increase in the RAB that translates to price surges.

At the same time, interest rates are at the lowest point in history meaning that in the medium term the rate of return may rise. Further, energy volumes have been significantly declining over the last decade with more customers consuming household solar energy.

5.3 Future research – policy settings

The analysis presented in this thesis demonstrates the importance of policy settings that prevent future price shocks, particularly for networks which have unfavourable metrics. Below we have briefly touched on future policy changes that may avert price shocks in the future, which we hope to explore in detail in future research. Within our analysis we emphasise that the transition to a renewable energy market characterised by increased solar, batteries and electric vehicles is a key factor that will impact price movements of networks. In turn, this is crucial for how regulators incentivise networks to increase the capacity of their network without increasing costs.

Firstly, we consider that the AER's assessment needs to consider and report on long-term outcomes of its decision, including estimating future prices. This may uncover unsustainable decisions in the past such as asset write downs, and may also give rise to questions on whether replacement levels are at a sustainable long term level.

Secondly, future research could consider banking mechanisms to smooth expected periods of high price increases. This could be achieved by asking consumers to pay CPI-inflated prices when there is a downward period of network price changes, and using these funds to help pay higher prices in the future. Further, the regulator may consider applying a long term rate of return to decisions, and banking excess returns in low interest environments to cover periods of high interest rates.

Thirdly, networks should be provided incentives to optimise and slim their network over time. We consider there may be opportunities to use new technologies such as solar and battery to slim the current grid. This would have the effect of reducing the value of the replacement cost, such that it draws closer to the value of the RAB. Further, networks should have strong incentives for demand management to minimise growth capex. This should include strong tariff structures which support efficient consumption decisions.

Fourthly, a re-think of asset lives may be required if assets are being kept in service longer than expected. The current mis-match between financial and asset life is potentially causing assets to be fully depreciated when in service, leading to a deceptively low RAB.

When investment is required, the RAB increases significantly, putting upward pressure on prices.

Finally, networks should be encouraged to increase energy sales by promoting technologies such as electric vehicles. This would increase energy sales, and lead to lower average prices per unit for customers. The key to this policy change will be to incentivise customers to charge their vehicles in non-congested times, particularly times when there is excess solar being generated. This will require a radical re-think of tariff design to provide customers with the right price signals.

While the thesis has focused on the Australian experience, we note that the research design could be expanded to identify the mechanics at play behind price movements in other countries. The model would need to be modified to reflect the specific regulatory framework and calculations used by the regulator to set prices.

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Glossary

Term	Long title and description
ABS	Australian Bureau of Statistics
ACCC	Australian Competition and Consumer Commission
AEMC	Australian Energy Market Commission (Rule maker in the NEM)
AER	Australian Energy Regulator (Economic regulator of all Australian distribution and transmission networks except those in Western Australia)
Capex	Capital expenditure
DORC	Depreciated Optimised Replacement Cost (cost of replacing all non-stranded assets today, minus depreciation already paid out)
FY	Financial Year
Gamma	Value of imputation credits for AER calculation of tax
IPART	Independent Pricing and Regulatory Tribunal (Economic regulator of NSW distribution networks from 1996 to 2008)
kWh	Kilowatt hours (measure energy consumption)
LMR	Limited Merits Review (process to appeal AER decision)
MW	Megawatts (measure of instantaneous demand
MWh	Megawatt hours (measure of energy consumption)
NEL	National Electricity Law
NEM	National Electricity Market
NER	National Electricity Rules
Opex	Operating expenditure
ORC	Optimized Replacement Cost (cost of replacing all non-stranded assets today)
RAB	Regulatory Asset Base
RC	Replacement cost (cost of replacing all assets today)
Repex	Replacement capital expenditure
SCS	Standard control services

Appendix 1 – Model and data analysis links

We have collated the model and data sources on the following website page: http://www.dynamicanalysis.com.au/research

The buttons on the webpage provide open access to the following spreadsheets that have been provided as part of this thesis:

- **The price movement model**: This includes the schema, case studies, the model, calculations, scenarios and appendix of source material for values in the case studies.
- **Analysis and Source Data - Figure 2 and 3 - Electricity Cost Increases**: This sets out the analysis and ABS source data for real electricity cost changes in Australia and capital cities between 1980 and 2019.
- **Analysis and Source Data - Figure 4 - Price shocks for all goods and services**: This provides the analysis and ABS source data for comparing the maximum 5 year rolling average price increase for 133 goods and services, and which shows that electricity prices were among the top 5 price shocks between 1980 and 2019.
- **Analysis and Source Data - Figure 6 – Network residential price increases - ACCC adjusted for Victoria**: This uses the ACCC Retail Price Inquiry (2018, p10-23) data and methods as a source to graph network price increases between 2007-08 and 2017-18. We made adjustments to Victoria's network prices to include smart metering revenue, which was excluded by the ACCC. We have included this on the basis that it was a relevant increase in the network electricity bill paid by Victorian residential customers.
- **Analysis and Source Data - Figure 7 to 10, and 35 - Cents per kWh and Revenue**: This provides analysis we have undertaken on Standard control services revenue and energy volumes of 14 networks subject to AER economic regulation between FY2006 and FY2020. This allows analysis on cents per kWh (ie: revenue divided by volumes) for each network and by state and private ownership. The source is network responses to the AER benchmarking Regulatory Information Notices for this period (AER, 2006-19, tab 1 and 5)

- **Analysis and Source Data - Figure 36 to 40 - Replacement Cost , RAB, Replacement Value and Asset Age**: This provides the underlying source data and analysis for calculating the replacement cost to RAB ratio, the replacement capex to replacement cost ratio, and the asset age statistics. The source data is network responses to the AER's category analysis Regulatory Information Notices for the 2015-18 periods (AER, 2015-18, tab 2.1 and 5.2). This source data has been compiled into a database. We have also relied on AER source data for RAB values (AER, 2019, p136).
- **Analysis and Source Data - Section 1.1.1 - Income to Electricity Bill Analysis**: This provides the underlying source data to calculate the change in electricity bill to income ratio for low-income quintile households in Australia. This relies on ACCC Inquiry data (2018, pv) and ABS data (ABS, 2019).

Figure 41 - Visual of website that provides links to the model and data analysis