WESTERN AUSTRALIA'S ENERGY FUTURE

Responding to a sector in change

November 2017

ATCO

FOREWORD

We are in the midst of an energy transformation as the economic, political and technological underpinnings of our energy supply change in rapid and unpredictable ways.

It is a fascinating and promising time for our organisation, our customers and the communities within which we operate.

Founded on entrepreneurial spirit, ATCO has embraced innovation from its earliest days. As traditional energy systems transform and the needs of customers change, we stand committed to developing solutions to meet these changes, while continuing to deliver reliable, affordable and sustainable energy around the world.

From extensive consultation and engagement with our customers, to developing and delivering integrated energy solutions, we take our responsibility as a trusted energy partner seriously.

In Western Australia, where we own and operate the state's largest natural gas network - delivering natural gas to more than 750,000 homes and businesses is our priority.

We recognise that the delivery of stable and affordable energy is critical to Western Australia's growth, and importantly, our customers are telling us that gas will continue to play a key role as part of their energy mix.

With this in mind, our strategic priority remains the delivery of services that our customers value now, and into the future. We envisage the evolution of a cleaner, more competitive and customer centric energy system, while also acknowledging that successfully navigating to this future state will be complex and challenging.

The investment planning process for energy networks used to be relatively simple, based on predictable long-term forecasts with little competition for services. Today, planning needs to consider a range of complex policy drivers, rapid technological change and an increasingly empowered customer base. It is therefore imperative that energy services companies incorporate this broader set of factors into their planning processes and business model design.

> This paper is part of our routine strategic surveillance and scenario planning program. We have published this paper to help Western Australian energy market participants understand, prepare and respond to an uncertain energy future.

ATCO is committed to actively working with policy makers, market participants, our customers and communities in navigating through this uncertain environment towards a stable, sustainable and affordable energy future for Western Australia.

$20B
in assets
(CAD)

88,000K
Electric power li

ATCO: GLOBAL, INTEGRATED & DIVERSIFIED

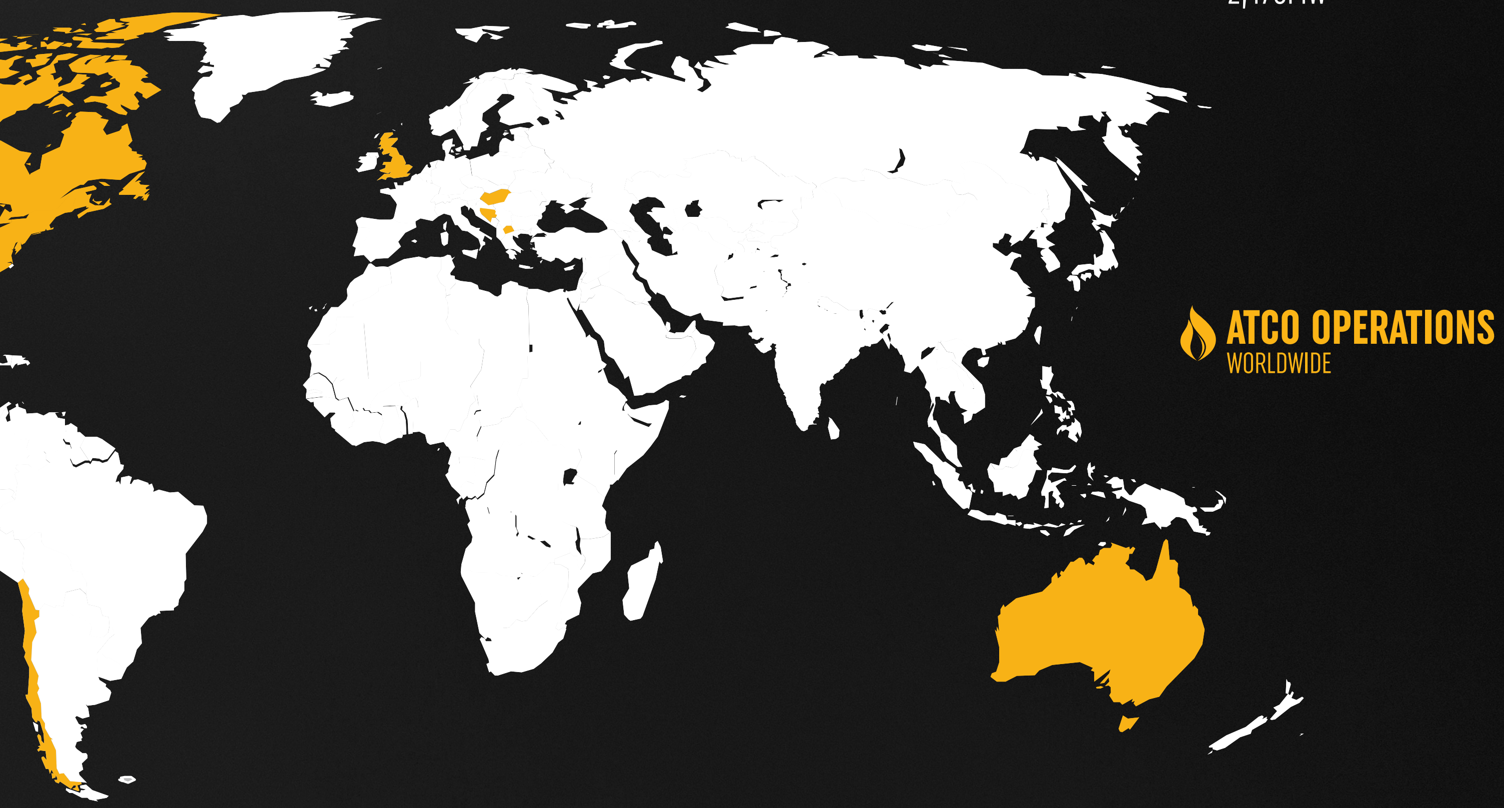
Approximately
7,000
employees

200,000M³
Hydrocarbon storage capacity

2M+
Global customers

100+
Countries in our 70-year history

18
Power plants with a combined generating capacity share of 2,473MW*



M
ines

7
Modular building Manufacturing facilities

52PJ
Natural gas storage capacity***

65,000KM
Natural gas pipelines

85,200M³/D
Water infrastructure capacity**

*megawatts **cubic metres per day ***petajoules

CONTENTS

EXECUTIVE SUMMARY

We are in the midst of an energy transformation as the economic, political and technological underpinnings of our energy supply change in rapid and unpredictable ways.

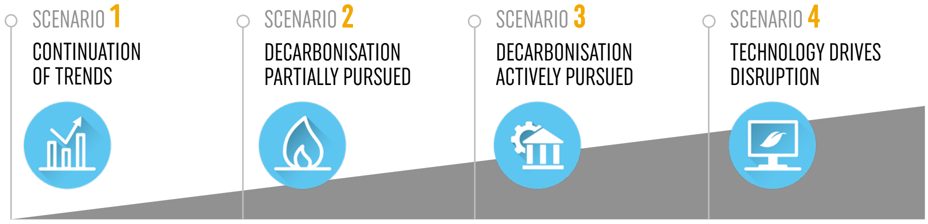


FIGURE 1: THE FOUR SCENARIOS

Traditional energy systems are transforming, and the needs of customers around the world and here in Western Australia are changing too. Given this landscape, the delivery of stable and affordable energy is critical to Western Australia's growth and ATCO is committed to engaging with market participants to develop opportunities that provide flexible, innovative solutions to support the economy now and into the future.

The publishing of this paper is an important step in this journey and is intended to help Western Australian energy market participants understand, prepare and respond to an uncertain energy future. To help address this uncertainty, we have used scenarios to contemplate a range of possible energy futures for Western Australia. Contemplating more than one future helps us resist the tendency to be locked into an outlook that is not adaptable to circumstances as they unfold. Using the Energy Networks Australia and CSIRO Network Transformation Roadmap (April 2017) as inspiration, we created four scenarios (Figure 1) with each describing a different economic, technological and policy environment in which we might find ourselves in.

This paper has been supplemented with insight from a series of customer forums held in late 2016 and early 2017. Our analysis also involved reviews of energy literature and industry thought leadership both nationally and internationally. The creation of the scenarios and related assumptions involved extensive energy market modelling to explore the impact on energy demand, network prices and capital investment.

The assumptions that underpin each scenario can be aggregated into three key factors of change – *energy policy*, *technological change* and *customer behaviour*.

Like most jurisdictions, the overarching global trend toward decarbonisation is shaping an increasingly complex national and local energy policy response. It is also a catalyst for innovation and the emergence and adoption of new technologies. Customers, who are now more empowered than ever before, are realising the value of these technologies and the environmental and cost benefits they provide.

FIGURE 2: KEY ASPECTS AND OUTCOMES OF SCENARIO 1 - CONTINUATION OF TRENDS

SCENARIO 1

CONTINUATION OF TRENDS

Under Scenario 1 the current trends regarding energy policy, power generation and energy use continue. A key and dominant feature of this scenario is the ongoing energy policy uncertainty at both the State and Federal levels. The key aspects and outcomes of this scenario are outlined in Figure 2.

WHAT WE IMAGINED

- Federal Government is not willing to employ market-based climate policy instruments.
- The existing renewable energy target is maintained, but there is a lack of clarity regarding the best strategy is to support the transition to a low carbon future.
- The possibility that energy and climate policy might change dramatically in future electoral cycles continues to play on the minds of investors.
- As a result, investment in large scale renewable energy projects is stifled in Western Australia.
- The Western Australian energy mix continues its progression towards lower carbon energy sources mainly as a result of growth in the adoption of residential and small scale commercial photovoltaic (PV) solar.

WHAT WE FOUND

- Slow growth in retail electricity prices is partly due to average unit costs for the network falling as consumption grows at a faster pace than network expenditure.
- The slow growth in electricity retail prices leads to consistent growth in residential electricity demand.
- Gas retail prices decline and residential gas consumption increases. This, combined with a growing population, results in an increased number of residential connections to the gas network and an increase in residential gas consumption overall.
- Residential customers continue to use natural gas in the same way they do now- primarily for cooking and water heating.
- While the cost of supplying gas remains relatively constant, the retail gas price is quite low, encouraging greater consumption.

WHAT IT MIGHT MEAN

- The lack of large-scale renewable energy investment is expected to constrain Western Australian retailers in procuring large-scale renewable energy certificates locally.
- As a result we expect to see a flow of capital from Western Australia to the eastern states.
- The residential gas supply industry comes under a small amount of margin pressure towards the end of the modelling period even though the impact of disruptive forces on the energy sector is not as strong as that under the other scenarios.
- Residential gas customers enjoy comparatively low prices, without significant risk of their suppliers coming under so much pressure that they consider exiting the market.

SCENARIO 2
DECARBONISATION PARTIALLY PURSUED

Under Scenario 2, intermittent renewable energy growth is supported by a boom in natural gas-fired firming capacity, which is used as a low emissions alternative to coal-fired generated electricity and as a means of supporting Western Australia's transition toward a renewable energy-based grid. The key aspects and outcomes of this scenario are outlined in Figure 3.

FIGURE 3: KEY ASPECTS AND OUTCOMES OF SCENARIO 12 - DECARBONISATION PARTIALLY PURSUED

WHAT WE IMAGINED

- The Western Australian Government plays a more active role in energy policy. The continued Federal energy policy uncertainty prompts the State Government to adopt its own state-based renewable energy target- 50% renewable energy generation by 2050.
- Regulatory and grid connection barriers are removed and renewable energy investment increases.
- The energy mix moves toward lower carbon energy sources as a result of the state-based renewable energy target, continued uptake of rooftop solar PV, and indirectly to increased use of natural gas to support intermittent renewable generators.

WHAT WE FOUND

- Similarly to Scenario 1, retail electricity prices continue toward a more cost-reflective price.
- Residential electricity demand rises in response to slow growth in retail electricity prices.
- The cost of supplying gas increases, which is driven by an increase in wholesale gas prices due to a rapid increase in the demand for wholesale gas.
- The continued competition in the retail gas market maintains downward pressure on retail gas margins.
- As the retail gas prices decline we see residential gas consumption rise.
- Substituting natural gas with electricity in a highly competitive retail environment results in continued falling gas prices.
- The use of gas as an enabling fuel and resulting higher wholesale natural gas prices, causes wholesale electricity prices to increase sharply just after the state-based renewable energy target is introduced.

WHAT IT MIGHT MEAN

- The declining demand for residential gas, coupled with an increasing cost of supply places pressure on gas retailers.
- The retail gas margin decreases rapidly, falling below the sustainable long-term benchmark of 25% by 2024.
- The proportion of gas revenue collected from residential customers decreases and is replaced in part by growth in commercial and industrial customers.
- The transition toward a clean energy future within a fractured policy environment creates sub-optimal, and unintended outcomes for the gas sector.
- The unintended outcomes of this scenario highlights the need for any emissions reduction policy to be developed in a way that considers interactions with other policies, technological and engineering constraints, market behaviours, and customer preferences.

SCENARIO 3

DECARBONISATION ACTIVELY PURSUED

Under Scenario 3, the Federal Government pursues decarbonisation to meet Australia's commitments under the Paris Agreement. This results in aggressive policy measures that force the investment in and uptake of renewable sources of energy, despite them remaining a higher cost option. The key aspects and outcomes of this scenario are outlined in figure 4.

FIGURE 4: KEY ASPECTS AND OUTCOMES OF SCENARIO 3 - DECARBONISATION ACTIVELY PURSUED

WHAT WE IMAGINED

- The Federal government establishes a transparent and stable emissions reduction mechanism. The WA State Government follows other states and adopts an ambitious target of 100% renewable energy by 2050.
- Rapid regulatory reform occurs in WA along with the adoption of a constrained network access framework. Full retail contestability is also introduced giving customers greater choice in where they buy their power.
- Policy changes and reforms are flagged to the market in a timely manner allowing industry investors to respond accordingly.
- Gas distribution networks are adapted to allow low emissions biogas followed by hydrogen gas by 2050.
- The energy mix shifts towards lower carbon energy, and battery storage costs fall to a point where enabling renewable energy technologies start to become economically viable in residential and commercial applications.

WHAT WE FOUND

- Residential electricity demand flattens as prices rise, while retail gas prices initially rise, then fall.
- Small-use customers reduce their grid consumption of electricity, but most remain connected for backup and security purposes.
- The state-based renewable energy target drives an increase in grid capital expenditure to support the rapid inflow of large-scale renewables.
- Retail electricity prices increase by approximately 20% between 2018 and 2030. This rise is driven by both an increase in the cost of supply and a reduction in electricity demand.
- As prices rise, customers look to substitute grid-supplied electricity with cheaper energy sources.
- Towards the end of the modelling period, we see the beginning of a vicious circle, as demand for grid supplied electricity decreases and electricity prices continue to rise.
- The regulated retail gas price initially increases, then begins to decrease until it plateaus between 2027 and 2030.

WHAT IT MIGHT MEAN

- The coal-fired generation industry ceases to exist under this scenario as a result of strong government prohibitions against that form of supply.
- The large- scale renewable energy industry thrives.
- The electricity network is not seriously threatened by the policy push towards alternatives, although it is likely under this scenario that it would need to move towards pricing structures that are not based on energy throughput.
- As retail gas prices fall and the average cost of supplying gas to residential customers increase, we see retail gas margins fall. However, these margins are still relatively healthy in a competitive landscape.
- Hence, we can conclude that even with policy disruption and an increased capital cost to convert the network to hydrogen by 2050, that residential gas supply will remain competitive in the short to medium term.

FIGURE 5: KEY ASPECTS AND OUTCOMES OF SCENARIO 4 - TECHNOLOGY DRIVES DISRUPTION

SCENARIO **4**

TECHNOLOGY DRIVES DISRUPTION

Under Scenario 4, disruptive technologies are aggressively pursued and become cost competitive with conventional power supply options. Households and businesses generate and store power and effectively manage their own energy needs. This changes the traditional role of generators, network operators and retailers and the services they provide. The key aspects and outcomes of this scenario are outlined in figure 5.

WHAT WE IMAGINED

- Rapid regulatory reforms remove barriers to entry for disruptive technologies and in turn, they are aggressively pursued and adopted.
- In WA, reforms include the implementation of a constrained network access framework and full retail contestability. This drives healthy competition and rapid innovation in the electricity sector.
- Wholesale electricity market reforms and digital technologies allow aggregated behind–the-meter solutions to be dispatched as if they were larger, centralised generators.
- Smaller scale stand-alone power systems are further facilitated by peer-to-peer trading using the distribution network infrastructure.
- Renewable technologies become increasingly cost-competitive compared to conventional sources.
- Customers change their consumption patterns through the use of integrated smart appliances or operate 'off the grid' by generating and storing their own energy.

WHAT WE FOUND

- In the wholesale electricity market, demand slows and prices do not increase at the same level as under the other scenarios.
- High residential electricity prices are driven by an increase in the cost of supplying electricity and a reduction in the customer base as people increasingly defect from the grid, particularly its transmission backbone.
- A vicious circle between electricity prices and demand emerges, as retail gas prices slowly decline.
- The retail gas price initially increases until 2021, but then rapidly declines between 2021-2022, before flattening between 2022 and 2030.
- A $1Bn investment (over 5 years) will be required to convert the existing network to carry hydrogen by 2030 and will result in an increase in the cost of supplying gas.

WHAT IT MIGHT MEAN

- The key implication of technological disruption for the traditional supply industry is that it reduces the demand for electricity supplied through the transmission network and fundamentally changes the traditional roles of both the electricity network operator and electricity retailers.
- It is easy to imagine today's electricity network starting to disaggregate under such a scenario to form a number of smaller, islanded networks.
- For the residential gas supply industry, technological disruption increases supply costs, so that the retail gas margin converges towards, but does not fall below, what we assume to be the sustainable long-term benchmark retail margin of 25%.
- Despite the significant investment in the distribution network to convert it to biogas and hydrogen, and ongoing competition in the retail sector, gas retailers remain viable over the modelling period.

The summary table in figure 6 compares the four scenarios across several key metrics. Understanding the complexity of the energy system as a whole, it is not surprising there is no 'one size fits all' solution to the challenges we are facing. Each scenario will have its own winners and losers, and it is the responsibility of policymakers and industry players to balance the long-term needs of customers, investors and the environment.

FIGURE 6: SCENARIO SUMMARY TABLE

MOST FAVOURABLE (blue)
LEAST FAVOURABLE (grey)

	SCENARIO 1 Continuation of trends	SCENARIO 2 Decarbonisation partially pursued	SCENARIO 3 Decarbonisation actively pursued	SCENARIO 4 Technology drives disruption
Carbon emissions reduction: *Paris Agreement commitments*	Unlikely to achieve Paris Agreement	Less likely to achieve Paris Agreement	Likely to achieve Paris Agreement	Likely to achieve Paris Agreement
Energy Forecasts for the WEM (**GWh**)	**21587**	**21587**	20148	**17958**
Residential Retail Electricity Price (**c/kWh**)	**33.2**	33.9	34.4	**37.0**
Residential Retail Gas Price (**c/kWh**)	**11.6**	12.1	**14.4**	13.0
Residential Gas Demand (**GWh**)	**3431.1**	3391.0	**3148.0**	3345.5
Wholesale Gas Prices (**$/Gj**)	2.88	**5.08**	3.71	**2.03**
WA Balancing Market Wholesale Electricity Price (**$/MWh**)	75.54	**87.41**	55.87	**46.47**
Estimated gas retail margin (**%**)	23%	**6.9%**	28.3%	**29.5%**
Carbon Prices (**$/t**)	0.0	13.5	47.7	0.0
Large scale renewable energy as % of wholesale generation (**%**)	21.6%	26.6%	**45.3%**	**18.2%**
Electricity Network CAPEX profiles (**$ million**)	473.0	497.5	**563.0**	**452.9**
Gas Distribution Network CAPEX profiles (**$ million**)	**101.2**	111.2	139.6	**272.8**

Each scenario will have its own winners and losers, and it is the responsibility of policymakers and industry players to balance the long-term needs of customers, investors and the environment.

INTRODUCTION

> Although we can't stop change from occurring, we can plan for how we respond and take advantage of it.

The purpose of this paper is to help Western Australian energy market participants understand, prepare and respond to an uncertain energy future.

To do this, we have imagined four future energy scenarios for Western Australia between 2018 and 2030. The scenarios are not intended to predict Western Australia's energy future, but instead to stimulate thinking and foster discussion with and between customers, market participants and policy makers.

This paper has been supplemented with insight from a series of customer forums held in late 2016 and early 2017. Our analysis also involved reviews of energy literature both nationally and internationally. The creation of the scenarios and related assumptions involved extensive energy market modelling to explore the impact on energy demand, network prices and capital investment.

By exploring these scenarios, we will learn more about potential impacts on our energy market, our customers and how market participants and policy makers might respond to future changes.

SCENARIO 1
CONTINUATION OF TRENDS

SCENARIO 2
DECARBONISATION PARTIALLY PURSUED

SCENARIO 3
DECARBONISATION ACTIVELY PURSUED

SCENARIO 4
TECHNOLOGY DRIVES DISRUPTION

THE WESTERN AUSTRALIAN ENERGY LANDSCAPE:
A SECTOR IN CHANGE

The Western Australian energy sector is experiencing a period of unprecedented change. Energy policy, technology and customer behaviour are key factors that will influence the future energy landscape.

How do energy market participants and policy makers address Australia's energy trilemma, stimulate investment in new technology and help contribute toward a more sustainable future?

A number of uncertainties are influencing the Western Australian energy landscape. Like most jurisdictions, the overarching global trend toward decarbonisation is shaping an increasingly complex national and local energy policy response. It is also a catalyst for innovation and the emergence and adoption of new technologies. Customers, who are now more empowered than ever before, are realising the value of these technologies and the environmental benefits they provide.

ENERGY POLICY

Recognition of the risks presented by global warming and the drive to decouple emissions from economic activity, is shaping public policy and potentially the structure of the energy sector. The Paris climate agreement resulted in 197 countries, including Australia, demonstrating a commitment to reduce greenhouse gas emissions. Many industry commentators believe that a united approach will be required from both the private sector and all levels of government if Australia is to achieve its commitment.

However, energy and climate change represent two of the most politically contested areas of public policy in Australia. For example, the introduction and subsequent removal of a carbon pricing mechanism is one example of how the nation's approach to decarbonisation has shifted across electoral cycles. Policy uncertainty adds further complexity to challenges faced by energy utilities when trying to balance the three elements of the energy trilemma (see figure 7).

Western Australia's Minister for Energy, Ben Wyatt, has indicated that a nationally consistent approach to supporting renewable energy uptake would provide the best conditions for investor confidence in the energy sector. In this regard, the Federal Government recently announced that a National Energy Guarantee policy would be pursued in lieu of the Clean Energy Target originally proposed by the Chief Scientist. While the National Energy Guarantee concept has received support from some market commentators, the challenge of aligning all stakeholders remains significant.

For example, the National Energy Guarantee's successful implementation will require the support of Australian States and Territories, and recent indications are that this may not be forthcoming.

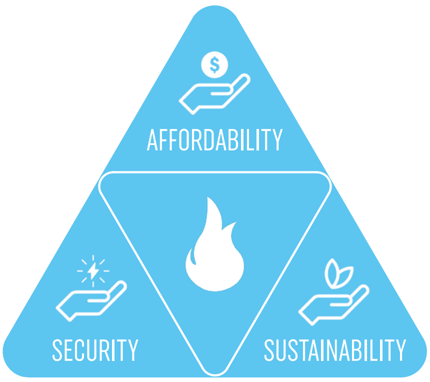
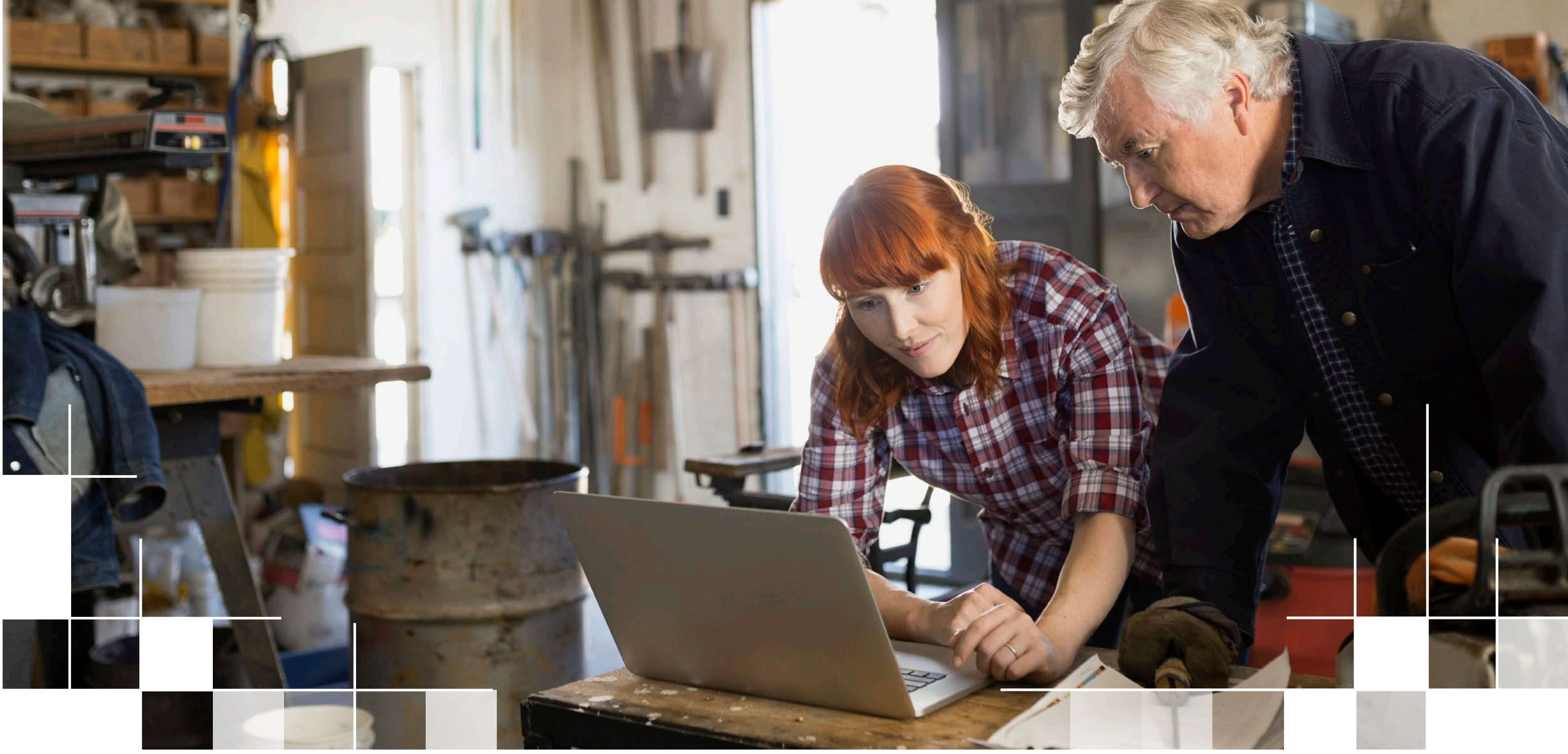


FIGURE 7: THE ENERGY TRILEMMA



> This [the National Energy Guarantee] is a welcome change for a few reasons. Firstly, it marks a well-needed shift away from reviews and interventions, and signals a reliance on the market to derive the future generation mix. Secondly, it hits the security limb of the energy trilemma directly. These two factors combined will provide certainty to the market to lock in strategies around the provision of new capacity. Like any policy, there will be winners and losers. We expect mass market retailers, who bear the brunt of the obligations and guarantees, to be negatively impacted by the changes, as well as the renewables development industry. Gas power will play a much more significant role in providing system security under this policy, putting continued pressure on the availability of well-priced domestic natural gas supply. While not yet announced, we expect to see a growing focus by regulators on generation bidding behaviour as well as network prices over the next 12 months, as state and federal governments drill further into affordability as a key cost of living issue for households.
>
> **Matt Rennie**
> EY – Oceania Power & Utilities Leader

Continued policy uncertainty will reduce the willingness to invest in long-lived energy sector assets, including both fossil fuel and renewable energy infrastructure.

> What are the technologies that will make a difference in realising a cleaner energy future?
>
> Will they be provided by new entrants to market?
>
> Will consumers embrace them at the outset, or wait until they become more affordable?

TECHNOLOGICAL CHANGE

Western Australians are custodians of world class renewable energy resources and have the scientific and engineering capability to transition to a clean energy economy in a carbon-constrained world.

Consequently, Western Australia enjoys a significant comparative advantage in 'clean energy production' and is well positioned to respond to recent global trends toward renewable energy investment, technological innovation and cost reduction.

There are also a range of new technologies that offer substantially reduced greenhouse gas emissions while maintaining the safety, reliability and security of energy supply. The public policy response to climate change combined with these technologies is creating new markets with the potential to disrupt traditional energy business models.

The future direction of technology and its adoption is hard to model and thereby uncertain. For example, natural gas is produced in greater quantities today than it was five years ago because of technological advances in hydraulic fracturing. However, there is uncertainty over the rate at which greenhouse gas emitting fuels like natural gas will be replaced by very low emission or renewable alternatives.

Ultimately however, as clean energy technologies become cost competitive, or even substantially cheaper than conventional alternatives, it is likely that market forces will accelerate their adoption. In particular, the increasing commerciality of energy produced from renewable sources will have significant, but also somewhat unpredictable, impacts on the energy sector.

How will customers respond to new technology that offers increased efficiency and affordability, a lower carbon footprint and the ability to generate energy for both personal use and trading?

Will they defect from traditional utilities and respond positively to new entrants to market?

CUSTOMER BEHAVIOUR

Changing customer behaviour and preferences will play an important role in defining the future Western Australian energy technology and policy landscape. Customer choices will no longer be based purely on affordability and reliability as an increased awareness of climate change creates new markets for environmentally sustainable energy.

Customer sentiment can be both a cause and effect of technological and policy change. The development of new technologies gives customers a range of new choices over their energy supply options. Conversely, customer demand for new technologies can focus the efforts of government on supporting the commercialisation of these opportunities or alternatively, removing regulatory barriers to their adoption. Changing preferences can also have natural flow-on effects, where these new technologies are increasingly embraced as they become more familiar due to the consumption choices of others.

In Western Australia, the rapid uptake of residential rooftop solar and the installation of the first Tesla Powerwall battery indicate that customers are already embracing new energy solutions outside those provided by a traditional utility. Existing energy players are compelled to respond to this changing demand, not only by delivering affordable, safe and reliable energy solutions, but by delivering new energy solutions that are innovative, efficient and environmentally friendly.

Based on consistent feedback from our customers, ATCO is embracing this change and has taken the first steps in the journey through the development of our 'GasSola' solution as shown in Figure 8. This system combines photovoltaic (PV) solar panels, battery storage and a gas powered generator.

Until recently, achieving an energy supply package that provided both reliability and environmental sustainability came at a price that only some customers were willing to pay. However, the cost of renewable energy has been in rapid decline for many years now, and a number of recent energy procurement auctions have resulted in renewable energy solutions outbidding competing gas generators for energy supply contracts.

It is clear that the time will come when low emissions technologies are able to consistently provide a reliable energy supply at a lower cost than fossil fuel based options, at which stage we may see a 'tipping point' as traditional fossil fuel assets become stranded. The risk that this may happen soon is driving some of the uncertainty in energy markets. Holders of long-lived traditional energy assets are assessing their capital investment programs and engaging in scenario planning as a response.

Uncertainty over the timing and nature of a transition away from fossil fuel technologies may dampen investment incentives well before the transition occurs, with the reduction in supply impacting customers in the short term from both price and reliability perspectives.

FIGURE 8: ATCO'S GASSOLA SOLUTION

IMAGINING OUR ENERGY FUTURE

We have imagined four future energy scenarios for Western Australia. By analysing these scenarios, we hope to learn more about their potential impact on our energy market, the customers in that market, and how market participants and policy makers might respond.

WHY SCENARIOS?

The investment planning process for energy networks used to be relatively simple, based on predictable long-term forecasts with little competition for services. With disruption an almost everyday occurrence, our planning process has evolved, considering a wider range of policy, technological and customer trends.

This paper is an output of our routine strategic surveillance program and scenario planning. Using scenarios allows us to contemplate a range of conceivable futures, and helps us resist the tendency to be locked into an outlook that is not adaptable to changing circumstances.

We have developed four future energy scenarios that describe different economic, technological and policy environments in which WA energy market participants, including ATCO, might find themselves. The scenarios were developed from energy market modelling[1] that explores the impact on energy demand, network prices and capital investment.

[1] *The approach to the market modelling is included in the appendix to this paper*

THE SCENARIOS

SCENARIO 1: CONTINUATION OF TRENDS

This scenario assumes no meaningful change to the current WA energy landscape. It assumes recent disruptive influences on the WA energy sector continue at their current rate.

SCENARIO 2: DECARBONISATION PARTIALLY PURSUED

This scenario assumes rapid growth in large-scale renewables, and a policy/ technological choice to support that growth through an increased reliance on gas-fired technologies.

SCENARIO 3: DECARBONISATION ACTIVELY PURSUED

This is predominantly a 'policy push' scenario, where governments take a hard stand on forcing rapid emissions reductions, including a State Government 2050 target of 100% renewables.

SCENARIO 4: TECHNOLOGY DRIVES DISRUPTION

This is predominantly a 'technology pull' scenario, where rapid improvements in low emissions technologies and associated cost reductions outpace the need for early government intervention to meet carbon reduction targets.

SCENARIO 1
CONTINUATION OF TRENDS

Under this scenario, the current trends regarding energy policy, power generation and energy use continue. A key feature is the ongoing energy policy uncertainty at both the State and Federal levels.

Slow growth in electricity retail prices leads to consistent growth in residential electricity demand, as gas retail prices decline and residential gas consumption increases.

WHAT WE IMAGINED

The dominant theme of this scenario is one of continuing energy policy uncertainty at the Federal level. While the existing renewable energy target is maintained, it is unclear what the best strategy is to support the transition to a low carbon future.

Under this scenario, the Federal Government is not willing to employ market-based climate policy instruments such as a carbon price, or more prescriptive interventions such as prohibitions on internal combustion engines or coal-fired power stations. Similarly, under tight fiscal environments at both the State and Federal levels, and continuing political contest over how Australia will meet its international climate change commitments, incentive-based mechanisms such as subsidisation of electric vehicles and expanded renewable energy support schemes remain difficult to implement and sustain.

The possibility that energy and climate policy could change dramatically in future electoral cycles continues to play on the minds of investors and energy industry players that are considering investing capital into long-lived assets.

This uncertainty at the Federal level is coupled with regulatory and electricity grid connection barriers at the State level which continues to stifle investment in Western Australian-based large-scale renewable energy projects. Retail electricity prices in Western Australia continue to increase towards a condition of cost reflectivity, as State Government subsidies for most residential and small-scale commercial customers are removed.

In this scenario, the Western Australian energy mix continues its progression towards lower carbon energy sources mainly as a result of growth in adoption of residential and small scale commercial solar PV. Battery storage costs continue to fall in line with current trends, although the technology is not a cost-effective option for the majority of residential and commercial customers who have installed solar panels.

WHAT WE FOUND

As shown in figure 9, the quantity of electricity demanded continues to grow in line with current trends due to the lack of cost-effective energy storage solutions, even though growth in solar PV uptake flattens peak electricity demand.

As shown in figure 10, the real retail electricity price increases by about 15% over the modelling horizon. This slow growth in retail electricity prices is partly due to average unit costs for the network falling as electricity consumption grows at a faster pace than network expenditure. Further driving this slow growth is comparatively-low augmentation or growth-related capital-expenditure in the electricity network under this scenario, as a result of flattening peak demand and relatively modest renewable energy uptake.
The retail cost of electricity under this scenario increases in line with the slow growth in capital expenditure related network costs, which rise from 38% of total cost in 2018 to 45% of total cost in 2030.

Continued competition in the retail gas market maintains downward pressure on retail gas prices, which

FIGURE 9: OPERATIONAL ENERGY FORECASTS FOR THE WESTERN AUSTRALIAN WHOLESALE ELECTRICITY MARKET

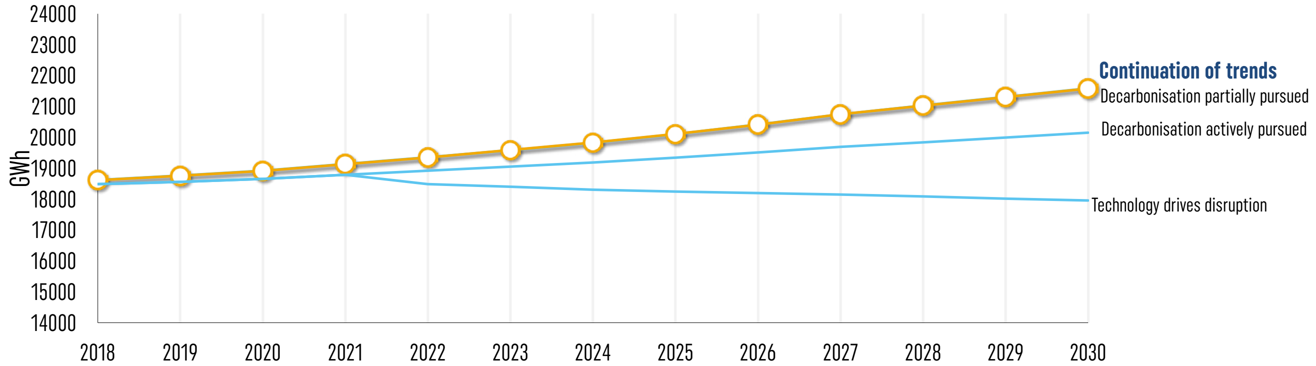
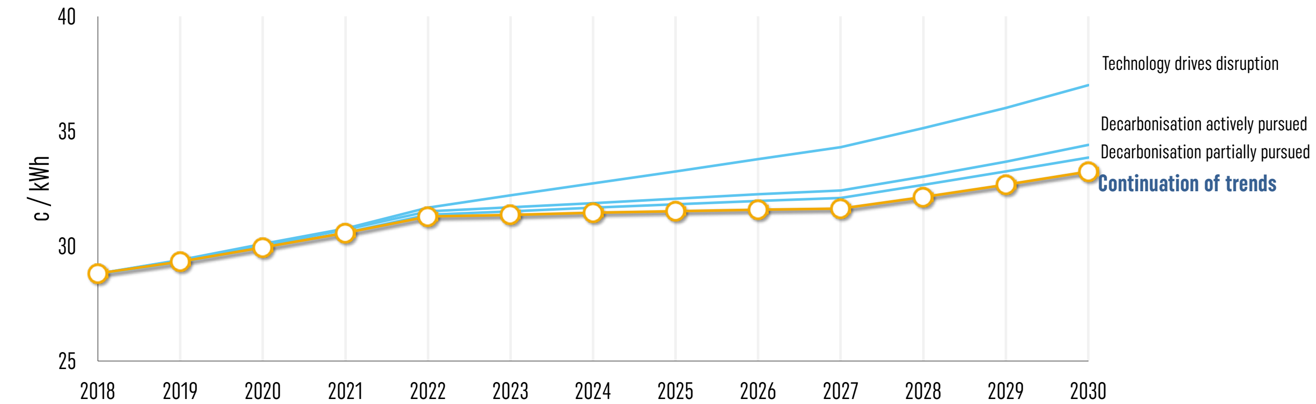


FIGURE 10: RESIDENTIAL RETAIL ELECTRICITY PRICE



fall by approximately 31% over the model period. Falling gas prices and a growing population result in an increased number of residential connections to the gas network and an increase in residential gas consumption overall. Residential customers continue to use natural gas in the same way they do now, primarily for cooking and water heating.

We observe that there is a slight increase in the upstream costs that retailers incur in supplying gas to residential customers under this scenario. This is driven by a small increase in wholesale gas prices from about $5.83 /GJ in 2018 to $8.06/GJ in 2030 in real terms.

The distribution and transmission network components of this cost remain relatively constant, with the latter increasing by only 3% over the model period due to limited growth in related capex.

While the cost of supplying gas remains relatively constant, the retail gas price is quite low under this scenario (see figure 11) which encourages greater consumption. The level of residential gas demand is the highest across the four scenarios (see figure 12).

SCENARIO 1 CONTINUATION OF TRENDS

WHAT IT MIGHT MEAN

The lack of large-scale renewable energy investment under this scenario constrains the ability of WA retailers, including Government-owned trading enterprises, to procure large-scale renewable energy certificates locally. This results in a flow of capital from WA to the eastern states. Energy policy uncertainty also makes the viability of long-term investments in coal plants questionable.

The residential gas supply industry comes under a small amount of margin pressure towards the end of the modelling period (see figure 13), even though the impact of disruptive forces on the energy sector is not as strong as that under the other scenarios. The retail gas margin reduces from 53% in 2018 to 23% in 2030. This may not be a major concern, as the retail

FIGURE 11: RESIDENTIAL RETAIL GAS PRICES

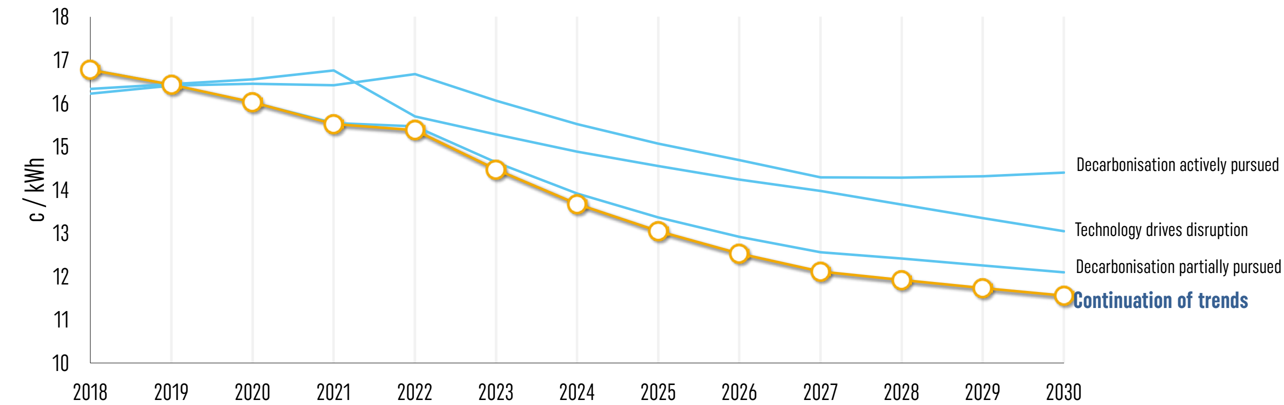
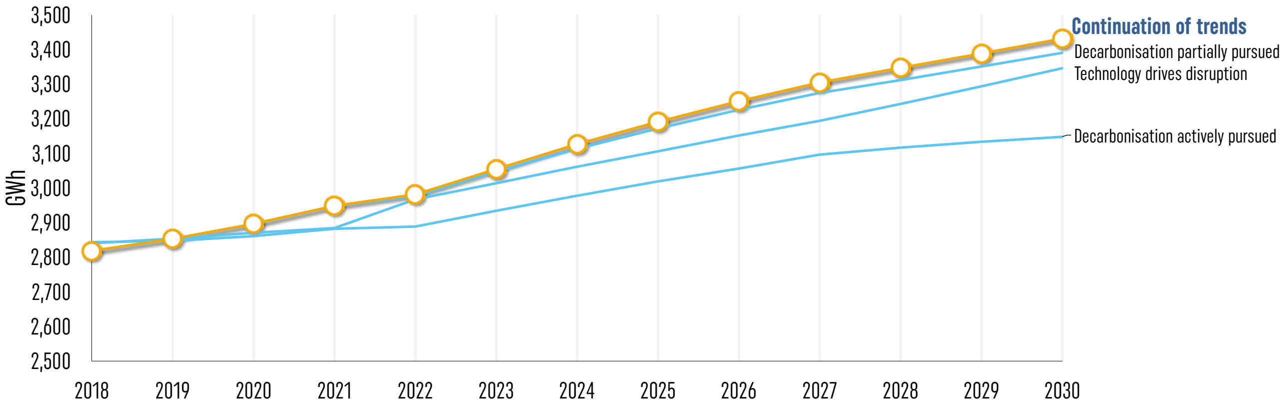


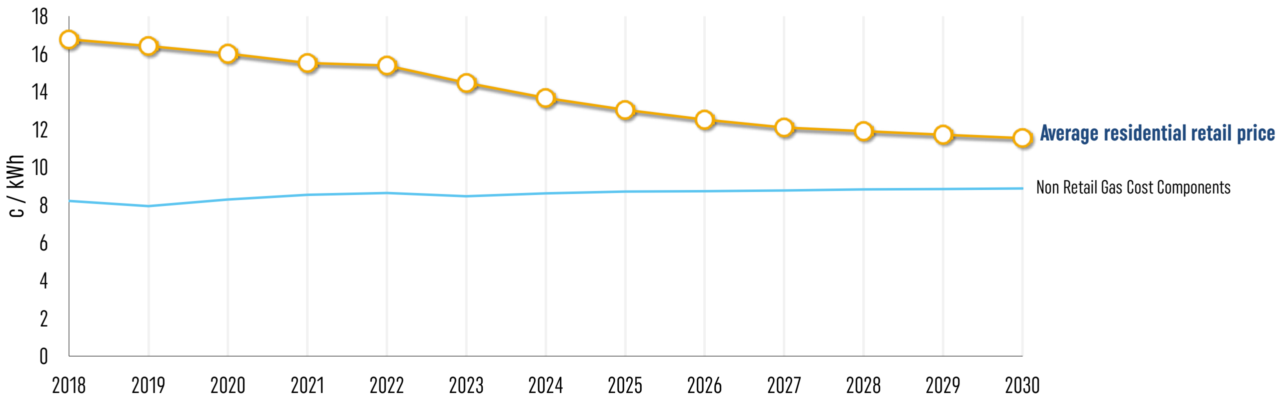
FIGURE 12: RESIDENTIAL GAS VOLUMES DEMANDED



gas margin remains above the sustainable long-term benchmark of 25% for the majority of the modelling period and is supported by relatively high demand. Historical data relating to retail gas suggests that there is a degree of allowable variation in the retail gas margin that the industry can withstand. Retail margins have fluctuated from as little as 3% in 2008 to 45% in 2011.

So, residential gas customers enjoy comparatively low prices under this scenario, without significant risk of their suppliers coming under so much pressure that they consider exiting the market. Overall, this scenario highlights the need for resilient energy solutions which have the capacity to adapt and respond in an uncertain, highly regulated and changeable policy environment.

FIGURE 13: RETAIL GAS PRICE & NON RETAIL GAS COST COMPONENTS



SCENARIO 2
DECARBONISATION PARTIALLY PURSUED

Under this scenario, intermittent renewable energy growth is supported by a boom in natural gas-fired firming capacity, which is used as a low emissions alternative to coal-fired generated electricity and as a means of supporting Western Australia's transition toward a renewable energy-based grid.

The Western Australian Government plays a more active role in the energy policy space.

Residential electricity demand rises in response to slow growth in retail electricity prices, while retail gas prices decline and residential gas consumption rises.

WHAT WE IMAGINED

Under this scenario, continued Federal energy policy uncertainty prompts the Western Australian Government to adopt its own state-based renewable energy target, pursing 50% renewable energy generation by 2050. To enable this, regulatory and grid connection barriers are removed resulting in an increase in renewable energy investment. This investment translates into a steady and rapid increase in Western Australia's renewable energy generation capacity. Policy changes, while moderate and relatively slow, are flagged to the market well ahead of their implementation, so that investors, particularly in flexible, gas-fired peaking plants, can respond accordingly.

Similar to Scenario 1, retail electricity prices continue to increase toward a more cost-reflective price, while continued competition in the retail gas market maintains downward pressure on retail gas margins.

Battery storage costs continue to fall in line with current trends. However, storage technology is not a cost-effective option for the majority of residential and commercial customers who have installed solar panels, and so firming capacity comes from flexible, natural gas generators.

The energy mix moves toward lower carbon energy sources, not only as a direct result of the state-based renewable energy target and continued uptake of rooftop solar PV but also indirectly as a result of increased use of natural gas to support intermittent renewable generators. In combination, renewables and natural gas take significant market share away from coal-fired generators under this scenario.

WHAT WE FOUND

In this scenario, we see an increase in the cost of supplying gas, which is driven by a 117% increase in wholesale gas prices (figure 14). This increase is mainly due to a rapid increase in the demand for wholesale gas as:

- Tri-generation and co-generation technology evolves and is increasingly adopted at the large-scale commercial and industrial levels,[2] resulting in an increase in the wholesale customer base.
- High carbon-emitting industries, such as those in the mining industry use natural gas as their primary source of backup generation.
- Gas provides a source of dispatchable generation to meet network security requirements as renewable energy penetration increases.

The use of gas as an enabling fuel and the resulting higher wholesale natural gas prices, causes wholesale electricity prices to increase sharply (figure 15) just after the state-based renewable energy target is introduced.

[2] Co-generation and tri-generation technologies improve the efficiency of fuel use by generating electricity and useful heat at the same time as part of an integrated process.

FIGURE 14: WHOLESALE GAS PRICES

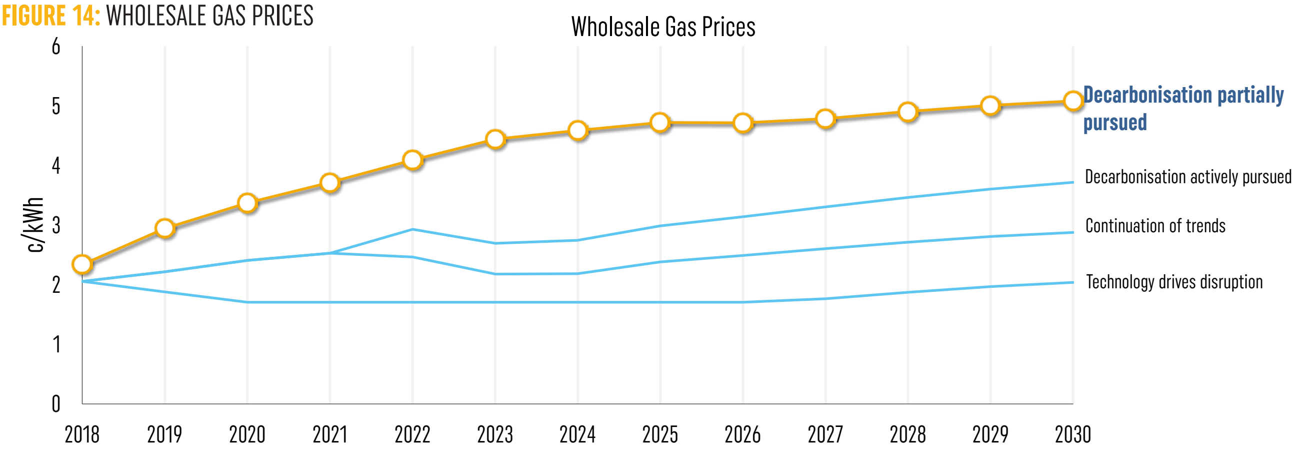
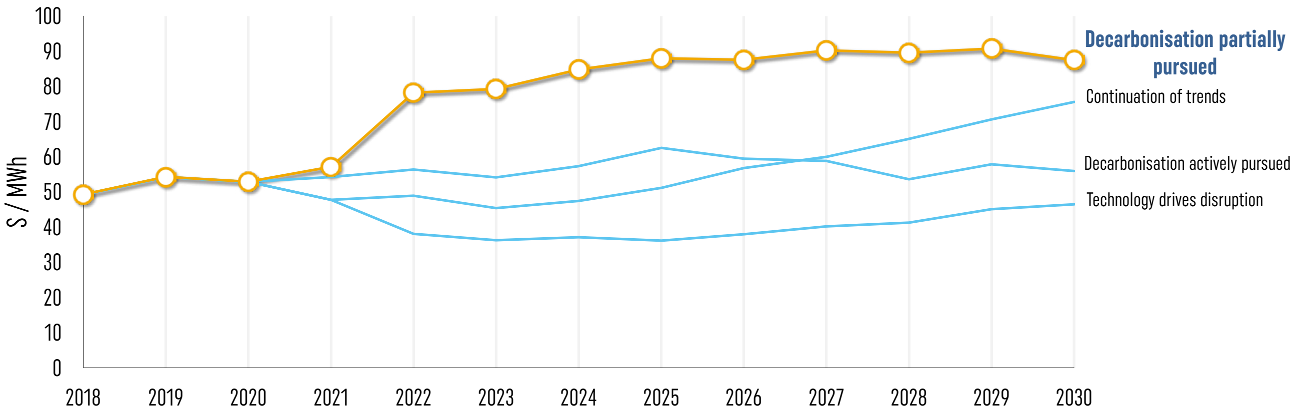


FIGURE 15: WESTERN AUSTRALIAN BALANCING MARKET WHOLESALE ELECTRICITY PRICE



The growth in PV uptake will place some downward pressure on peak electricity demand and normally this would lessen network augmentation requirements. However, under this scenario, the state-based renewable energy target drives an *increase* in electricity network augmentation-related capital expenditure, to support the inflow of large-scale renewables. The combination of high wholesale prices and growing network costs causes retail electricity prices to grow slightly faster in this scenario than they do under Scenario 1.

The increase in wholesale gas prices impacts gas retail prices more than electricity retail prices. As a result, there is gradual substitution away from the use of gas towards electricity, offsetting reductions in electricity demand due to increasing electricity retail prices. Residential customers continue to use gas for cooking and water heating, but increasingly rely upon electricity for space heating. The net effect is that residential electricity demand is similar to that under Scenario 1, even though

SCENARIO 2
DECARBONISATION PARTIALLY PURSUED

retail electricity prices are slightly higher when gas is used as an enabling fuel.

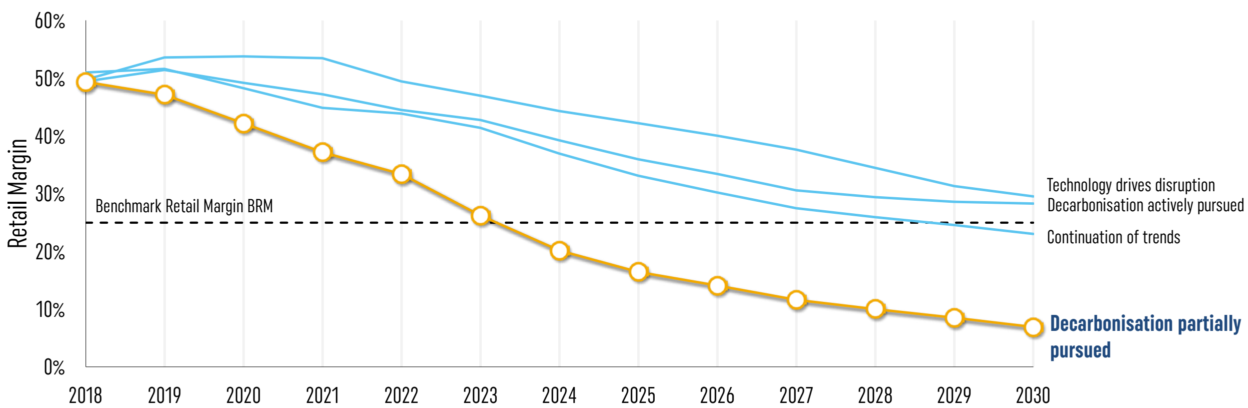
The trend of substituting natural gas with electricity in a highly competitive retail environment results in falling gas prices over the modelling period. Falling prices in turn leads to increased household connections to the gas network as population grows over the period, and so an increase in overall residential gas consumption, although at a declining average rate.

WHAT IT MIGHT MEAN

This scenario combines a falling demand for residential gas, with an increasing cost of supply driven by high wholesale gas prices. This results in significant pressure being placed on gas retailers. As a result, the estimated retail gas margin decreases rapidly and falls below the sustainable long-term benchmark of 25% by 2024 (see figure 16).

Under this scenario, the use of gas as a means of rapidly transitioning to a low carbon economy does not result in a favourable outcome for the residential gas supply industry. In this scenario, the existing high proportion of the gas supply industry's revenue that is currently collected from residential customers decreases, and is replaced to some extent by growth in revenue collected from commercial and industrial customers. While the industrial and commercial component of the gas distribution supply chain remains commercially sustainable, it is possible that the residential component may not without government intervention. It is likely residential

FIGURE 16: ESTIMATED RETAIL MARGIN VERSUS INDICATIVE BENCHMARK RETAIL MARGIN



customers would react negatively to the inconvenience of natural gas suppliers exiting the market. This may be of concern to government if demands are placed on them to subsidise residential gas prices to alleviate cost pressures, or to industry if government decides to manage the situation by implementing cross subsidies that put large gas users out of pocket.

In any case, there will be winners and losers under this scenario, and it shows that the transition toward a clean energy future within a fractured policy environment may create sub-optimal or unintended outcomes for the gas sector. It is therefore critical that emissions reduction policy be developed in a way that considers interactions between policies developed at different levels of government, technological and engineering constraints, market behaviours, and consumer preferences. In particular, action must centre on developing and implementing cohesive commonwealth and state government policies that recognise the need to deliver affordable, reliable and commercially-sustainable energy solutions.

SCENARIO 3
DECARBONISATION ACTIVELY PURSUED

Under this scenario, the Federal Government pursues decarbonisation to meet Australia's commitments under the Paris Agreement. This results in aggressive policy measures that force the investment in and uptake of renewable sources of energy, despite them remaining a higher cost option than conventional forms of power supply.

Aggressive regulatory reform and policy change

WHAT WE IMAGINED

Under this scenario, we imagine strong bipartisan support emerges at the Federal level to establish a transparent and stable emissions reduction mechanism. This may be in response to public pressure after a series of significant climate-related events or the threat of trade sanctions against nations that do not meet their emission reduction targets. This includes the introduction of a strong carbon pricing mechanism starting in 2021 to encourage the achievement of Australia's commitments under the Paris Agreement.

The Western Australian State Government follows the example of other Australian states and adopts an ambitious state-based renewable energy target, which aims to have 100% renewable energy generation by 2050. To achieve this, the state engages in rapid regulatory reform, adopting a constrained network access framework similar to that implemented in the National Electricity Market. This reform allows generators to connect to the network, even when there is insufficient network capacity for them to deliver their maximum output to demand nodes throughout the year. This removes grid connection barriers, which contributes to a renewable energy boom in the state. In addition to adopting a constrained network access framework, the Western Australian Government adopts full retail contestability, which gives customers greater power to choose who they buy their energy from. These aggressive policy changes and regulatory reforms are flagged to the market in a timely manner so that energy industry investors are able to respond accordingly.

A significant proportion of coal-fired generators voluntarily retire early, (i.e. at a faster rate than they do under scenarios 1 and 2) due to the increase in renewable generation capacity pushing them off the grid in the middle of the day. In addition, towards the end of the period, the government begins to mandate the *even earlier* closure of coal plants. The heavy government intervention in markets causes gross state product to grow at a slower rate than it does under the other scenarios.

Forced coal retirements send a signal to the gas-fired investment community that policy contagion may spread to their sector, in the form of direct restrictions on the use of natural gas beyond the modelling period. For similar reasons, gas distribution businesses start undertaking capital expenditure programs to allow the existing network infrastructure to carry low emissions gas- initially biogas, followed by hydrogen gas by 2050. This occurs in the context of an increasingly competitive Western Australian retail gas market.

In this scenario, largely due to the high carbon price (see figure 17) the energy mix progresses rapidly towards lower carbon energy sources, boosted by the aforementioned ambitious State and Federal renewable energy and emissions reduction targets, mandated closure of coal fired-generators, and rapid growth in residential and small-scale commercial solar PV uptake. Unlike scenarios 1 and 2, battery storage costs fall to a point where enabling renewable energy technologies start to become economically viable in residential and commercial markets towards the end of the modelling period.

WHAT WE FOUND

Our modelling for this scenario assumes the growth in solar PV uptake, coupled with the reduction in battery storage costs, results in reduced residential demand for electricity from the grid as well as a flattening of peak wholesale electricity demand. The effect is that, while small use customers reduce their consumption of electricity from the grid, most remain connected to the network for backup and security purposes. Although demand flattens, the state-based renewable energy target drives an increase in electricity network augmentation-related capital expenditure, required to support the rapid inflow of investment in large-scale renewables (see figure 18).

FIGURE 17: CARBON PRICES

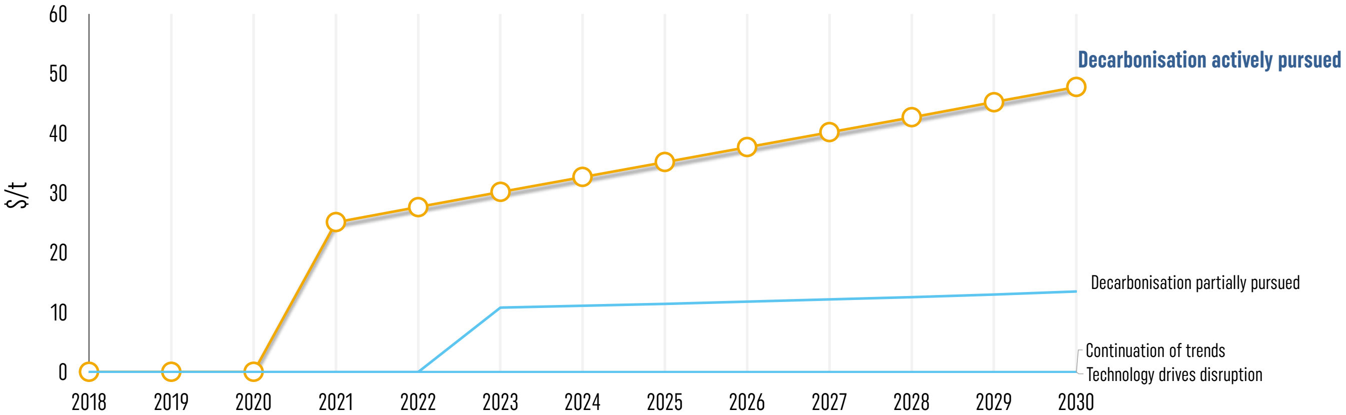
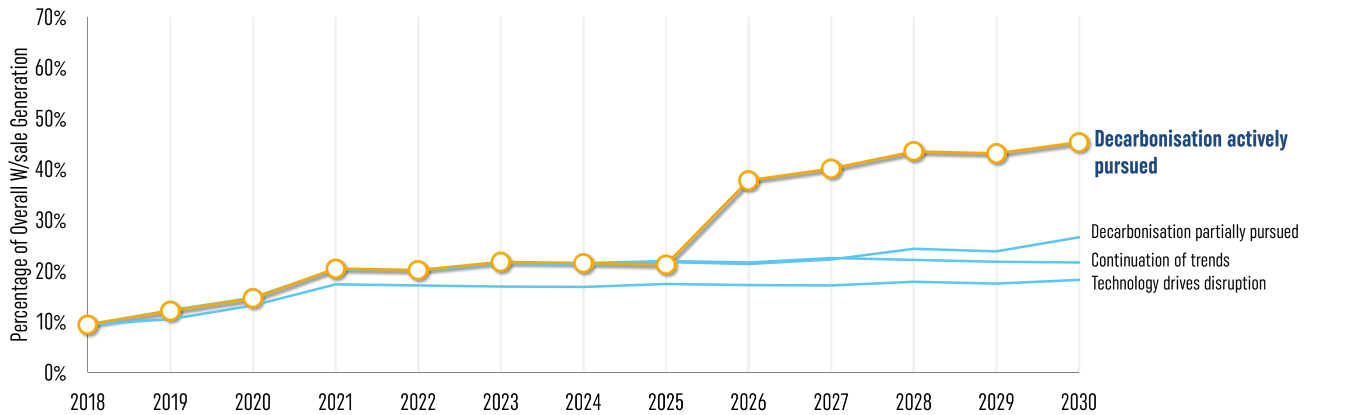


FIGURE 18: LARGE-SCALE RENEWABLE ENERGY AS A PERCENTAGE OF OVERALL WHOLESALE GENERATION



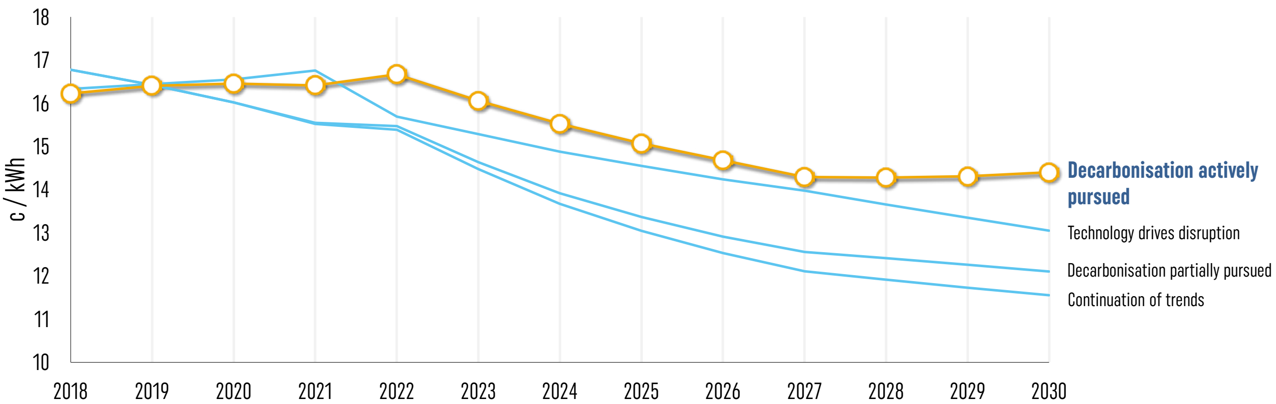
SCENARIO 3
DECARBONISATION ACTIVELY PURSUED

Residential electricity demand flattens as retail electricity prices rise, while retail gas prices initially rise then fall.

Retail electricity prices under this scenario increase by approximately 20% between 2018 and 2030. This rise is driven by both an increase in the cost of supplying electricity and a reduction in the quantity of electricity demanded. The increase in the cost of supplying electricity is largely induced by the strong climate policy interventions, and includes increases in network augmentation-related capital expenditure required to support the rapid uptake in renewables. There is an increased cost associated with supplying less energy, which drives up unit prices. As prices continue to rise, customers increasingly look to substitute grid-supplied electricity with cheaper energy sources. Towards the end of the modelling period, this results in what might be the beginning of a vicious circle, as demand for grid supplied electricity continues to decrease and electricity prices continue to rise.

While the regulated retail gas price initially increases, it then begins to decrease until it plateaus between 2027 and 2030 (see figure 19). The modelled gas price is driven by a rising electricity price, to which some consumers respond by increasing their gas consumption, and a slowing growth in gross state product, which reduces demand for all forms of energy. The relative influence of these two factors changes throughout the modelling period.

FIGURE 19: COMPARISON OF RESIDENTIAL RETAIL GAS PRICES



WHAT IT MIGHT MEAN

The implications of this scenario for many industry participants are self-evident in its description. The coal-fired generation industry, for example, ceases to exist under this scenario as a result of strong government prohibitions against that form of supply. On the other hand, the large-scale renewable energy industry thrives. The electricity network is not seriously threatened by the policy push towards alternatives, although it is likely under this scenario it would need to move towards pricing structures that are not based on energy throughput.

For the residential gas supply industry, it is worth noting that as retail gas prices gradually fall under this scenario, the average costs of supplying gas to residential customers increases, and as a consequence, retail gas margins fall from 49% in 2018 before plateauing to around 30% between 2028 and 2030. This is still a healthy margin in an increasingly competitive environment. The modelling results indicate that even with significant policy disruption and an increase in capital expenditure for hydrogen conversion, it is possible for the residential gas supply industry to remain competitive and commercial over the short to medium term.

SCENARIO 4
TECHNOLOGY DRIVES DISRUPTION

Under this scenario, disruptive technologies are aggressively pursued and become cost competitive with conventional power supply options. Households and businesses generate and store power and effectively manage their own energy needs. This completely changes the traditional role of generators, network operators and retailers and the services they provide.

> Regulatory and policy barriers are removed and rapid technological advancement drives dramatic change in the traditional energy supply chain.

WHAT WE IMAGINED

Under this scenario, regulatory reforms occur rapidly, removing barriers to entry for disruptive technologies which causes them to be aggressively pursued, realised and adopted. In Western Australia, these reforms include the implementation of a constrained network access framework and full retail contestability, which drives healthy competition and rapid innovation in the electricity sector. Wholesale electricity market reforms and digital technologies allow aggregated behind–the-meter solutions to be dispatched as if they were larger, centralised generators. Smaller scale stand-alone power systems are further facilitated by peer-to-peer trading using the distribution network infrastructure. Regulatory and policy changes are flagged to the market in a timely manner, allowing energy industry players to determine their response. That being said, policy is not the primary driver of increased uptake and efficiencies in renewable energy technologies. Instead, the investment in development and commercialisation of these technologies is pursued on the basis of them being able to outcompete traditional energy supply options on price and reliability.

As renewable technologies evolve, they become increasingly cost-competitive in comparison to conventional alternatives. So much so that solar PV, hydrogen, battery storage technologies and electric vehicles become the norm for a large proportion of residential households and commercial businesses. Customers change their consumption patterns through the use of integrated smart appliances or operate 'off the grid' by generating and storing their own energy. At the wholesale level, the mining sector begins adopting on-site renewable generation with storage. Energy supply choices by industry include the use of hydrogen and concentrated solar thermal plants.

We also contemplate a scenario where some of the ability to leave the electricity network may be enabled by the entry of gas, or hydrogen-powered combined heat and power technologies into the residential market. Fuel cells in cars also rapidly advance. We assume that the gas distribution network is able to undertake a full scale conversion to carry hydrogen by 2030, obviously at a non-trivial cost. All of this occurs in an environment of increasing competition in the Western Australia retail gas market.

WHAT WE FOUND

In the wholesale electricity market, demand slows and prices do not increase at the same level as under the other modelled scenarios. High residential electricity prices are driven by an increase in the cost of supplying electricity and a reduction in the customer base as people increasingly defect from the grid, particularly its transmission backbone. The increase in the cost of supplying electricity to small use customers is despite the fact that increases in network augmentation-related capital expenditure are relatively low under this scenario as shown in figure 20. This is because the augmentation required to support the new technologies is more than offset by the deferral of network investment as customers defect from the grid.

> A vicious circle between electricity prices and demand emerges, as retail gas prices slowly decline.

Grid defection implies that the increased cost of supplying electricity is allocated between fewer people, driving retail electricity prices up in real terms from 28 cents per unit in 2018 to 37 cents per unit in 2030 as shown in figure 21.

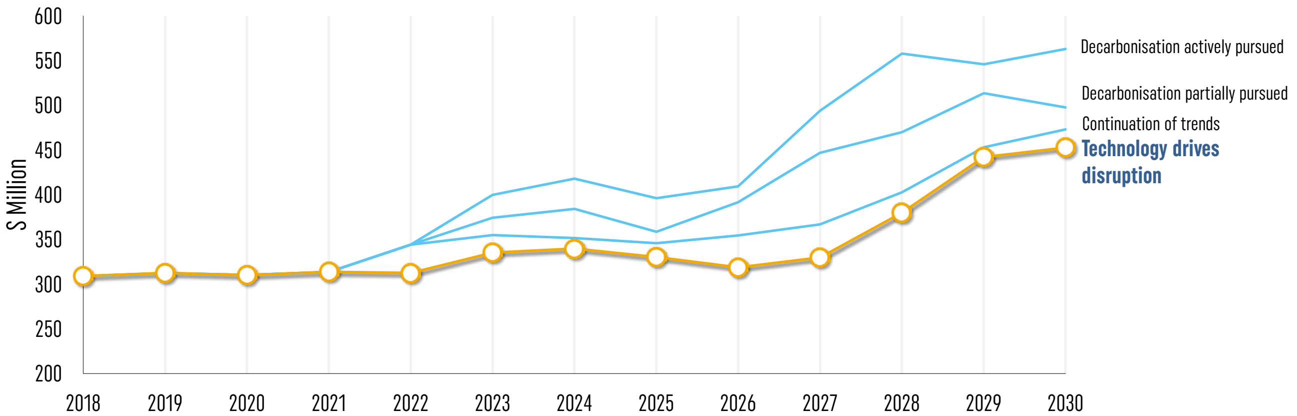
This results in a vicious circle of falling electricity demand and increasing electricity prices.

This effect takes place much faster under this scenario than it does under Scenario 3.

As electricity prices continue to rise, customers increasingly look to substitute electricity for relatively cheaper energy sources, including gas. This is consistent with the choice to defect from the electricity grid, particularly in a world where fuel cells become a viable behind-the-meter electricity generation option. The retail gas price increases initially until 2021, then declines rapidly between 2021-2022, before flattening between 2022 and 2030. Overall it decreases by 20% over the modelling period (see figure 22).

As highlighted in figure 22, for illustrative purposes it is assumed under this scenario that a $1Bn investment (over 5 years) will be required to convert the existing network to carry hydrogen by 2030, effectively doubling the current value of the network asset. This results in an increase in the cost of supplying gas under this scenario. Evenly allocating these costs between 2026 and 2030 increases the distribution network cost component by approximately 13% over the same period. This occurs as residential gas prices fall due to increasing competition in the retail sector.

FIGURE 20: ELECTRICITY NETWORK CAPEX PROFILES



SCENARIO 4
TECHNOLOGY DRIVES DISRUPTION

FIGURE 21: RESIDENTIAL RETAIL ELECTRICITY PRICE

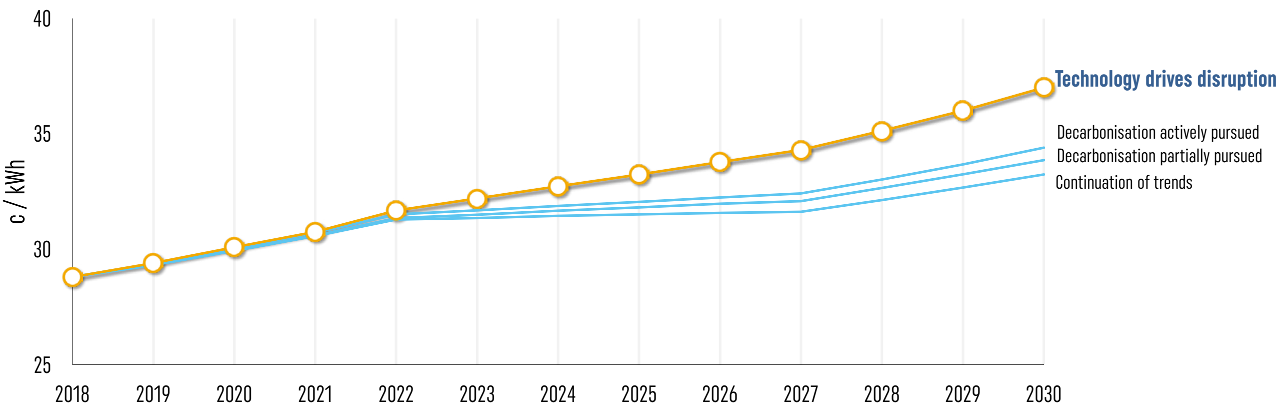
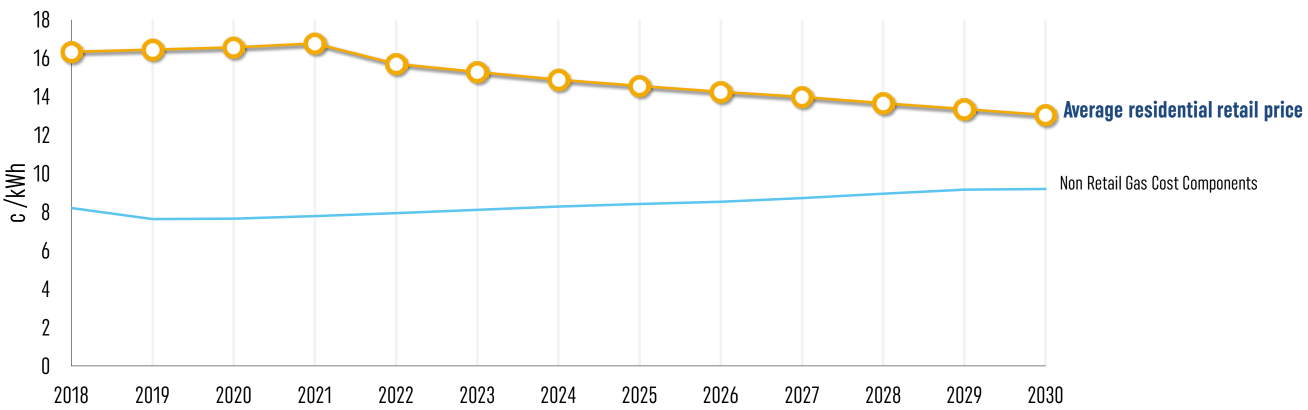


FIGURE 22: RETAIL GAS PRICE AND NON-RETAIL GAS PRICE COMPONENTS

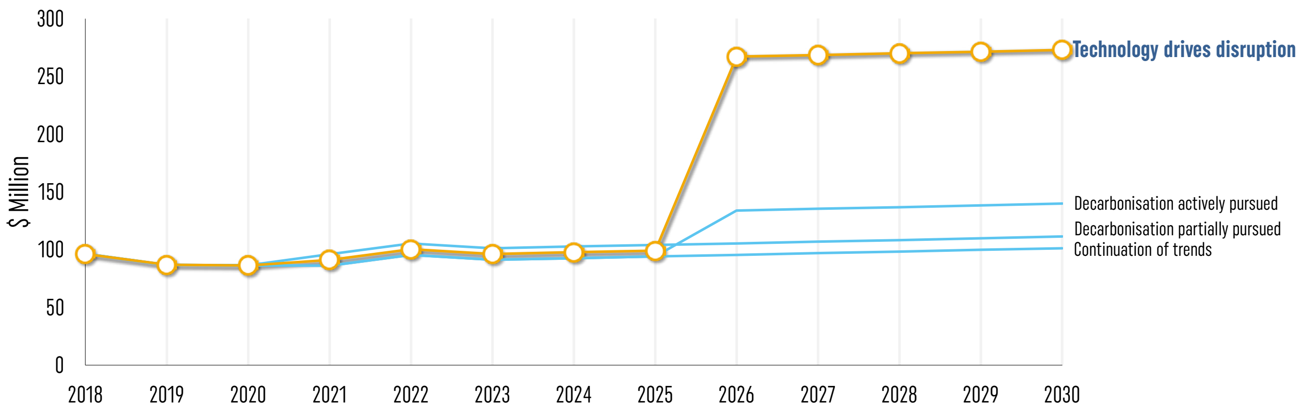


WHAT IT MIGHT MEAN

For consumers, technological disruption implies that tastes and preferences may fundamentally change as new technologies come to market. Increasingly, many consumers may start to see grid-supplied electricity as being inferior to new alternative supply options, such that their demand for conventional power sources no longer increases with incomes. As a result, the impact of economic growth and price increases on electricity demanded from the grid will be weaker in the face of technological disruption.

The key implication of technological disruption for the traditional supply industry is that it reduces the demand for electricity supplied through the transmission

FIGURE 23: GAS DISTRIBUTION NETWORK CAPEX PROFILES



network and fundamentally changes the traditional roles of both the electricity network operator and retailers. It is easy to imagine today's electricity network starting to disaggregate under such a scenario to form a number of smaller, islanded networks. Customers with a high cost of service, many located well within the current edge of the grid, will likely choose to defect to stand-alone power systems or micro-grid solutions if they offer superior reliability at a lower cost. If this transition is well managed, the disaggregated electricity distribution network should continue to provide an important service to its existing customers, but perhaps more in the form of a 'capacitor' and a 'trading platform' than as a conduit of energy.

For the residential gas supply industry, technological disruption increases supply costs. The retail gas margin converges towards, but does not fall below, what we assume to be the sustainable long-term benchmark retail margin of 25%. Therefore, despite the significant investment to convert the gas network to biogas and hydrogen, and ongoing competition in the retail sector, gas retailers remain viable over the modelling period. It is also worth considering some of the implications that may occur after the modelling period as a result of the conversion for hydrogen:

- It is likely that hydrogen will be produced close to the point of demand. Therefore, gas transmission costs may become irrelevant for residential and small commercial gas customers. Eliminating these costs will decrease the costs of supplying gas and reduce the pressure placed on retail margins.
- A hydrogen gas network could be used as a large 'battery' to store significant amounts of renewable energy, creating interoperability between the hydrogen gas and electricity networks.
- Converting the network to hydrogen could establish WA as a hydrogen export hub.
- Over the very long term, it is possible to imagine the gas transmission network infrastructure being repurposed to transport gas in the *opposite* direction, i.e. to allow carbon dioxide to be stored in the depleted gas fields of the North West Shelf.

CONCLUDING REMARKS

The scenarios presented in this paper are not intended to predict Western Australia's energy future, but to assist our customers, policy makers and market participants when developing their own strategies, plans and policies.

At the time of writing this paper, the Federal Government had recently announced a new energy policy that will look for competitive markets to deliver the required future generation mix, coupled with maintenance of minimum reliability standards.

In this regard, the energy market modelling that underpins this paper is consistent with the projected outcomes of the Federal Government's new energy policy.

For gas to continue playing a role in the delivery of safe, reliable and affordable energy, careful planning will be required that is informed by scenario modelling such as that outlined in this paper.

The insights from this paper will be used to inform discussions with our customers and stakeholders as we continue to refine our investment plans and strategies. We are also committed to working with other market participants and policy makers to identify investment opportunities that will deliver sustainable energy solutions for all Western Australians.

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APPENDICES

APPENDIX A: SCENARIO MODELLING APPROACH

THE MODEL

To examine the scenarios and in particular, the impact of each on the Western Australian residential gas market to which ATCO is most exposed, we developed an integrated economic and energy market model. The qualitative scenarios and their assumptions described in the paper were converted to quantitative measures on the basis of scenario-specific assumptions and forecasts for the purposes of providing inputs to the model. The model was primarily designed to explore the impact of the four sets of assumptions associated with each scenario on the WA residential gas supply chain.

Figure 23 illustrates, at a high level, the model's inputs, outputs and computational components. The model provides a range of outputs at various stages within its data flow structure, ultimately producing a time series of residential gas prices and cost components.

The model design is focused on how changes in the price and volume of electricity may impact the price, cost and volume of natural gas. In short, the approach is to model the 'price push' impact of the various scenario themes (e.g. policy change and technological disruption) on the gas distribution network.

On the electricity sector side of the model, this is done by:

- Using outputs from a wholesale electricity market dispatch engine to estimate wholesale energy, capacity credit, and Large-Scale Generation Certificate cost components
- Estimating the operational and capital expenditure requirements in the generation sector and in the electricity network sector in response to the scenario themes (e.g. the amount of network augmentation expenditure required to support a certain level of renewable energy development under a scenario)
- Inputting these capital expenditure requirements into an electricity regulatory building block model to estimate network costs
- Applying a retail margin and carbon pricing assumptions to estimate the time profile of retail electricity prices.

A key feature of the model is the inclusion of a set of consumer behaviour assumptions in the form of two demand functions, one for residential electricity supply and one for residential gas supply. These demand functions treat energy consumption as a function of income (in the form of gross state product), regulated electricity price levels, regulated gas price levels and temperature variables. Importantly, each demand function includes a 'cross price elasticity of demand' parameter, which describes the impact of changes in the price of one form of energy (e.g. electricity) on the demand for the other form of energy (e.g. gas). As electricity and gas are substitutes for one another, an increase in the price of one should, all else being equal, result in an increase in demand for the other.

For the residential electricity demand function, all variables other than the retail gas price are either pre-defined by the scenario assumptions, or else emerge as outputs from the electricity sector side of the model, as described above. With the electricity sector modelling complete, the retail gas price is the only unknown variable in the residential electricity demand function,

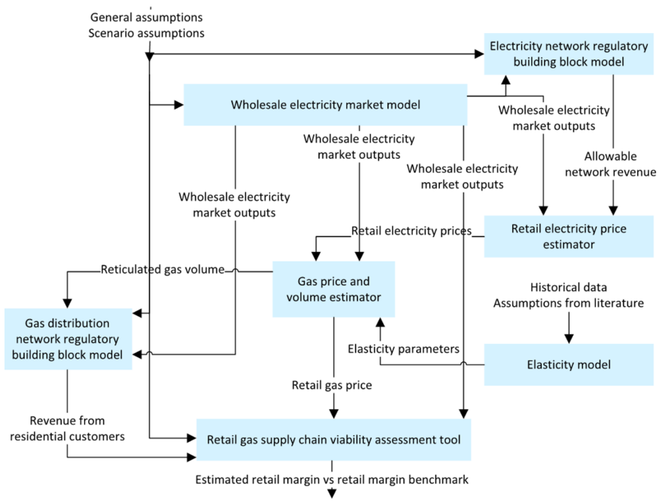


FIGURE 23: MODEL OVERVIEW

which means it is able to be solved (as an estimated value).

Having solved for the residential gas price, the only unknown variable in the residential gas demand function is the gas volume, which therefore allows it to be solved (again, as an estimated value). The residential gas consumption volume is then fed into the ATCO building block model component, along with a set of expenditure assumptions associated with each scenario to calculate the gas distribution network cost components. This is then added to wholesale gas, carbon pricing and transmission pricing assumptions, and divided by volumes to determine the average cost for residential customers. The retail gross margin is then calculated as the difference between these cost components and the residential gas price.

The final computational component of the model, 'the retail gas supply chain viability assessment tool', estimates a time series of estimated retail margins (ERMs) as percentages of all residential gas costs that occur upstream of the retail sector, and then compares this to a benchmark retail margin (BRM), assumed to be 25% in all scenarios.

This final output allows a statement to be made about the economic viability of the Western Australian residential gas supply chain under each of the agreed scenario assumption sets. If the model indicates that the ERM for a particular scenario falls below the BRM, it may be concluded that retail margins are coming under pressure to the point where the residential gas supply chain may become economically unviable. The costs associated with ATCO's assets represent an important cost component for residential customers. Hence, to the extent that the pressure on the overall supply chain impacts ATCO's profitability, the results of the scenario modelling might be seen to reflect the sustainability of the gas distribution network and the role that it might play under each future state.

DEMAND BEHAVIOUR MODELLING

Consumer demand functions – modelling price and income elasticities to develop consumer choice assumptions.

Residential electricity and residential gas demand functions – modelling price and income elasticity estimation

As discussed a key feature of the model built to inform this paper is the inclusion of a set of consumer behaviour assumptions in the form of two demand functions, one for residential electricity supply and one for residential gas supply. These demand functions treat energy consumption as a function of income (using gross state product as a proxy), regulated electricity price levels, regulated gas price levels and temperature variables.

For scenarios 1, 2, and 3, the parameters of both demand functions were derived from a combination of literature review of own price and cross price elasticity of energy demand studies in Australia, and a statistical analysis of Western Australian time series data.

For scenario 4, it was assumed that in the case of electricity, historical consumer behaviours would change due to the introduction of new consumer choice options (e.g. the option to defect from the electricity grid), so the demand function parameters in this case were based on a combination of professional judgement and statistical analysis.

Elasticity parameters for the quantity of electricity demanded: Scenarios 1, 2 and 3

Elasticity is a measure of how responsive economic variables are to changes in other variables. It is generally defined as the ratio of the percentage change in one variable to the percentage change in another. For example:

- An income elasticity of electricity demand equal to

0.6 would indicate that, all else being equal, a one per cent increase in income would result in a 0.6 per cent increase in electricity consumption.

- An 'own price' price elasticity of electricity demand equal to-0.32 would indicate that, all else being equal, a 1 per cent increase in the price of electricity would result in electricity demand falling by 0.32 per cent (all else being equal).
- A gas 'cross price' elasticity of electricity demand equal to 0.13 would indicate that, all else being equal, a 1 percent increase in the price of gas would result in a 0.13 per cent increase in the demand for electricity, as consumers respond to the increase in the gas price by substituting away from it and towards electricity. The cross price elasticity measure is thus related to the concept of substitute goods, in this case electricity can be used as a substitute for gas and vice versa.

The model's electricity demand function expresses the quantity of electricity demanded, Q_e, as a function of the price of electricity, P_e, the price of gas, P_g, income (represented by gross state product), Y, and the average summer maximum temperature, T_s. Thus, for the general demand function f:

$$Q_e = f(P_e,\ P_g, Y, T_s). \qquad (1)$$

The modelling conducted for this paper assumes that the elasticity measures remain constant over time, with the specific 'constant elasticity' function having the following functional form:

$$Q_e = \lambda P_e^{\beta_1} P_g^{\beta_2} Y^{\beta_3} T_s^{\beta_4}, \qquad (2)$$

where λ is a scaling parameter, β_1 is the own price elasticity of electricity demand, β_2 is the gas cross price elasticity of electricity demand, which is a measure of the relationships between a change in the quantity of electricity demanded and a change in the price of gas (a substitute good), β_3 is the income elasticity of electricity demand, and β_4 is the elasticity parameter that determines the relationship between the annual quantity of electricity demanded and the average summer maximum temperature.

The own and cross price elasticities of demand were taken from Rai et al.'s (2014) state-level price elasticity estimates for residential electricity demand between 1970 and 2011[3]. That study estimated that over the long run, the own price elasticity of electricity demand in WA was-0.32 and the gas cross price elasticity of electricity demand was 0.13.

The income and temperature parameters as well as the coefficient were estimated using a log-linear statistical model. To enable this, a transformation was used to convert equation (2) to a linear one for the purposes of regression modelling. Putting β_1=-0.32 and β_2=0.13, and then taking the natural logarithm of both sides of equation (2) yields the following linear regression equation for estimation of the remaining parameters (β_3 and β_4):

$$\begin{aligned} \ln Q_e = \hat{\beta}_0 - \widehat{0.32} \ln P_e + \widehat{0.13} \ln P_g \\ + \hat{\beta}_3 \ln Y + \hat{\beta}_4 \ln T_s + e \end{aligned} \qquad (3)$$

where β_0, is the intercept and e is the residual between ordinary least squares fitted values and the independent variable ln Q_e . Note that $\hat{\lambda}$=exp ($\hat{\beta}_0$). The hat notation indicates the regression equation provides statistical estimates of the 'true' parameter values.

Using historical data, the unknown coefficients in equation (3) were estimated using the lm() function in the R statistical computing software package. This yielded the following results: $\hat{\beta}_0$=-2.88, $\hat{\beta}_3$= 0.58, $\hat{\beta}_4$=3.81. The R output is provided in figure 24.

[3] *Rai, Alan, Luke Reedman and Paul Graham. 2014. Price and income elasticities of residential electricity demand: the Australian evidence. https://editorialexpress.com/cgi-bin/conference/download.cgi?db_name=ESAMACE2014&paper_id=95*

```
Call:
lm(formula = response_elect123 ~ gsp + summer_av_max_temp)

Residuals:
      Min        1Q    Median        3Q       Max
-0.060881 -0.020093  0.003136  0.021494  0.038590

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)        -2.87964    4.48363  -0.642   0.5367
gsp                 0.58161    0.05305  10.964 1.65e-06 ***
summer_av_max_temp  3.80667    1.25635   3.030   0.0142 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.0322 on 9 degrees of freedom
Multiple R-squared:  0.9311,           Adjusted R-squared:  0.9158
F-statistic: 60.79 on 2 and 9 DF,  p-value: 5.924e-06
```

FIGURE 24: R STATISTICAL COMPUTING SOFTWARE OUTPUT OF THE ORDINARY LEAST SQUARES REGRESSION DEFINED BY EQUATION 3, CONDUCTED TO DEFINE ELECTRICITY CONSUMER BEHAVIOUR ASSUMPTIONS FOR SCENARIOS 1, 2 AND 3

Key assumptions of ordinary least squares regression appeared to hold. Plotting of the autocorrelation and partial autocorrelation functions of the residuals of the regression indicated they were stationary and that there were no issues with serial correlation (see figure 25).

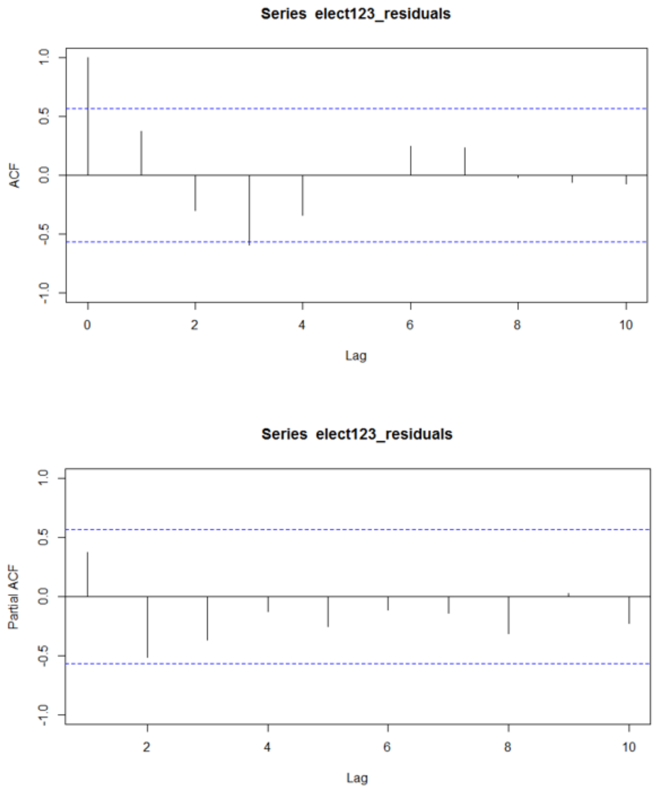


FIGURE 25: AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTIONS OF THE RESIDUALS OF THE REGRESSION DEFINED BY EQUATION 3.

A qq-plot suggested the residuals of the regression were approximately normally distributed (see figure 26).

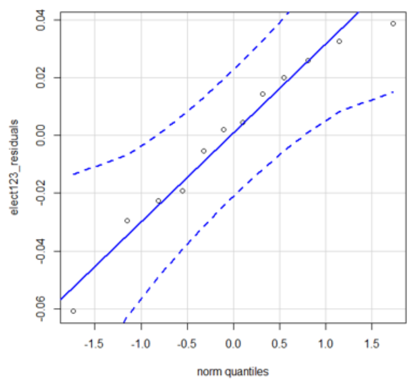


FIGURE 26: QQ-PLOT OUTPUT OF THE RESIDUALS OF THE REGRESSION DEFINED BY EQUATION 3

Elasticity parameters for quantity of electricity demanded: Scenario 4

One of the key insights of the modelling process came from the modelling of Scenario 4, which contemplates a level of technological change in the electricity sector that involves customers starting to defect from the electricity network. Initially, scenario 4 was modelled using the same electricity demand elasticity assumptions that were used for scenarios 1, 2 and 3. However, this resulted in a deep and rapid collapse in the residential gas price, to the extent that by halfway through the modelling period, the modelled residential price could not support the residential gas supply chain upstream of the retail sector. Exploration of the cause of this modelling output found it to be an artefact of the reduction in electricity volumes associated with grid defection. Under normal circumstances, a large reduction in electricity volumes might suggest that a rapid fall in the gas price had affected substitution away from electricity and towards gas.

Upon reflection, it seemed reasonable to consider that demand elasticity might change dramatically after the entry of a new disruptive technology into the market. Grid defection implies that some consumers begin to see the conventional electricity supply option as an ‘inferior good’, which in economic terms is defined by a negative income elasticity of demand (i.e. the demand for the good decreases as incomes go up). Also consistent with the choice to defect from the grid is the idea that the gas cross price elasticity of electricity demand may be higher under scenario 4 than under the other scenarios, as the scenario contemplates that some of the ability to leave the electricity network may be enabled by the entry of gas- or hydrogen-powered combined heat and power technologies into the residential market.

As such, the final modelling of scenario 4 was conducted on the basis of an assumed, lower income elasticity of demand of 0.1 (compared to 0.58 for scenarios 1, 2 and 3), and an assumed, higher gas cross price elasticity of demand of 0.4 (compared to 0.13 for scenarios 1, 2 and 3). For scenario 4, the log-linear regression equation was thus:

$$\ln Q_e = \hat{\gamma}_0 + \hat{\gamma}_1 \ln P_e + \widehat{0.4} \ln P_g + \widehat{0.1} \ln Y + \hat{\gamma}_4 \ln T_s + e \qquad (4)$$

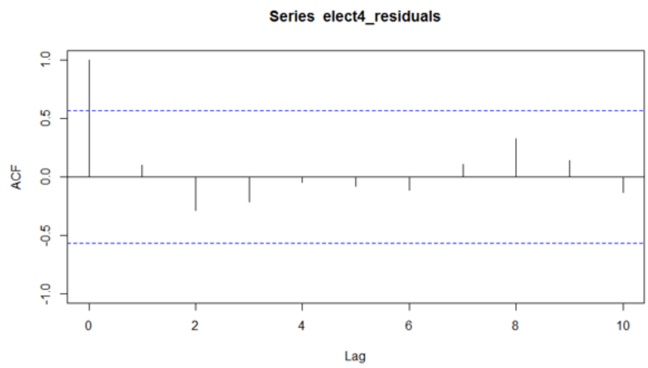
where $\hat{\gamma}_0$ is the intercept and $\hat{\gamma}_1$ is the own price elasticity of electricity demand. Using the lm() function in the R statistical computing software package this yielded the following results:
$\hat{\gamma}_0$= 8.37, $\hat{\gamma}_1$=-0.03 and $\hat{\gamma}_4$=2.10.

The R output is provided in figure 27.

```
Call:
lm(formula = response_elect4 ~ elect_p + summer_av_max_temp)

Residuals:
      Min        1Q    Median        3Q       Max
-0.049703 -0.016485  0.001403  0.015069  0.042058

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)         8.36737    3.76115   2.225   0.0532 .
elect_p            -0.02735    0.04447  -0.615   0.5538
summer_av_max_temp  2.10709    1.09024   1.933   0.0853 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.02836 on 9 degrees of freedom
Multiple R-squared:  0.3169,           Adjusted R-squared:  0.1651
F-statistic: 2.088 on 2 and 9 DF,  p-value: 0.18
```

FIGURE 27: R STATISTICAL COMPUTING SOFTWARE OUTPUT OF THE ORDINARY LEAST SQUARES REGRESSION DEFINED BY EQUATION 4, CONDUCTED TO DEFINE ELECTRICITY CONSUMER BEHAVIOUR ASSUMPTIONS FOR SCENARIOS 4

Key assumptions of ordinary least squares regression appeared to hold. Plotting of the autocorrelation and partial autocorrelation functions of the residuals of the regression indicated they were stationary and that there were no issues with serial correlation (see figure 28).



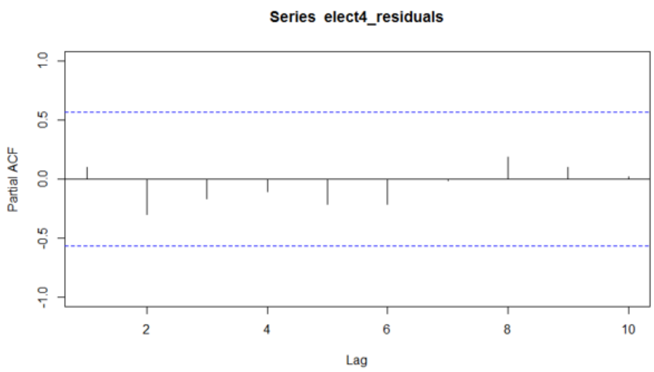


FIGURE 28: AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTIONS OF THE RESIDUALS OF THE REGRESSION DEFINED BY EQUATION 4.

A qq-plot suggested the residuals of the regression were approximately normally distributed (see figure

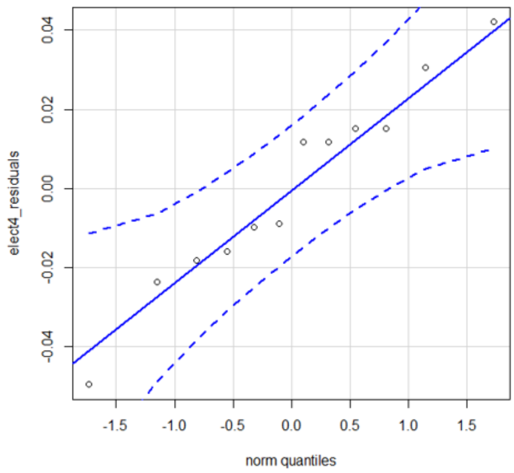


FIGURE 29: QQ-PLOT OUTPUT OF THE RESIDUALS OF THE REGRESSION DEFINED BY EQUATION 4.

Elasticity parameters for quantity of gas demanded: All Scenarios

The quantity of gas demanded, Q_g, was modelled as a function of the price of electricity, P_e, the price of gas, P_g, income (represented by gross state product), Y, and the average winter minimum temperature, T_w, thus:

$$Q_g = f\left(P_e,\ P_g, Y, T_w\right). \tag{5}$$

This generalised function was expressed as the following function form:

$$Q_g = \rho P_e^{\alpha_1} P_g^{\alpha_2} Y^{\alpha_3} T_w^{\alpha_4}. \tag{6}$$

where α_1 is the own price elasticity of gas demand, α_2 is the electricity cross price elasticity of gas demand, α_3 is the income elasticity of gas demand, α_4 is the elasticity parameter that describes the relationship between the quantity of gas demanded and the average winter minimum temperature, and ρ is a scaling parameter.

The own and cross price elasticities of gas demand were taken from the 'expected' values listed in the Energy Networks Association's 2014 Gas Network Sector Study[4]. That study estimated that over the long run, the own price elasticity of gas demand in Australia was-0.3 and the electricity cross price elasticity of gas demand was 0.1.

The income and temperature parameters as well as the coefficient were estimated using a linear model equivalent to the approach taken in the section above for the electricity demand function,

$$\ln Q_g = \hat{\alpha}_0 +\ 0.10 \ln P_e - 0.30 \ln P_g + \hat{\alpha}_3 \ln Y\ + \hat{\alpha}_4 \ln T_w + e. \tag{7}$$

where $\hat{\alpha}_0$ is the estimated intercept term. Using historical data, the unknown coefficients in the linear regression model represented by equation (6) were estimated using the Ordinary Least Squares (OLS) method. This yielded the following results: $\hat{\alpha}_0$= 21, $\hat{\alpha}_3$= 0.17 and $\hat{\alpha}_4$=-0.20. The R output is provided in figure 30.

```
Call:
lm(formula = response_gas ~ gsp + winter_av_min_temp)

Residuals:
      Min        1Q    Median        3Q       Max
-0.05576 -0.01897 -0.00786  0.01200  0.06095

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)        20.53602    0.70241  29.237 3.13e-10 ***
gsp                 0.17055    0.05941   2.871   0.0185 *
winter_av_min_temp -0.19840    0.09147  -2.169   0.0582 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.03548 on 9 degrees of freedom
Multiple R-squared:  0.5388,	Adjusted R-squared:  0.4363
F-statistic: 5.256 on 2 and 9 DF,  p-value: 0.03074
```

FIGURE 30: R STATISTICAL COMPUTING SOFTWARE OUTPUT OF THE ORDINARY LEAST SQUARES REGRESSION DEFINED BY EQUATION 7, CONDUCTED TO DEFINE GAS CONSUMER BEHAVIOUR ASSUMPTIONS FOR ALL SCENARIOS

[4] *Energy Networks Association, Gas Network Sector Study, August 2014*

As with the electricity demand regressions, key assumptions of ordinary least squares regression appeared to hold. Plotting of the autocorrelation and partial autocorrelation functions of the residuals of the regression indicated they were stationary and that there were no issues with serial correlation (see figure 31).

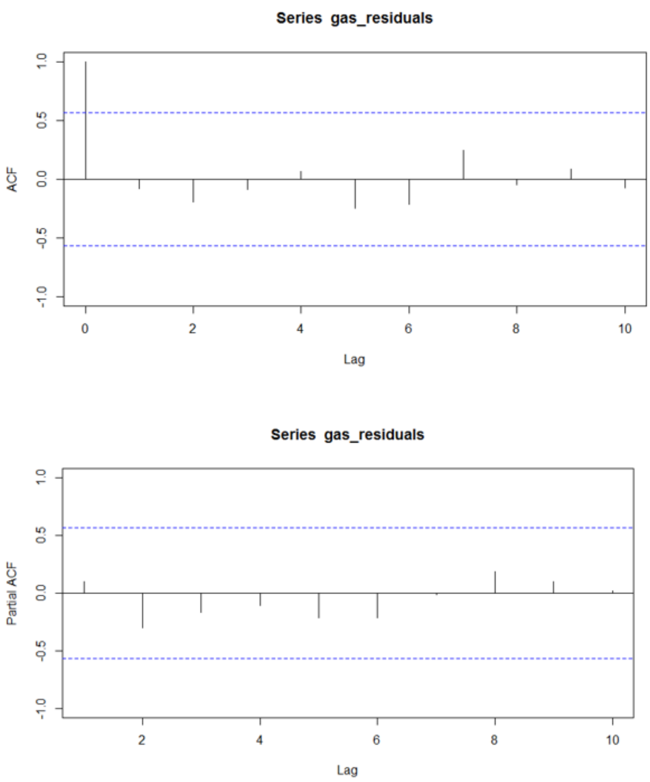


FIGURE 31: AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTIONS OF THE RESIDUALS OF THE REGRESSION DEFINED BY EQUATION 7.

A qq-plot suggested the residuals of the regression were approximately normally distributed (see figure 32).

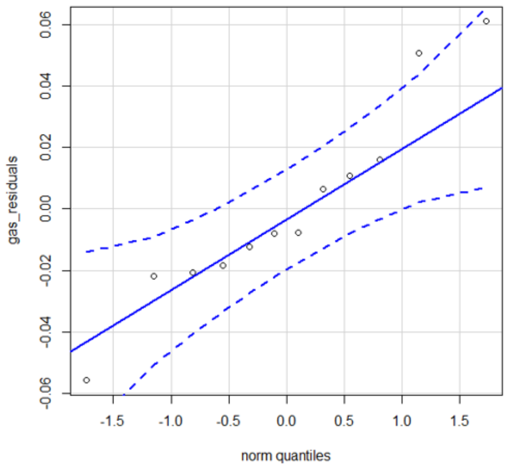


FIGURE 32: QQ-PLOT OUTPUT OF THE RESIDUALS OF THE REGRESSION DEFINED BY EQUATION 7

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