Est. 2008 Oakley Greenwood

Environmental Effects Statement - WORM Pipeline Project

Expert Witness Statement- Energy Policy

Hall & Wilcox Lawyers on Behalf of APA | 22 September 2021

DISCLAIMER

This Expert Witness Report has been prepared according to a Letter of Instruction from Hall & Wilcox Lawyers acting under instructions from APA Transmission Pty Ltd and APA VTS (Operations) Pty Ltd (**APA**) in relation to the Environmental Effects Statement (**EES**) for the Western Outer Ring Main (**WORM**) Gas Pipeline Project (**Project**). This is in relation to the Inquiry (**Inquiry**) appointed by the Minister for Planning on 10 June 2021, to conduct an inquiry into the Project's environmental effects and the Panel appointed by the Minister for Energy, Environment and Climate Change on 3 September 2021 to consider the application for a pipeline licence under section 40 of the Pipelines Act 2005.

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DOCUMENT INFORMATION

Project	Expert Witness Report - Energy Policy
Client	Hall & Wilcox Lawyers on Behalf of APA
Status	Final Report
Report prepared by	Jim Snow, Executive Director & Adjunct Professor
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1. Introduction

1.1. Background

I, James Arthur Snow of 142 Griffith Road, Newport, Queensland, was engaged as an Expert Witness in relation to energy policy matters (and related gas matters) by Hall & Willcox Lawyers acting under instructions from APA Transmission Pty Ltd and APA VTS (Operations) Pty Ltd (**APA**) in relation to the Environmental Effects Statement (**EES**) for the Western Outer Ring Main (**WORM**) Gas Pipeline Project (**Project**). This is in relation to the Inquiry (**Inquiry**) appointed by the Minister for Planning on 10 June 2021, to conduct an inquiry into the Project's environmental effects and the Panel appointed by the Minister for Energy, Environment and Climate Change on 3 September 2021 to consider the application for a pipeline licence under section 40 of the Pipelines Act 2005..

1.2. Purpose of this Expert Report

I have been instructed to prepare this Expert Report with regard to the consistency of the Project with State and Federal energy policy, and to address specific related concerns raised by various third parties and Authorities in their submissions in response to published EES and related Inquiry.

I was issued with a Letter of Instruction, dated 2 September 2021, and given access to the public documents of the EES.

Please note that where *Italics* are used in my report, they denote direct quotes.

1.3. Guide to expert evidence for the Inquiry

I am advised that my conduct as an Expert Witness in this Inquiry should abide by the *G7: Guide to expert evidence* (**Guide**) issued by the Inquiry Panel (February 2020 Version).

I have been provided a copy of this Guide, which I have read, and I agree to be bound by the provisions of the Guide and to assist the Inquiry Panel impartially on matters relevant to my areas of expertise.

My opinions in this Expert Report are based wholly or substantially on specialised knowledge arising from my expert training, study or experience.

I would also note that I was assisted in the detailed reviewing of material and data collection by William John Williams and Angus Rich, who both have gas industry and energy policy expertise, but note that they worked under my strict direction and the opinions outlined in this report are my own.

I am also currently engaged in my role as an Executive Director of Oakley Greenwood by APA to lead a small Oakley Greenwood team to complete an independent report on the *Issues Affecting Demand and Supply for Gas on the Victorian Transmission System.* This is in support of APA's upcoming Victorian Transmission System Access Arrangement, due to be lodged with the Australian Energy Regulator by 1 December 2021. This project has involved me in addressing the APA Roundtable meetings and public forums on these issues and our report drafts. The report has been focused on providing updated analysis post the publication of the Australian Energy Market Operator's Gas Statement of Opportunities in March 20201.

In accordance with the Guide, I attach a copy of my relevant qualifications and experience at Appendix A. I am a recognised expert in energy policy and related gas matters regularly providing advice to: Courts in terms of commercial litigation and regulatory enforcement matters; and to Arbitration and Mediation matters under Expert Witness Codes of Conduct.

As requested by the Guide, I hereby declare that, in reaching the conclusions set out in this report:

I have made all the inquiries that I believe are desirable and appropriate and that no matters of significance which I regard as relevant have, to my knowledge, been withheld from the Panel.

1.4. Instructions

In the Hall & Wilcox Letter of Instruction I was instructed to prepare this Expert Report based on the following.

You are instructed to:

- *review the relevant EES documentation, focusing on:*
  - *Chapter 2 - Project Rationale,*
  - *Chapter 10 - Waste Management (includes Greenhouse);*
  - *relevant Technical Reports - including Technical Report H - Greenhouse;*
  - *the mitigation measures recommended in Chapter 19 of the EES;*
- *review and respond to relevant submissions filed by third parties and Authorities, noting that you will also be provided with a copy Submissions Response Report that APA and GHD are preparing and will be able to comment on this as relevant;*
- *prepare an expert witness statement that summarises your opinion and analysis regarding the consistency of the Project with State and Federal energy policy;*
- *review and comment on any expert evidence filed by other parties in relation to energy policy (we do not expect there will be any); and*
- *prepare a PowerPoint summary of your evidence and appear at the public inquiry hearing to present your evidence.*

This Expert report was to be filed by midday 22 September 2021. I also note that some 26 submissions have been received by the Inquiry.

1.5. Acronyms and some technical terms

Term	Explanation	Term	Explanation
AER	Australian Energy Regulator	AEMO	Australian Energy Market Operator
Biomethane	Has the same chemical composition as methane, the principal component of natural gas, by removing impurities, biogas can be upgraded into biomethane which can then be injected into existing gas networks.	DAC	Direct Air Capture - this is technology that extracts the carbon dioxide from the atmosphere.
Dispatchable Generation or Capacity	Dispatchable generation or capacity is the ability to turn on and off at any time a source of electricity supply. This supply could for example be gas generation, hydro generation, battery discharge.	ESB	Energy Security Board
Firming	This is where dispatchable generation is used to unsure intermittent generation (such as wind and solar) is made a continuous, reliable supply to customers.	GWh	Gigawatt Hours (1,000 MWh)
GSOO and ESOO	Gas Statement of Opportunities Electricity Statement of Opportunity (AEMO)	ISP	Integrated System Plan (AEMO)
IV	Infrastructure Victoria	Linepack	Linepack is the ability to store gas in pipelines as gas can be compressed. This form of gas storage is sold as a service on many major gas transmission pipelines and is sometimes called “Park and Loan Services” or “Imbalance Accounts”.
NEM	National Electricity Market	MW, MWh	Megawatts, Megawatt Hours
ODP	Optimal Development Path	PJ	Petajoule (10 PJ = 2.8 TWh)
PV	Solar photovoltaic technology, also known as solar cells, are panels that convert sunlight to electrical energy.	Renewable or zero emission methane	This gas is manufacture from renewable electricity, carbon dioxide and water. It can be achieved by the methanation of hydrogen with carbon dioxide or in a one ste reactor. The carbon dioxide must be either drawn from biogas or by DAC to be recognised as zero emission.
TJ	Terajoule (1,000 TJ = 1 PJ)	TWh	Terawatt Hours (1,000,000 MWh, 3.6 PJ)
VGPR	Victorian Gas Planning Report	VRET	Victorian Renewable Energy Target.
VTS	Victorian (Gas) Transmission System.	UGS	Underground Gas Storage (Facility).

2. Future of gas infrastructure and the Project Rationale

In preparing this evidence I have drawn from the APA EES the Project Rationale[1], from my work related to the Victorian Transmission System Demand and Supply analysis being also undertaken for APA, and from other market knowledge acquired across recent projects related to gas supply in Victoria and South Australia, nationally and projects in Victoria looking at the production of, and markets for, zero emission gases. These include hydrogen, biomethane and zero emission methane.

Victoria is the largest user of domestic gas in terms of consumption by residential, commercial and industrial consumers than any other state or territory. Gas consumption in Victoria is 20% more in energy terms than the total grid electricity consumed in Victoria, and on a straight energy basis it is equivalent to the entire grid electricity consumption of Queensland. Gas storage capacity on the east coast is also world class at some 80 to 100 times Snowy 2.0 energy storage capacity for example.

One of the key reasons gas is so popular in Victoria is that it is an excellent way to heat homes and businesses in such a cold climate during the winter months. It has also been popular for businesses in manufacturing, and as a feedstock, due to its past abundant supply from the closely located Bass Strait.

As a result, the State is serviced by world class gas infrastructure in gas transmission and distribution systems, high levels of gas storage and gas fired power stations. This infrastructure has developed through far sighted investments in supply capacity at Longford and at later times from other supply sources inside and outside of Victoria. The Victorian Transmission System for example is a major energy artery and a valuable asset to the Victorian economy.

2.1. Outline of this evidence– transitioning to net zero

This evidence, in line with my Instructions, largely deals with the future of gas infrastructure, like the WORM, in a very different and rapidly changing policy world where:

- Decarbonisation of fossil fuels is a paramount concern – for Governments through policy initiatives – but also for consumers, and for businesses.
  - There is very strong support for endeavouring to reach a target of net zero emissions by 2050.
  - This naturally brings with it huge challenges for the energy system to transition, for consumers to also transition, and for investors to back this transition while ensuring a reliable and affordable supply of energy.
  - The backbone of this transition will be the development of renewable electricity sources (and potentially bioenergy resources).
  - This will be used for:
    - Direct electricity consumption - residential, commercial, industrial, and vehicular.
    - The displacement of natural gas - either directly or indirectly through the production of hydrogen and zero emission methane, and

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1 APA EES Chapter 2 – Project Rationale.

        - Displacement of liquid fuels with zero emission gases or liquid fuels derived from renewable electricity (such as hydrogen, ammonia, methanol, etc.).
    - In this new world, as this evidence outlines, gas infrastructure has the potential to play a very critical role.
- Natural gas supplies are having to be increasingly drawn more from other states to service Victorian gas demand as the Bass Strait gas fields wind down. With more and more gas being drawn from:
    - Queensland.
    - Potentially from LNG importation.
    - Displaced with manufactured zero emission gases.

The Project Rationale though has to date be based on the very real need to keep gas supplies flowing in order to meet the current levels of demand until the transition can occur.

As this evidence makes clear this transition, largely driven by decarbonisation policies, will not be quick due to investment and other timing constraints, and specifically over the next 10 to 15 years will still have a very high reliance on the gas infrastructure to meet demand.

Trying to transition too early to electricity for example would also increase greenhouse gas emissions significantly as the electricity grid itself is still 75% dependent on fossil fuel generation.

- There are various promising options to get to zero emissions energy in Victoria that I explore in this evidence, and I present the Oakley Greenwood South Australian Case Study to demonstrate these options.
- The issue is the timing of the transition, and this is in the end driven largely by the pace of investment that can be achieved and ensuring that the transition is reliable and affordable for customers.
    - But it is achievable, and gas infrastructure can play a vital role as the SA Case Study demonstrates.
- I also outline that we need to separate the concept of gas infrastructure from that of natural gas as the fuel, as this creates a major risk that we will foreclose on a range of what could be valuable options in this transition to zero emissions.
    - Gas infrastructure can be used for zero emissions gases, and they are an excellent form of renewable electricity storage and use of renewable resources in their production.

2.2. Project Rationale – the WORM has already been factored into the transition

In looking forward to the future roles for gas infrastructure (and associated investments) it has been a given that:

- Existing infrastructure investments, that have been extensively scrutinised and justified, will be made to ensure energy security and reliability (and affordability) during that transition, and
- That in undertaking those considerations that this transition can occur in as greenhouse friendly a way as is practically possible.

The WORM is one of those investments that has been considered by all of the energy planners as being not only essential but has also already been approved by the Australian Energy Regulator (AER) after having been through extensive analysis and justification.

The Australian Energy Market Operator (AEMO) has fully factored in this investment in its future market development analysis, and as I understand it has the support of the Victorian Government in its Gas Substitution Roadmap, and the Commonwealth Government in its National Gas Infrastructure Plan.

Therefore, it is with this background that the EES Project Rationale was written and submitted as I understand the process, and I can outline here some of the reasons this has been factored into the transitional pathway as presented in the EES.

2.2.1. It fits with Victorian Government Policy

The Victorian Government has identified four key energy policy objectives to guide the operation and evolution of its energy sector. These objectives are to ensure:

- An efficient and secure energy system.
- That energy supplies are delivered reliably and safely.
- That consumers can access energy at affordable prices.
- That energy supplies and the way we use them are environmentally sustainable and less greenhouse intensive.

The Victorian Gas Substitution Roadmap reiterates these points and makes the same timing arguments as I have already outlined[2]:

> *Given the reliance on gas in Victoria, gas will continue to play a role in meeting Victoria's energy needs for years to come. Until such time as renewable and zero emissions alternatives become available at scale and are embraced by the market, it is important to maintain a reliable supply of affordable gas.*

The Consultation Paper also recognises that there are many options for decarbonisation as I have outlined and in the short term there is uncertainty that needs to be recognised.

> *There are many ways to reduce emissions from today's gas use. These include improving energy efficiency and switching to alternative, lower emissions energy sources. Reducing fugitive emissions from the production and transport of gas will also be important. The right combination of these 'decarbonisation pathways' is uncertain today.*

2.2.2. Forecast gas supply shortfall during peak demand periods

The Australian Energy Market Operator monitors, manages and undertakes forecast planning for gas systems across Australia. AEMO manage the distribution of gas flow throughout Victoria based on supply and demand requirements.

AEMO in 2020 identified risks of a natural gas supply shortfall in Victoria in the winter months, from 2024 onwards.

That predicted shortfall is due to supply constraint factors rather than changes in demand, which are discussed in further detail in Section 2.4 (of the EES Chapter 2), and include:

- Some of Victoria's key gas sources approaching end of life or forecast to cease operation.
- Uncertainty about the status of future gas supply projects for Victoria.

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2 Victorian Gas Substitution Roadmap - Consultation Paper, page 42, Key Issue 3: Maintaining the reliability, affordability and safety of gas supply (June 2021).

- Network capacity constraints, which will result in inadequate transfer and storage rates over summer to meet winter peak demand.
- This assumption regarding available peak day supply capacity is forecasted to increase, following the expected completion of the WORM project in late 2022.

As can be seen from the AEMO work presented in the EES the WORM construction has already been factored into the gas supply forecasts and even over the short term, after the WORM comes on-line, Victoria will still be reliant on other gas supply investments to meet gas demand from 2024 onward.

> *The threat of shortfall is expected to be addressed through the commitment from Australian Industrial Energy (AIE) to construct the Port Kembla (New South Wales) liquefied natural gas import terminal and Jemena's commitment to modify the Eastern Gas Pipeline to permit reverse flow from Port Kembla into the DTS.*

It may well be argued (as it has in some of the submissions) that other options may exist in that timeframe (after 2024) to assist in meeting peak day gas demand, but it is clear that the completion of the WORM by late 2022 is critical to ensuring that energy supplies are maintained for Victorian consumers and businesses.

I do in this evidence address the issues related to early transference of gas heating demand in winter to the electricity system. Apart from how this may actually impact the electricity network the key issue is that such a move would also likely increase greenhouse gas emissions due to the time it will take to build the necessary renewable electricity generation assets and how these intermittent generators will need to be supported with dispatchable generation. The South Australia case study included in this report is a good example of the issues and potential solutions.

This investment timing issue is also recognised in the Victorian Gas Substitution Roadmap Consultation Paper[3] (page 40, Key Issue 1).

> *Electrification will likely play a significant role in decarbonising gas in Victoria. But this will increase electricity demand, including at peak times, and so may place additional stress on the electricity grid. Decarbonising the energy sector tests the capability of the electricity networks to accommodate the increase in demand if gas load is converted to electrical load through electrification or hydrogen production*

2.2.3. The role of gas supply in Victoria's energy mix

The APA EES addresses the role gas infrastructure plays in assisting the development of renewable electricity generation, and this is a theme I explore in a lot more detail in this evidence as we all seek to implement the net zero emission policies. As outlined in the EES:

- Beyond 2024, the role of gas will increase in proportion to the decline in coal generation, with gas playing a particularly important role between 2030 and 2050 as the clean energy sector expands in line with VRET and broader climate change policy. However, the Australian Energy Regulator (AER)'s State of the Energy Market 2020 report has identified that the energy transition underway in Australia has led to increased concerns about reliability as the clean energy sector develops.

3 Victorian Gas Substitution Roadmap - Consultation Paper, page 40, Key Issue 1: Maintaining electricity reliability with new sources of demand (June 2021).

- The (AER) report notes that increased wind and solar generation in the national electricity market is creating more volatile supply and demand conditions in the energy sector. As the market transitions to a cleaner energy base, the energy grid must respond to sudden changes in renewable output, which indicates an increasing need for energy generation, storage and demand responses that can respond quickly to these changes. It notes that gas, hydro and batteries are well able to respond to the variability of wind and solar.

What is important to also add is that in the end the need for dispatchable generation (gas, hydro, batteries, etc.) is indeed critical but these options will compete for market share in providing that duty.

- Zero emission gases are a serious option for a variety of reasons I outline in this evidence but will need access to gas infrastructure. In fact, the existing gas infrastructure investments give them a distinct advantage in this competition to be the least cost form of renewable electricity storage to back up supply reliability.

The point is that gas infrastructure should not be seen as just being inevitably a stranded asset (as some submissions have proffered) but could in fact be a critical transitional and zero emission operational asset. It is vitally important not to foreclose on any of these dispatchable generation/storage options and allow the market to develop.

In this regard, given that the WORM plays a vital role in providing gas storage capability close to the Victorian energy market and is needed to address short term peak demand shortfalls, it could be a very good strategic asset in the development of a net zero emission energy system in Victoria (and I note that it is being designed to take all forms of zero emissions gases).

2.2.4. Gas storage in Victoria and the importance of gas transfer to the west

The EES outlines this major service that the WORM will supply in Victoria in terms of unlocking more access to storage and peak injection capability from the underground gas storage assets in the west (Iona Underground Storage Facility - Iona UGS).

The Iona UGS is Victoria's largest natural gas storage facility and is responsible for storing as much of Victoria's gas supplies as it can over the summer, for use in the winter. The facility has a storage reservoir capacity of 26 PJ – which is equivalent to 7.2 TWh – and to put that into perspective this is equivalent on energy terms to about 20 times that of Snowy 2.0.

That is one big "battery" if it can be repurposed using zero emissions gases and this is entirely possible (and storage of this type is explored in this report). It is also not only the gas storage that could and does assist bring gas to Victoria and these assets both a) in the transition to a zero emission energy system and b) potentially once that is completed. They are very strategic assets to try and repurpose. Again, this is highly possible and likely to be every competitive with other forms of renewable energy storage systems.

2.2.5. Other WORM benefits

The APA EES does outline other technical benefits that the WORM brings to the Victorian energy grid such as flexibility in flows around the networks, assisting to move gas from intestate receipt points to where it is needed in the networks, and even the ability to store more gas on the gas grid itself (linepack) which assists with energy security when managing the supply and demand balance for consumers and businesses.

The overview though is that the WORM has been factored in by energy planners, Governments, approved by the lead regulator for construction after strict testing of its needs (as the costs are socialised across consumers and businesses) and it also meets the needs of the transition to a zero emissions energy system in Victoria.

This is an issue I explore in this evidence as it addresses objections about its future value, more than its current necessity which has already been heavily assessed and factored into the reliable, and affordable supply of energy in Victoria in the near term by those charged with delivering this outcome for consumers and business, every day.

3. Relevant energy policy matters

The relevant energy policy matters, in regard to the Inquiry submissions in particular and specifically relevant to gas in Victoria include:

- The move toward delivering net-zero greenhouse gas emission outcomes in various jurisdictions, for the benefit of the community.
  - This ambition is also shared by many Commercial and Industrial energy users and has become part of their undertakings to their various shareholders and stakeholder groups in recent times. This trend is becoming well established.
- A need to ensure sufficient gas supply to customers at all times, at an affordable cost, for as long as they require such supply.

3.1. Victorian Climate Change Act 2017.

This Act legislates a net-zero greenhouse gas emissions, long-term target, for Victoria by 2050.

- Requires 5 yearly interim targets, to keep Victoria on track to meet this long-term target (reduce emissions by 28-33% by 2025, and 40-50% by 2030), and
- Sits alongside other Victorian Government initiatives including the Victorian Climate Change Framework, Climate Change Adaption Plan and Renewable Energy Action Plan.

The net-zero target means that natural gas use must be significantly abated, and the Victorian Government is developing the Gas Substitution Roadmap[4] to help achieve these interim targets and navigate the path to net-zero emissions.

> *The roadmap will detail the transition pathways and identify policy mechanisms to achieve Victoria's emissions reduction targets through reduced fugitive emissions, more efficient use of gas, electrification and increased use of sustainable gas alternatives such as hydrogen and biogas.*
>
> *Throughout the transition to fully sustainable alternative energy sources, the government's key priorities are maintaining energy affordability, security, reliability and safety for consumers and creating clean energy jobs and new skills over the coming decades.*

3.2. Victorian Gas Substitution Roadmap - Consultation Paper

The Victorian Government has:

> *….developed a consultation paper to discuss potential transition pathways to achieve net zero emissions and identifies key issues, which must be considered throughout this transition. We seek the views of the Victorian community and industry to help us better understand the opportunities and challenges that this transition will bring[5].*

This paper has two key sections, that also largely reflect the underlying work program being managed by the Department of Environment, Land, Water and Planning (DELWP), and Infrastructure Victoria (IV).

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4 Have Your Say On Victoria's Gas Substitution Roadmap, 26 June 2021, Media Release, The Hon Lilly D'Ambrosio MP, Minister for Energy, the Environment Climate Change.

5 "*Looking to the Future*", Energy Victoria website. Submissions on the Victorian Gas Substitution Roadmap Consultation Paper are now closed.

3.2.1. Decarbonisation pathways for the (Victorian) gas sector

There is modelling and other work being undertaken by Government agencies in Victoria (DELWP, IV) to consider the potential options and pathways to decarbonisation of the natural gas use in Victoria and longer-term impacts on energy infrastructure (gas and electricity), and consumers.

These include[6]:

- *Improving energy efficiency*
  - *Housing efficiency upgrades*
  - *Appliance upgrades*
- *Electrification*
  - *Substituting gas appliances with electric appliances and equipment*
- *Substituting natural gas with hydrogen*
  - *Or other renewable gases produced from hydrogen* [renewable methane[7]].
- *Substituting natural gas with biogas*
  - *From anaerobic digestion of organic material* [e.g., biomethane].
- *Emerging technologies*
  - *Concentrated solar thermal, carbon capture and storage, geothermal*
- *Addressing fugitive emissions*
  - *Leaks, venting and flaring of gases in the extraction, production, processing, storage and transportation of fossil fuels.*

As part of this endeavour the Government is:

> *…undertaking extensive analysis and stakeholder engagement to inform the development of the Roadmap.*

and

> *…….has commenced 'deep-dive' investigations.*

The deep dive investigations include:

6 Victorian Gas Substitution Roadmap Consultation Paper, pages 26

7 Renewable methane is produced by the methanation of hydrogen - taking renewable hydrogen and carbon dioxide (from the atmosphere) - it is a net-zero emission form of methane, much like biomethane.

Figure 1: Gas Substitution Roadmap Consultation Paper – Deep Dive Investigations

Deep dive investigations include:

- A detailed scenario analysis of the costs, benefits, barriers and impacts of different transition pathways on all sectors of the Victorian economy
- A study to identify opportunities to reduce fugitive emissions across the natural gas supply chain
- An examination of potential measures to enhance reliability across the gas supply chain
- An investigation of potential policy mechanisms to support the increased uptake of renewable options such as hydrogen and biogas

The Government has also:

> *……sought advice from Infrastructure Victoria (IV) on the nature and optimal timing of decisions supporting the decarbonisation of gas use in Victoria, including opportunities to support increased use of more renewable and zero emissions energy alternatives. The work is also intended to promote improved understanding of the key opportunities, issues, choices, costs and benefits associated with decisions impacting gas infrastructure.*
>
> *IV will consult on its early findings in mid-2021 and provide a final report to the Treasurer by 31 December 2021. The IV workstream will inform the development of the Roadmap.*
>
> *This advice will be an important input into the broader gas decarbonisation pathway analysis being undertaken in the development of the Roadmap and in the identification of key milestones and actions that can harness Victoria's existing gas infrastructure to help Victoria achieve emission reductions through the use of hydrogen, biomethane and carbon capture and storage (CCS).*

These deep dive investigations are yet to report, but IV has issued its: *Interim Report - Towards 2050: Gas infrastructure in a zero emissions economy*.

3.2.2. IV Interim Report

IV have[8]:

> *….considered four illustrative scenarios to achieve net zero emissions for gas use in Victoria by 2050.*

8 Infrastructure Victoria Interim Report (July 2021): Gas infrastructure in a zero emissions economy, page 4.

The scenarios test key variables regarding the potential technology mix (electrification, natural gas, hydrogen and biogas) and the mechanism by which net zero emissions can be achieved - that is, whether emissions are eliminated or managed by solutions such carbon offsets and/or carbon capture and storage (CCS). The scenarios illustrate the performance of these key variables but are not intended to be definitive or reflect an optimal scenario.

In brief, the four scenarios are:

- *Scenario A: full electrification, no natural gas (by 2050), no CCS.*
- *Scenario B: partial electrification, limited natural gas use (in 2050), limited CCS.*
- *Scenario C: green and blue hydrogen with carbon offsets, electrification, no natural gas (by 2050), no CCS.*
- *Scenario D: large-scale brown hydrogen, large-scale CCS, no natural gas (by 2050).*

The interim report notes that to meet the State's interim emission reduction targets:

….an immediate scaling up of proven, reliable and relatively low-cost solutions is likely to be required, including energy efficiency, electrification and biogas.

There is also an early recognition of the critical issues related to hard to abate industries:

Reducing overall demand for natural gas will also help preserve available supplies for certain industrial uses which cannot yet move to other energy sources or chemical inputs.

This Interim Report though expressed some scepticism in terms of the long-term viability of the total reuse of the natural gas infrastructure (limited by its ability to be repurposed):

Under all scenarios that we considered, the opportunity to repurpose existing natural gas infrastructure over the long term (beyond 2040) is limited. Some existing infrastructure is reaching end of life, limiting its potential for reuse (for example, over half of Victoria's onshore pipeline infrastructure is over 40 years old). However, careful development, blending and optimisation of biogas and hydrogen over the short to medium term could maximise re-use of some existing pipeline infrastructure, although hydrogen production and use is not yet proven at scale.

The Interim Report does though hedge this position about gas infrastructure should there be an economic pathway for renewable gases to replace natural gas.

The future of low or net zero emissions gases, such as hydrogen produced with renewable electricity and seawater (known as green hydrogen), and decarbonisation pathways such as CCS remains uncertain. Victoria could support further research and development in these technologies until their economic and environmental viability at scale is known, ***with the aim of keeping Victoria's options open rather than locking in a single approach which may not turn out to be the best course of action [emphasis added]****.*

The IV interim report offers no solutions as yet, but does note the huge challenges that are faced in seeking to decarbonise the gas use in Victoria, including the potential costs for consumers:

The changes required to Victoria's energy sector, including gas, will have significant implications for consumers. These may include switching fuel, upgrading appliances, adopting new technologies and increasing energy efficiency efforts. The scale of the change required, and likely financial implications for energy users, suggest a clear role for government in managing affordability and equity issues associated with any transition away from gas, particularly given existing consumer concerns with energy affordability.

It is definitely worth considering some of the challenges of achieving a significant level of gas decarbonisation in Victoria, and to also acknowledge that a lot of other work is being undertaken on potential solutions (e.g., the DEWP studies) with for example promising modelling of renewable methane production (not yet considered by IV but has been included in the DELWP deep dive programs) and the potential levels of biomethane resources.

Clearly these are early days still in this analysis and it is important to keep:

……Victoria's options open rather than locking in a single approach which may not turn out to be the best course of action [emphasis added].

3.2.3. Transition issues and challenges

The transitional issues and challenges are explored in the Gas Substitution Roadmap Consultation Paper:

> *Section 4: Gas industry transition issues and challenges*.

These transition issues and challenges include:

- *Key Issue 1 - Maintaining electricity reliability with new sources of demand.*
  - *What policies are needed to ensure that the electricity network can reliably serve new sources of demand from electrification of gas demand, hydrogen production and electric vehicles?*
  - *What is the role for gas-fired power generation and hydrogen in maintaining electricity reliability?*
- *Key Issue 2 - Transitioning to more sustainable gaseous fuels with minimal disruption to end-users.*
  - *What are the key technical challenges in converting existing gas networks to accommodate more sustainable gaseous fuels?*
  - *What are the potential costs and opportunities in switching to more sustainable gaseous fuels for consumers?*
- *Key Issue 3 - Maintaining the reliability, affordability and safety of gas supply.*
  - *What are the affordability, reliability and safety considerations related to gas supply and gas infrastructure, both in the short term and during a long-term transition to a decarbonised gas sector?*
  - *What policies are needed to ensure that the gas system continues to operate reliably and safely and remain affordable for end-users during this transition?*
- *Key Issue 4 - Supporting Victoria's workforce, industry and the institutions that support them.*
  - *What workforce skills and industry capabilities are required to transition to new and emerging energy sources?*
  - *How can government, industry and unions best work together, including through the Victorian TAFE and Training system, to help to build these skills and capabilities, and support existing workers through the transition?*
  - *How do we maximise local job opportunities, including for industry training centres such as that operated by the Plumbing Industry Climate Action Centre, to prepare workers for the future?*
- *Key Issue 5 - Managing uncertainty in the transition.*

  - *What key uncertainties should the Roadmap take into account, and what is the government's role in reducing these uncertainties?*
- *Key Issue 6 – Transitioning the Victorian economy efficiently and equitable.*
  - *How can we ensure that the costs of transition to lower emissions energy sources are borne equitably?*
  - *How can we help low-income and vulnerable households manage any upfront costs in changing energy sources?*
  - *What are the barriers for households in improving the efficiency of their use of gas for heating, cooking and hot water and/or switching to solar/pump hot water in existing homes?*
  - *What are the opportunities for the Victorian Energy Upgrades program to incentivise efficient gas use, thermal upgrades of buildings (e.g. insulation) and electrification?*
  - What issues and elements do you see as most important to improve the energy and emissions performance of new homes?

These are indeed critical questions and it can be seen that the massive change in the Victorian energy sector that will be required in order to reach net zero emissions is very complex and needs to be well researched, modelled and considered in order to ensure sustainable outcomes for customers and industry, while achieving these goals.

3.2.4. Concerns about sufficient gas supplies to Victoria and the east coast

The Gas Substitution Roadmap Consultation Paper does not lose sight of the transitional issues related to ensuring an affordable (natural) gas supply and meeting customer demands over these periods referencing recent AEMO analysis, as outlined in Figure 2. This also aligns with the Project rationale as outlined in Section 2.

- The AEMO supply and demand analysis via the GSOO and VGPR[9] is well documented and a subject of other work being undertaken as part of the APA Victorian Transmission System regulatory review process by Oakley Greenwood, and others.

There are clearly concerns out to 2030 for gas supplies in Victoria and how these will be met – gas supply overall and peak demand for gas in the winter (largely to meet residential heating needs).

From a gas policy perspective this is a major issue not only outlined in the Victorian Gas Substitution Roadmap Consultation Paper but is also a key issue for the Commonwealth Government and is driving a number of their key policy initiatives that are covered in the next section of this Report.

9 Gas Statement of Opportunity 2021 (March 2021), Victorian Gas Planning Report (March 2021).

Figure 2: Vic Gas Substitution Roadmap Consultation Paper – Gas supply outlook for Victoria

Gas supply outlook for Victoria

For over fifty years, Victoria has had access to low cost, abundant natural gas, extracted from offshore gas fields located in Bass Strait.

However, as AEMO has indicated in its 2021 Gas Statement of Opportunities (GSOO), these gas fields are rapidly depleting. AEMO is forecasting an overall decline in Victoria's production of 43 per cent from 360 PJ per year in 2021 to 205PJ per year in 2025. AEMO has indicated that the establishment of an LNG import terminal at Port Kembla in New South Wales, together with the Eastern Gas Pipeline being made bidirectional to enable south-bound flow of gas to Victoria, addresses the risk of an imbalance in supply and demand, provided that the import terminal is operating by 2023.[1]

Victoria has already acted to bolster local gas supply with the restart of the onshore conventional gas industry from 1 July 2021 and the 2018 release of new gas exploration blocks in Victorian offshore waters (within three nautical miles of the Victorian coast). The Victorian Government will require gas producers to prioritise domestic gas consumers by first making reasonable and genuine offers to the domestic market for any gas production arising in Victoria.

The Victorian Government passed the Petroleum Legislation Amendment Act (2020) to set up the framework for an orderly restart of conventional gas exploration and development in 2021. To ensure a best practice regulatory regime, the Government is updating the supporting Petroleum Regulations and will be releasing a Regulatory Impact Statement for public consultation soon.

Lochard Energy's proposal to expand Victoria's underground storage capacity at the Iona Underground Storage facility and GB Energy's proposal to develop Golden Beach gas field as a gas production site before converting it into an underground storage facility will assist to meet winter peak demand.

The expected completion of the Western Outer Ring Main in 2022, a proposed 50-kilometre buried transmission gas pipeline to connect existing pipelines in Melbourne's west and north, will help to alleviate current constraints in Victoria's south-west pipeline and improve the ability to refill the Iona Underground Storage facility.

Other gas infrastructure proposals, including potential to import LNG directly to Victoria, may also play an important role in securing Victoria's gas supply by supporting an increased diversity of suppliers. Any proposals but must be fully compliant with Victorian environmental and planning laws to proceed.

1 Australian Energy Market Operator (AEMO), Gas Statement of Opportunities, 2021

3.3. Commonwealth gas policy matters

Gas supply and infrastructure development is a key policy focus for the Commonwealth Government. This focus has been on the immediate concerns about:

- The current supply of natural gas and how demand for gas will be met over the coming years, and
  - To assist to make that gas affordable for business and the community.
- The development of sufficient gas power generation capacity to support renewable electricity development and ensure a stable operation of the NEM in particular, and
- To assist where practicable and affordable the development of gas decarbonisation options through the development and adoption of suitable technologies.

The Commonwealth Government considers that natural gas can lead in the economic recovery of Australia post Covid – what they have termed the *Gas Fired Recovery*[10].

> *Gas will help re-establish a strong economy as part of the Government's JobMaker plan, making energy affordable for families and businesses and supporting jobs as part of Australia's recovery from the COVID-19 recession.*
>
> *Prime Minister Scott Morrison said the Government would reset the east coast gas market and create a more competitive and transparent Australian Gas Hub by unlocking gas supply, delivering an efficient pipeline and transportation market, and empowering gas customers.*

This is driving plans and activities to ensure there is sufficient investment in the gas market and infrastructure to ensure there is affordable gas available for gas use by consumers and power generation.

> *The Government will get more gas into the market by:*
>
> - *Setting new gas supply targets with states and territories and enforce potential "use-it or lose-it" requirements on gas licenses.*
> - *Unlocking five key gas basins starting with the Beetaloo Basin in the NT and the North Bowen and Galilee Basin in Queensland, at a cost of $28.3 million for the plans.*
> - *Avoiding any supply shortfall in the gas market with new agreements with the three east coast LNG exporters that will also strengthen price commitments.*
> - *Supporting CSIRO's Gas Industry Social and Environmental Research Alliance with $13.7 million.*
> - *Exploring options for a prospective gas reservation scheme to ensure Australian gas users get the energy they need at a reasonable price.*
>
> *We will boost the gas transport network by:*
>
> - *Identifying priority pipelines and critical infrastructure as part of an inaugural National Gas Infrastructure Plan (NGIP) worth $10.9 million that will also highlight where the government will step in if the private sector doesn't invest.*
> - *Reforming the regulations on pipeline infrastructure to promote competition and transparency.*
> - *Improving pipeline access and competition by kick-starting work on a dynamic secondary pipeline capacity market.*
>
> *To better empower gas consumers, the Government will:*
>
> - *Establish an Australian Gas Hub at our most strategically located and connected gas trading hub at Wallumbilla in Queensland to deliver an open, transparent and liquid gas trading system.*
> - *Level the negotiating playing field for gas producers and consumers through a voluntary industry-led code of conduct, to be delivered by February 2021.*
> - *Ensure Australians are paying the right price for their gas by working with the ACCC to review the calculation of the LNG netback price which provides a guide on the export parity prices.*

10 Ga-Fired Recovery, Media Release , Prime Minister, Minister for Energy and Emissions Reduction, Minister for Resources, Water and Northern Australia, 15 September 2020.PM statement

- *Use the Natural Gas Infrastructure Plan (NGIP) to develop customer hubs or a book-build program that will give gas customers a more transparent and competitive process for meeting their needs.*

The Commonwealth also has concerns regarding hard to abate sectors, and the $49b/year LNG export industry.

> *Gas supports the manufacturing sector, which employs over 850,000 Australians and is an essential input in the production of plastics for PPE and fertiliser for food production. In 2019, Australia was the largest exporter of LNG, with an export value of $49 billion.*

The Commonwealth Government also considers that supporting natural gas use in generation will significantly bring down Australia's greenhouse gas emissions more quickly and affordably[11], and this issue is explored in more detail in the attached Oakley Greenwood Case Study[12] of the South Australian electricity market that shows:

- Gas infrastructure and the development and operation of high percentage renewable electricity generation supply systems are proving to be strongly interlinked, and
- Gas infrastructure is also not tied inextricably to natural gas as such, as this can be replaced with zero emission gases completing the task of decarbonising the energy sector – but they will need the gas infrastructure.

3.3.1. The Natural Gas Infrastructure Plan

On 7 May 2021, the Commonwealth Government released the:

> *National Gas Infrastructure Plan: Interim Report.*

This report:

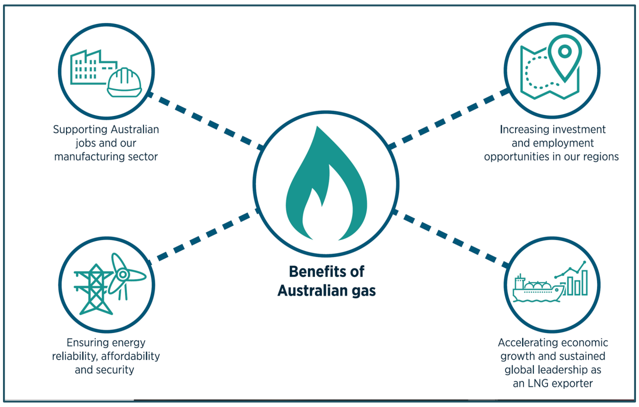
- Identifies the priority infrastructure developments required to alleviate forecast southern gas supply shortfalls in the near-term.
  - This included the WORM among others (e.g., Golden Beach & Iona gas storage developments in Victoria) being recognised as a Critical Infrastructure project:

    > *Upgrades to the South West Pipeline (SWP) are equally critical in order to unlock the additional storage potential of the Iona facility and could support additional production from new fields in the Otway Basin. The business case for further SWP expansion, beyond that already committed as part of the Western Outer Ring Main (WORM) project, warrants examination to assist in meeting peak demand.*
- The *critical role in complementing increased uptake of renewable energy technologies* that gas is playing.

11 National Gas Infrastructure Plan Interim Report, May 2021, pages 2, 4, 8.

12 This study also examines how to use gas to get to zero emission outcomes through the decarbonization of natural gas, using gas infrastructure.

Figure 3: NGIP: Benefits of Australian Gas



Source: NGIP

The Government has committed $58.6 million in funding in the 2021-22 Budget to continue to advance the work of the gas-fired recovery[13].

> *Through the 2021-22 Budget, the Government is building on the progress already made to drive Australia's gas-fired recovery through $58.6 million of new measures including:*
>
> - *The release of the National Gas Infrastructure Plan: Interim Report.*
> - *$38.7 million for targeted support of critical gas infrastructure projects to alleviate the forecast gas supply shortfall.*
> - *$3.5 million to design and implement the Future Gas Infrastructure Investment Framework to support the Commonwealth's consideration of medium to long-term critical gas projects identified by future National Gas Infrastructure Plans (NGIP).*
> - *$5.6 million to strengthen the Government's energy system planning framework by delivering a further NGIP in 2022.*
> - *$4.6 million to develop initiatives that empower gas-reliant businesses to negotiate competitive contract outcomes, including developing a voluntary standardised contract framework.*
> - *$6.2 million to continue work to accelerate the development of the Wallumbilla Gas Supply Hub in Queensland.*

Many of these initiatives are relevant to the Project as there needs to be sufficient gas supply into Victoria to allow gas to be stored and used in the peak winter periods.

3.3.2. Prospective National Gas Reservation Scheme

The Commonwealth Government has also released an Issues Paper[14]:

> *Options for a prospective national gas reservation scheme.*

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13 Minister for Energy and Emissions Reduction, Media Release regarding the NGIP Interim Report release, 7 May 2021: *Advancing Australia's gas-fired recovery*

14 DISER: Gas reservation issues paper (October 2020)

DISER has developed this issues paper outlining a range of issues on which it seeks information and feedback. The paper provides a short factual overview of Australia's gas markets and regulatory interventions to date and briefly summarises the issues created by prospective gas reservation.

The issues paper highlighted the concerns about future east coast gas supply shortages and how a national reservation scheme may impact investments in oil and gas supply projects.

No follow up publications appear to have been produced, but the responses to the Issues Paper and options are being considered.

The relevance to the Project of such a scheme would be to ensure that there is sufficient gas supply into Victoria, again to be able to manage the peak demand periods.

3.3.3. Other gas initiatives – ADGSM, GSG, Gas Inquiry, PCT - CTP & DAA, Part 23 NGR

These initiatives add to a number of existing gas initiatives that the Commonwealth Government has implemented over the last 4 to 5 years[15]. These include:

- The Australian Domestic Gas Security Mechanism (ADGSM)

  Introduced in July 2017, the ADGSM gives the Commonwealth Resources Minister the ability to restrict LNG exports in years where the domestic market is in shortfall. In 2019, the Government carried out a review into the ADGSM, finding it has been largely effective in securing gas supply.

  In October 2017 and September 2018, the east coast LNG exporters agreed with the Australian Government that they would offer uncontracted gas to the domestic market in the event of shortfall. On 15 September 2020, the Prime Minister announced that the Government would negotiate a new agreement with the east coast LNG exporters that would strengthen price commitments. [Note: this was agreed on 5 January 2021[16]]

- AEMO Gas Supply Guarantee

  In 2017, pipelines and producers committed to making gas available to meet peak demand periods in the National Electricity Market.

- Gas Inquiry 2017-2025.

  In 2017, the Government directed the ACCC to use its special powers to conduct an inquiry into Australia's natural gas markets, and to publish important information on gas supply and pricing from 2017 to 2020. In 2019, the Government announced the inquiry's extension to 2025.

- Gas Acceleration Program.

  Since 2017, the Government has provided $26 million to five projects to speed up the development of onshore gas projects for the domestic market.

- Bilateral State Energy Deals

15 DISER: Gas reservation issues paper (October 2020), page 6.

16 Australian East Coast Domestic Gas Supply Commitment Heads of Agreement, 1 January 2021.

The Government is entering into bilateral agreements with state and territory governments on energy and emissions reductions. The first bilateral agreement, which committed $960 million from the Commonwealth, was signed with New South Wales on 31 January 2020. Agreements with other states are being negotiated and will be finalised progressively.

> *On 31 January 2020, the Hon Scott Morrison MP, Prime Minister, and the Hon Gladys Berejiklian MP, Premier of NSW, signed an agreement, worth more than $2 billion, committing both governments to collaborate on a number of initiatives that will:*
>
> - *increase gas and electricity supply in NSW by encouraging investment.*
> - *improve grid security by supporting transmission interconnection and network access.*
> - *support emissions reduction projects that deliver genuine abatement.*
>
> *On 30 April 2021 Minister Taylor (Australian Government Minister for Energy and Emissions Reduction) and Minister Kean (NSW Minister for Energy and Environment) signed a Joint Statement setting out how the governments will further cooperate.*

Other deals have also been signed that include South Australia and Tasmania.

> *On 18 April 2021, the Australian Government and Government of South Australia signed a $1.08 billion energy and emissions reduction agreement that will deliver secure, reliable and affordable energy to South Australians and the east coast market.*
>
> *Key components of the agreement include:*
>
> - *a gas target of an additional 50PJ (petajoules) per year by the end of 2023 and a stretch target of 80PJ per year by 2030*
> - *$400 million in Commonwealth funding for investment in priority areas such as carbon capture and storage, electric vehicles, hydrogen and other emissions reduction projects*
> - *up to $100 million for Project EnergyConnect through joint underwriting of key early works to boost the flow of power between South Australia and NSW*
> - *up to $110 million in Commonwealth concessional finance for solar thermal and other storage projects in South Australia.*
>
> *On 15 December 2020, the Australian Government and Tasmanian Government signed a bilateral energy and emissions reduction agreement to deliver secure, reliable and affordable power for Tasmanians. The deal will better connect Tasmania with mainland Australia and the National Electricity Market through the Marinus Link interconnector project and the Battery of the Nation initiative.*
>
> *Under the agreement, the Commonwealth will contribute a further $93.9 million, while Tasmania will provide $39 million, to progress the Marinus Link project towards a financial investment decision.*

- Pipeline regulation

Commonwealth, state and territory energy ministers are undertaking a process to develop options to improve gas pipeline regulation.

This has included:

- The **Pipeline Capacity Trading Platform and Day-Ahead Auction** (PCT, CTP, DAA) that incorporates standards for key contract terms and a reporting framework. This went live on 1 March 2019 and has been very effective at allowing access to unused gas transmission capacity.
- **Part 23** (Access to non-scheme pipelines) of the National Gas Rules (NGR) that provides for an arbitration to resolve access in relation to non-scheme pipelines.

  The arbitration mechanism is intended to provide a credible threat of intervention to constrain the exercise of market power during negotiations. If a dispute is referred to arbitration, the aim is to provide for final resolution in a cost-effective and efficient manner. Part 23 (Division 4) outlines the pricing and other principles that the arbitrator must have regard to when determining access disputes. These principles are designed to provide for access at prices and on other terms and conditions that, so far as practical, reflect the outcomes of a workably competitive market.

  This has similarly been a very effective initiative.

It can be seen that the Commonwealth Government has been heavily engaged with the gas industry for some 5 years to assist it in meeting its overriding goals of affordable and reliable gas supply for consumers. These goals align with those of the Project Rationale in terms of meeting customer demand in Victoria.

3.3.4. Energy Security Board (ESB) – Electricity Market Redesign.

The ESB was requested by the nation's energy ministers in March 2019 to examine the redesign of the National Electricity Market (NEM) – *The 2025 Project*[17].

> *The future course of energy investment and operation is at a turning point. The shift to new technologies and renewables is happening at speed and the need for reform is urgent as we lay the foundations for Australia's new energy future. More consumers and producers are taking up these opportunities. Just one example of consumer choices driving structural change is the rapid spread of rooftop solar, smart appliances and other distributed energy resources that are changing the face of the market. The shift to grid-scale renewables is equally important. Australia's power system may well become the most decentralised in the world.*

- The ESB has completed this work, after an extensive stakeholder engagement process.

  The ESB handed its final advice on the national electricity market redesign to energy ministers on the Energy National Cabinet Reform Committee on 27 July 2021 and the advice was publicly released on 26 August 2021. National Cabinet is now considering the full suite of recommendations. Some reforms foreshadowed in these recommendations cannot wait and work is already underway, with much more to come. This reform package as a whole is essential, not optional, to allow us to meet our future energy needs.

The ESB advice was a complex mix across NEM issues, and I have looked in this report to examine the relative issues for gas infrastructure. The ESB made the point[18] that:

> *We're not debating the merits of coal, storage, renewables or gas. The job is to get firm and flexible supply. To achieve that we need improved information, harmonised jurisdictional schemes and orderly generator exit and entry.*

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17 https://esb-post2025-market-design.aemc.gov.au/

18 ESB Final Advice July 2021 Material, page 2.

The long-term solution requires a stronger investment signal to lock in long-term revenue streams. Participants need sufficient incentives and confidence to invest in new capacity. Jurisdictions need assurance that participants will meet the power system's physical needs.

Principles for a common approach for all jurisdictional investment schemes will support competitive outcomes alongside current market frameworks.

A new opt-in, jurisdictional strategic reserve would give jurisdictions the option to procure any required reserves beyond the current market reliability standard if considered necessary for their region.

Extension of the existing South Australian ministerial 3 year ahead Retailer Reliability Obligation[19] (RRO) trigger so it is available to all ministers if they wish to use it while further detailed design is done on a new capacity mechanism.

There is significant concern to ensure that the investment is made in sufficient dispatchable capacity[20] in the NEM to back up the forecast growth in intermittent renewable electricity supplies as Australia transitions to a net zero emissions energy supply.

Based on the ESB advice an electricity generation capacity market mechanism may well be implemented to ensure this is the case. This is a process where a dispatchable form of generation or demand reduction is paid to be available to run or reduce demand when required by the market operator (under defined rules) largely to support the reliability of the electricity supply system[21]. This is often termed as Reserve Capacity and can be established for example by an auction process to ensure the lowest cost options are contracted.

The ESB also makes the following statements and observations in its advice[22].

An additional 55 GW of projects is being proposed across Australia's east coast, almost as much generation capacity as exists today.

They also note that the:

National electricity market coal fleet will halve by 2030.

and

Keeping lights on as the generation mix undergoes profound change.

This issue is explored in more detail in the (OGW) South Australia Case Study at Section 5, and is relevant to the Project in terms of the future potential role of gas infrastructure in these market transitions.

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19 AER: *The RRO is designed to support reliability in the National Electricity Market (NEM). In particular it encourages retailers, and some large energy users, to establish contracts for their share of demand for a prescribed period.*

20 Dispatchable capacity is the ability to turn on and off at any time a source of electricity supply. This supply could for example be gas generation, hydro generation, battery discharge.

21 The Western Australian Electricity Market incorporates a capacity market mechanism.

22 ESB Final Advice July 2021 Material, page 2.

4. Victorian gas industry transition issues and challenges

There are several things to keep in mind when considering the decarbonisation of natural gas (and not only in Victoria).

4.1. It is a lot of energy to decarbonise and will take a lot of time and investment

The relative size of the gas consumption in Victoria is a lot larger than most people realise, as the energy units used (PJ) is not well known outside the gas sector.

- The Victorian gas consumption is the largest domestic use by a State in Australia in terms of supplying residential and business customers and is much higher than the total electricity consumption of Victoria.
  - This is circa 200 to 230 PJ/year[23] which translates to some 55 TWh of electricity (55 million MWh).
  - This is the same size as the entire electricity load of Queensland.
  - Therefore, electrification could see this load added to that of the current Victorian electricity sector, which is lower at 44.3 TWh.
  - Which make Victoria the largest electricity demand centre in the country at circa 100 TWh/year – more than double the current electricity market.
  - This may be less in total due to relative appliance efficiencies between electricity and gas, but it is still a massive change, and this is also recognised in the Victorian Governments Gas Substitution Roadmap Consultation Paper (June 2021)[24]:

    Electrification will likely play a significant role in decarbonising gas in Victoria. But this will increase electricity demand, including at peak times, and so may place additional stress on the electricity grid. Decarbonising the energy sector tests the capability of the electricity networks to accommodate the increase in demand if gas load is converted to electrical load through electrification or hydrogen production.
- This new load would all have to be met by renewable generation as would the rest of the existing load in Victoria.
  - Victoria has some 12,000 MW of current generation capacity, including 2,292 of Hydro resources (if Snowy is to be included).
  - 60% of this is coal and gas generation at 7,250 MW (75% without Snowy).
  - AEMO's 2020 ISP[25] finds that at least 13,200 MW in renewable generation would be required to deliver the Victorian Renewable Energy Target under its Central scenario when using the latest demand forecasts. This target is 40% renewable energy generation by 2025 and 50% by 2030.
  - There is currently 4,750 MW renewable generation capacity in service and 2,500 committed to be built – so another 5 to 6,000 MW would need to be committed to reach 50% by 2030 – without gas decarbonisation.

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23 Victorian Gas Substitution Roadmap – Consultation Paper, June 2021, page 11.

24 Page 40.

25 2020 Victorian Annual Planning Report November 2020, page 8.

  - Presumably this level of renewable generation would have to double again to reach 100% by 2050 (although this is probably a serious underestimation of what would actually be needed due to capacity factors of such plant). So, another 13,200 MW to reach something like 26,00 to say 30,000 MW in total.
  - Gas decarbonisation would prime facie require doubling this level of renewable generation again – say another 26,000-30,000 MW – with totals in excess of 50,000 to 60,000 MW.
  - This is very simplified analysis, but it does demonstrate the size of the developments and investment needed.
- The second part of this analysis is how would this level of intermittent electricity generation be supported in terms of firming/back up?
  - This would mean having adequate storage of renewable electricity to be able to supply during extended periods where wind and/or solar generation is not available (wind not blowing, bad weather)
  - The sources of this storage could be zero emission gas, more pumped hydro, and batteries.
  - The attached Oakley Greenwood South Australian Case Study gives some example analysis of how large this storage may need to be to reach a zero emission outcome for the energy grid in that State.
  - It is not meant to be exacting analysis, just indicative and it shows that this will also require a massive investment in storage technologies.
  - Zero emission gases show real promise in being able to provide this duty and in Victoria the gas infrastructure, including access already to major underground gas storage, linepack and new storage assets gives zero emission gas options a major investment head start.
    - For example the Iona Under Ground Gas Storage Facility has a capacity of some – 26 PJ which is about 7,200 GWh = 20 times that of Snowy 2.0 – again this is just indicative of how efficiently energy can be stored using gas, and there are many other gas storage options available to Victorian in the east coast gas infrastructure.
    - I also note that the WORM project is vital in being able to access and use such storage very efficiently and at greater rates of reinjection.
  - The gas infrastructure that supports the Victorian market is world class with the Victorian Gas Transmission System (which is underground) flowing more energy than the entire electricity grid in Victoria.

It has to be a very high priority to be able to use these assets for decarbonisation, and the SA Case Study demonstrates why this should be a key objective for Government and why the WORM is a vital piece of infrastructure.

4.2. Investment timing issues

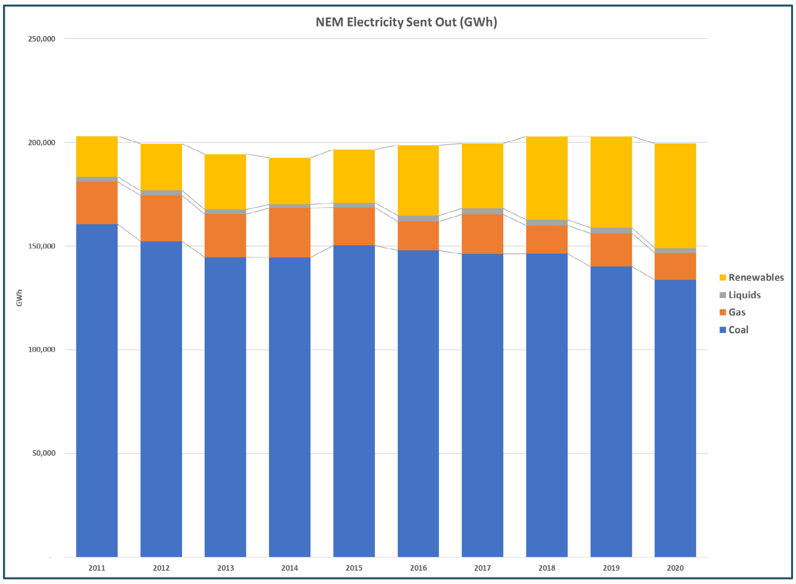
The quick look above at the relative quantum of renewable electricity generation that may be needed to reach net zero emissions shows that there will be decades of investment in these assets and storage systems and related assets required.

The current investment trends are instructive, as there has been a boom in investments in wind generation and solar generation (rooftop and large-scale grid connected systems) over the last decade which is very promising.

There is a lot more required to be built and installed which means investors need a high confidence in returns and that customers can see a reliable and affordable transition pathway being laid out by Government. But the task should not be underestimated.

- Figure 4 demonstrates the relative dependence still in the NEM on coal and gas generation, even after this solid decade of investment in renewable generation in the grid and on rooftops.

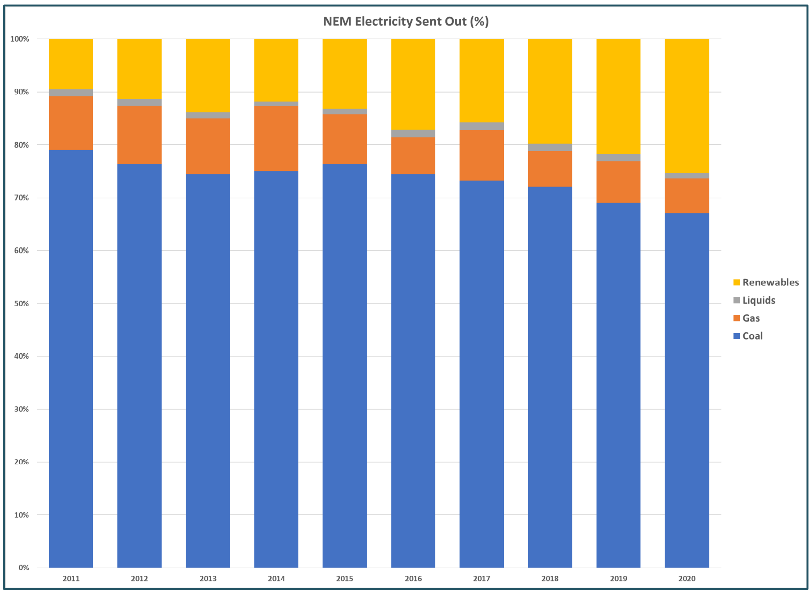
Figure 4: NEM generation mix trend 2011 to 2020 (GWh)



Source: Australian PV Institute analysis, AEMO 2020 ESOO data.

- This dependence can be seen in Figure 5 with some 75% of electricity generated being gas and coal derived. In 10 years we have added 15% renewable generation output.

Figure 5: NEM generation mix trend 2011 to 2020 (%)



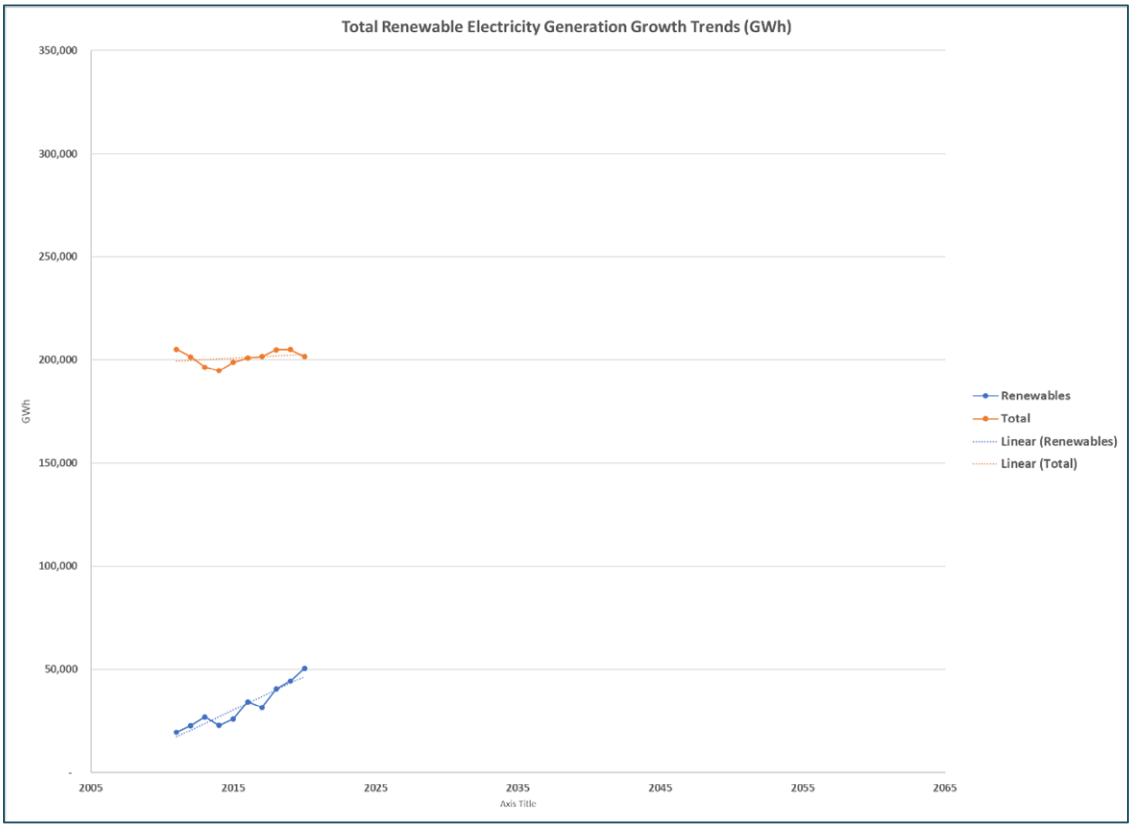
Source: Source: Australian PV Institute analysis, AEMO 2020 ESOO data.

The following chart is of interest when considering how to close the gap over to 2050 in terms of moving to a high level of renewable electricity concentration. Over the last 3 years the rate of growth in renewable generation output (MWh) has been some 3.2% per annum. This indicates that there is another 20 to 25 years of this level of investment needed to decarbonise the existing supply system (to say 2045) so this is prime facie reachable.

However, this does not account for the addition of the gas demand onto the electricity demand (by direct use or use of zero emission gases derived from renewable electricity[26]).

- This gas demand domestically on the east coast is circa 150 to 180 TWh (the National Electricity Market is 200 TWh), and even accounting for various potential efficiency gains using electricity instead of gas for some applications (such as reverse cycle air conditioning) this is an enormous addition to the electricity supply system – and at current rates of investment in renewable electricity generation would take circa 45 years (say 2065).

Figure 6: Renewable generation growth trends



Source: Source: Australian PV Institute analysis, AEMO 2020 ESOO data.

4.3. Customer transition issues

In Victoria there are some 2.2 million households[27] alone consuming gas (61% of the gas), and they will have to make decisions in the next decades as to which fuels they will be using in their homes.

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26 Both hydrogen and renewable methane are produced using renewable electricity, to a lesser extent biomethane production may consume some small quantities of renewable electricity.

27 Victorian Gas Substitution Roadmap - Consultation Paper, June 2021, page 20.

If these decisions mean taking electricity or hydrogen then they will have to replace the entire fleet of gas appliances in their homes – cookers, hot water services and heating systems.

- They may have to as well upgrade their internal gas or electricity piping or wiring depending on what appliances they choose and what they have now.
- The costs of these investments will largely fall to the consumer.
- If hydrogen is chosen then there will also likely be costs incurred in upgrading the gas networks and related infrastructure to accommodate the use of hydrogen, and in the whole conversion process (house by house turn in of hydrogen will likely be an expensive process) but it is not clear yet who would pay for this to occur.

If they are able to receive zero emission forms of methane gas, then they will not have to do anything in terms of changing the gas appliances they use other than update them as they fail or need replacing.

- The gas infrastructure will also be able to be totally repurposed.
- These advantages make a compelling case for serious examination of zero emission forms of methane production, and this is starting to be realised by groups like APA (who are trialling Australian technology for renewable methane – see Appendix B) and Governments when looking at zero emission policies.
  - This is for example mentioned in the Victorian Gas Substitution Roadmap Consultation Paper[28].

The same issues are facing businesses that use gas in their processes and as feedstock, and many of them cannot easily switch to using electricity – often termed hard-to-abate industries. This sector consumers 31% of the gas in Victoria and gas is 65% of Victoria's industrial energy use[29].

4.4. Fugitive CH4 emissions

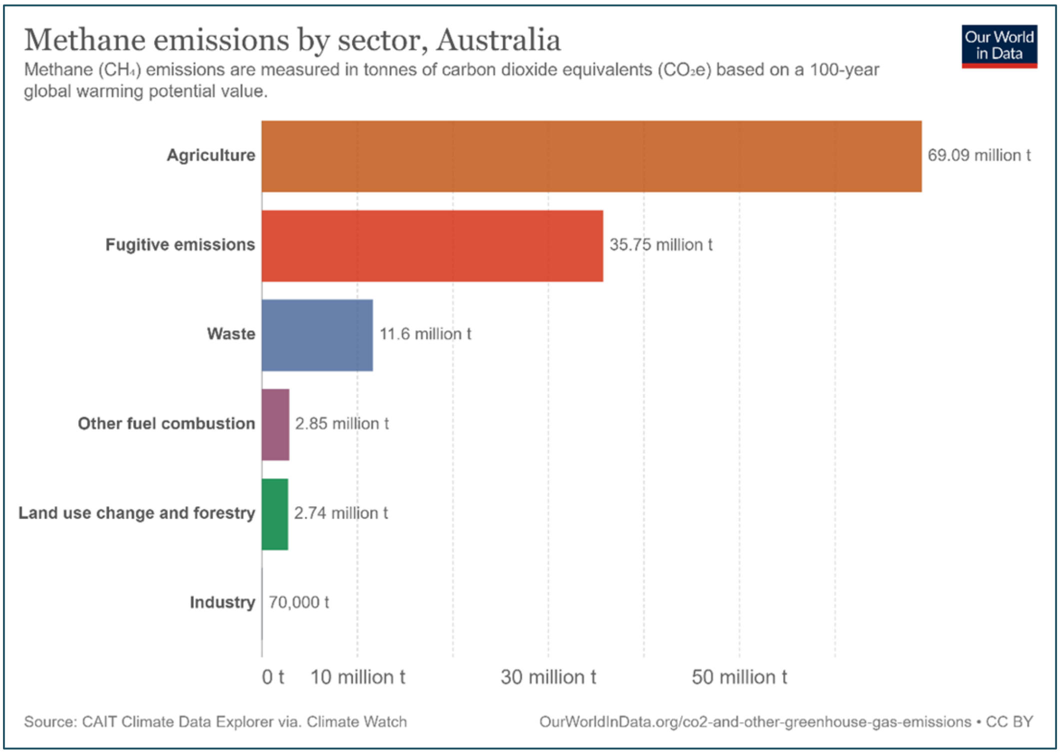
There are always questions raised about the potential level of fugitive emissions from gas pipelines (as opposed to gas production for example).

- Methane emissions from pipelines are in reality negligible – most gas that is "unaccounted for gas" (UCG) in my experience in a modern gas network are related to accounting issues with metering, not actual escapes of gas, and
  - This is understandable with steel and plastic piping networks that are pressurised, unlike the old days of bell and spigot piping with hemp or other joining material that was prone to leakage.
  - Nearly all of this has been replaced in Victoria through a specific program to achieve this outcome (to stop leakage from such older systems).
- This very low emission position for pipelines can be seen below in Figure 7 when we look at where the methane emissions originate in Australia – pipelines do not even rate.

28 Pages 26, 31

29 Victorian Gas Substitution Roadmap - Consultation Paper, June 2021, page 22.

Figure 7: Methane emissions by sector, Australia



Source: Our World in Data - www.climatewatchdata.org

The point here is that even zero emission gases that are a form of renewable methane will not contribute in any appreciable way to greenhouse emissions through "leakage".

5. The South Australian Case Study

South Australia's (SA) has the highest level of wind generation capacity within its energy mix[30] of any Australian State or Territory (2,140 MW in 2019-20). The amount of wind generation capacity in SA as a percentage of its total generation capacity is also very high by global standards.

Currently the scheduled[31] solar PV generation in SA is comparatively low (378 MW), but rooftop solar PV penetration is high (1,417 MW).

Of more importance for this case study though is that the wind generation contributed some 40% of the actual energy generated in South Australia in 2019-20 which is nearly as much as gas generation 43% (solar, including rooftop PV was 15%). South Australia has no coal fired generation.

This makes it worth having a close look at this market in terms of how renewable electricity generation may develop across other jurisdictions in the Australian National Electricity Market[32] as we head toward net-zero emissions from this sector, and the role gas (natural and zero emission gas) may play in that development.

5.1. SA current and future generation mix under the 2020 AEMO ISP

The following Table 1 compares the current generation mix in SA with that proposed in 2040 by AEMO, under what it terms the Optimal Development Path (ODP) in its current (2020) Integrated System Plan (ISP)[33] which forecasts generation outcomes under various scenarios and assumptions. The comparison below is based on the Central Scenario and assumed peak demands of 3,000MW for SA currently[34] and 40,000MW for the NEM in 2040.

Table 1: SA capacity comparisons – current and AEO ISP forecast 2040, Central Scenario

Comparison Parameters	South Australia	ODP 2040
Total SA generation installed (MW) relative to the peak demand (MW).	233%	259%
Dispatchable generation (MW) as % of peak demand (MW).	98%	55%
Solar generation, scheduled, non-scheduled and rooftop, (MW) as a % of peak demand (MW)	64%	104%
Wind generation (MW) as a % of peak demand (MW)	71%	63%

30 All capacity data was drawn from the AEMO South Australian Electricity Report 2019-20.

31 Scheduled solar PV plant is greater than 30 MW and has to be a registered generator in the National Electricity market.

32 The National Electricity Market generation dispatch process based on marginal bids does play a role in the underlying analysis as prices for example can be negative at times and this will constrain how generation decides to bid (as in may decide not to bid so they are dispatched).

33 AEMO 2020 Integrated System Plan, July 2020 for the National Electricity Market (NEM).

34 The South Australian summer peak in 2019/2020 was 3,221 MW and in 2020/2021 was 2,834 MW. The differences reflect the summer temperatures and weather experienced in each year. (Australian Energy Regulator: Seasonal Peak Demand - regions)

SA currently has proportionately more wind and dispatchable generation and less solar and battery capacity, than in the 2040 ODP forecast.

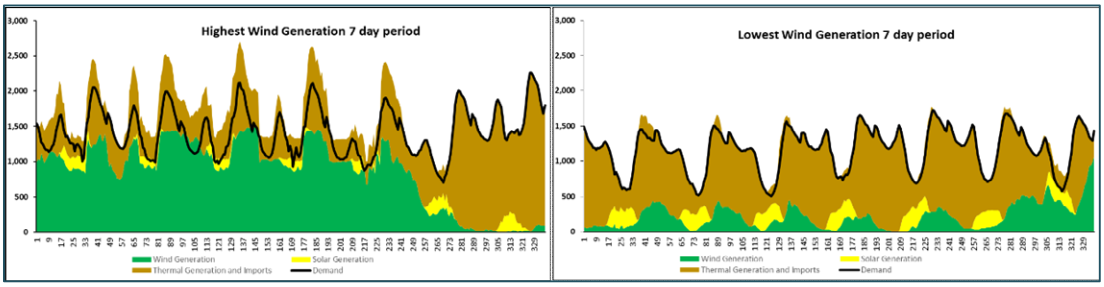
5.2. Impact of "wind droughts"

The SA electricity generation sector is a very useful, real time, example to try to understand the ability to store enough renewable electricity to deal with what are termed "wind droughts[35]", and to be able to meet peak demand under those circumstances. The focus on wind droughts is because wind is such a large contributor to the electricity generated in South Australia (40%), being as large as that from gas (43%).

To gain an understanding of the characteristics of wind generation in South Australia two years of AEMO dispatch and demand data was analysed – from 1/8/2019 to 31/7/2021 inclusive (the **Analysis Period**). Using this data, the 7 day period with the highest amount of wind generation (18/8/2020 to 24/8/2020) and the 7 day period with the lowest level of wind generation were identified (24/4/2021 to 30/4/2021) during the Analysis Period.

The following Figure 8 compares these 7 day periods and shows the level of dispatch of wind and utility solar generation separately and in combination the level of generation provided by gas and diesel generation located in SA (**SA Thermal Generation**) and electricity imported from Victoria (**Imports**). Demand is shown as a black line and where exceeded the excess generation is exported (into Victoria).

Figure 8: SA wind generation comparison – highest and lowest wind output weeks (MW)



Source: OGW analysis of AEMO dispatch and demand data (MW)

Figure 8 demonstrates the extent of the variability of wind generation levels with the high wind generation week having approximately 6 times the amount of electricity from wind than during the lowest wind generation week. Day-to-day variability can also be observed to be large even within a 7 day period. It also shows the dependence on other, dispatchable generation to support the wind generation.

Longer term, when no natural gas is available (or no imports that are not renewable electricity) as per the AEMO 2040 ODP, there will still be a high dependence on some form of dispatchable generation system or plant to support the renewable generation intermittency e.g., from battery storage, from hydro or from the use of renewable gases in generation such as hydrogen, biomethane or renewable methane[36] (all net-zero emission gases).

35 This is when the wind is not blowing for extended periods - similar periods do also occur for solar generation.

36 Renewable methane is created from the methanation of hydrogen using carbon dioxide drawn from the atmosphere or from biogenic sources, and various technologies exist for this type of production. Being methane based this form of gas like biomethane can be used in all existing natural gas infrastructure with no modification - pipelines, underground storage, power stations, appliances, etc.

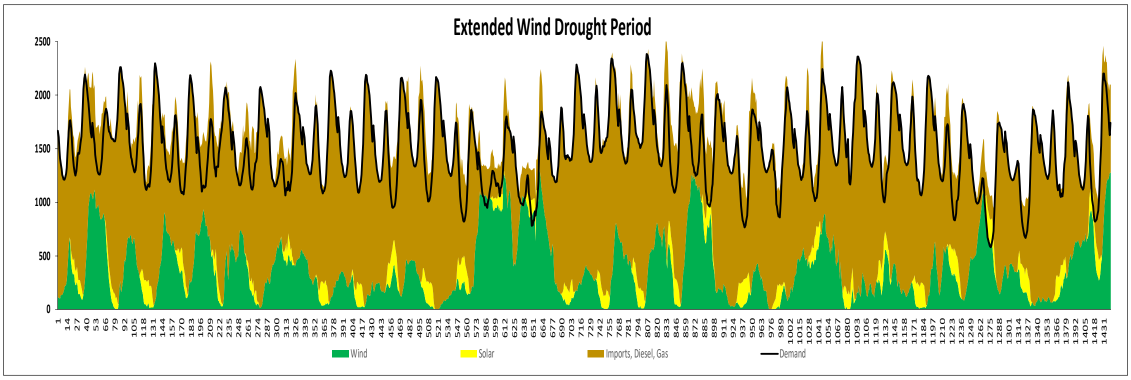
To gauge the depth of this issue of “wind droughts” in SA it is instructive to look at the SA dispatch data and the durations when wind generation was at less than 20% of installed wind generation capacity during the Analysis Period:

- In the last 2 years there were 292 days of 730 days (40%) where wind generation was less than 20%, and
  - 40 instances where wind generation was less than 20% on three consecutive days.
  - 18 instances where wind production was less than 20% on four consecutive days.
  - 9 instances of 5 consecutive days, and
  - 1 instance of 14 days.
- This is relevant as current “*Deep Storage*”[37] is considered as 48 hours of electricity storage by AEMO[38] and the CSIRO and yet there clearly appears to be a need for much longer periods of dispatchable electricity generation support.

In addition, the 30 day period (6/7/2020 to 4/8/2020 inclusive) where the most amount of SA Thermal Generation and Imports were required to meet demand was identified (the **Extended Wind Drought Period**).

Figure 9 below examines this Wind Drought Period which includes 20 days where the amount of electricity generated from wind generation was less than 20% of the installed wind generation capacity in total over the Period, though not on consecutive days.

Figure 9: SA 30 day Extended Wind Drought Period (MW)



Source: OGW analysis of AEMO dispatch and demand data (MW)

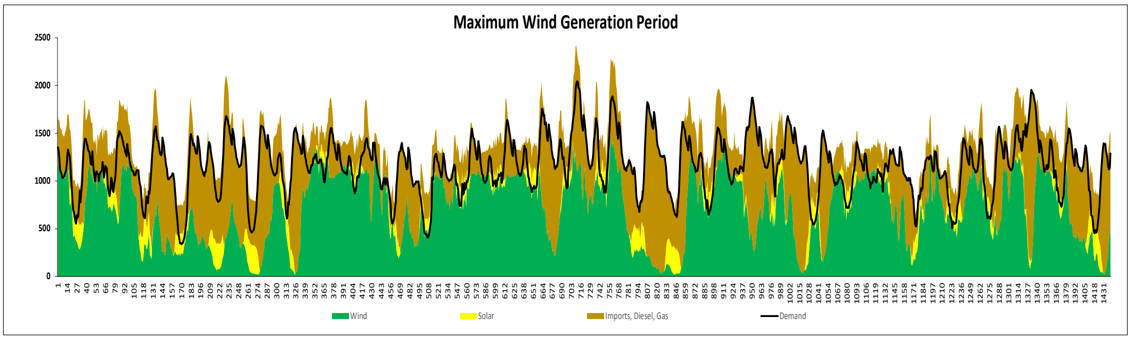
- During this Extended Wind Drought Period SA wind generation provided just over 25% of required demand, SA solar generation 4% and 71% of the required demand was supplied by a combination of SA Thermal Generation and Imports.

37 Deep Storage is the ability to store electricity in sufficient quantities that the storage can then deliver electricity continuously at a set level or capacity over an extended time period (e.g., 48 hours or longer). This is so that it can be used to cover periods when the wind is not blowing, or the sun is under cloud/storms and those forms of electricity generation are not available.

38 AEMO 2020 Integrated System Plan, July 2020 for the National Electricity Market, Bo x 5, page 5, and deep storage means the ability to back up the renewable generation supply for those periods - it can be storage of electricity or dispatchable generation, such as gas generation plants.

Figure 10 below shows the dispatch of generation during the 30 day period (10/9/2020 to 9/10/2020inclusive) where total wind generation was highest over the Analysis Period (the **Maximum Wind Generation Period**)

Figure 10: SA 30 day Maximum Wind Generation Period (MW)



Source: OGW analysis of AEMO dispatch and demand data (MW)

- During this Maximum Wind Generation Period SA wind generation provided almost 62% of required demand, SA solar generation 6% and 32% of the required demand was supplied by a combination of SA Thermal Generation and Imports.

5.3. Characteristics of wind generation in SA

The underlying characteristics of wind generation in SA needs to be explained so these results can be understood, in terms of:

- The energy delivered.
  - The quantity of wind generation (e.g., MWh).
- The level of generation occurring at the time of peak market demand.
  - The timing of the wind generation.
- How this interacts with the developing solar generation.
  - Be it behind the meter (e.g., rooftop solar) or grid connected.

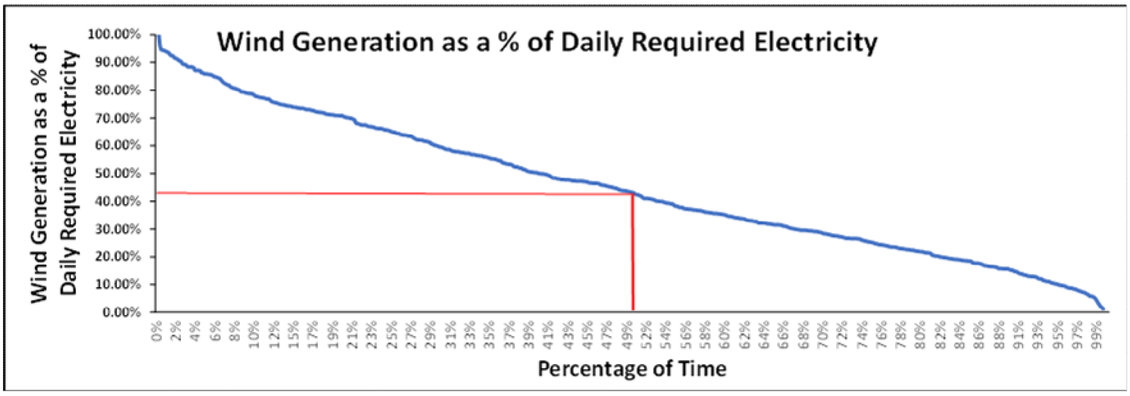
This is best done using load duration curves[39].

5.3.1. SA wind generation daily variability

Figure 11 below plots the level of wind generated in a day as a percentage of the daily requirement for electricity, from the highest day to lowest day in a year.

39 A load duration curve is similar to a load curve, but the demand or generation data is ordered in descending order of magnitude, rather than chronologically. (Wikipedia)

Figure 11: SA wind generation daily production as a percentage of daily requirement



Source: OGW analysis of AEMO dispatch and demand data

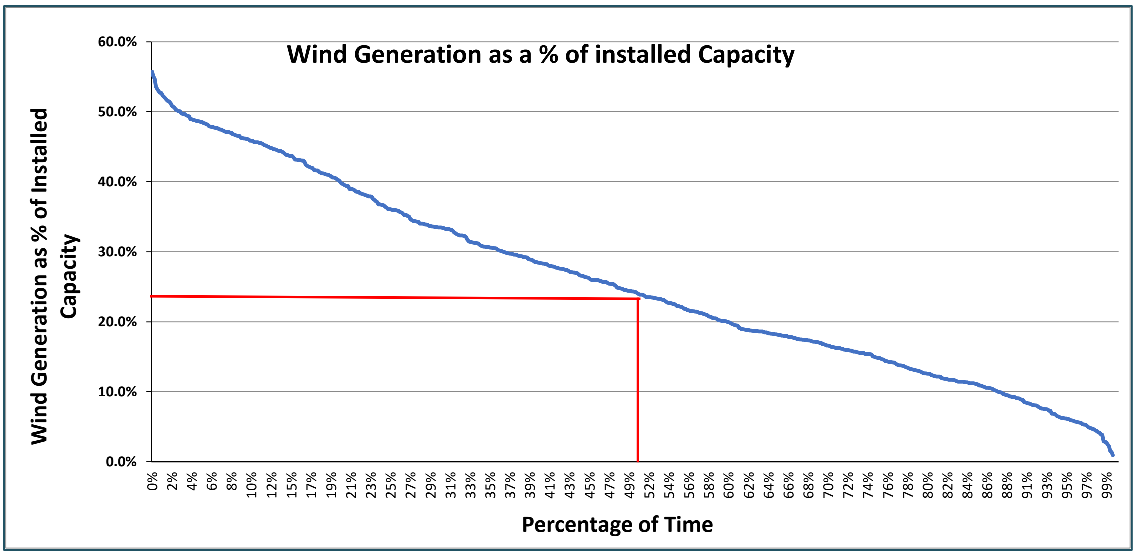
- Figure 11**Error! Reference source not found.** shows combined SA wind generation provide less than 50% of the daily electricity requirements less than 50% of the time, and
- It provides > 90% for less than 5% of the time.
  - So, on some days SA can literally be supplied by wind alone, and
  - On others it plays no part at all, and SA is very dependent on dispatchable generation (i.e., thermal generation and imports).

5.3.2. SA wind generation capacity utilisation

The reasons for this huge variance can be explained by examining the actual utilisation of the wind generation fleet in SA, how much it is actually generating relative to overall wind generation capacity.

To do this we can again look at the load duration curve for the daily generation actually provided as a percentage of the total electricity that could be provided by the Installed Wind Generation Capacity, if it was running at capacity. This is shown in Figure 12 below.

Figure 12: SA wind generation daily production as a percentage of capacity



Source: OGW analysis of AEMO dispatch and demand data

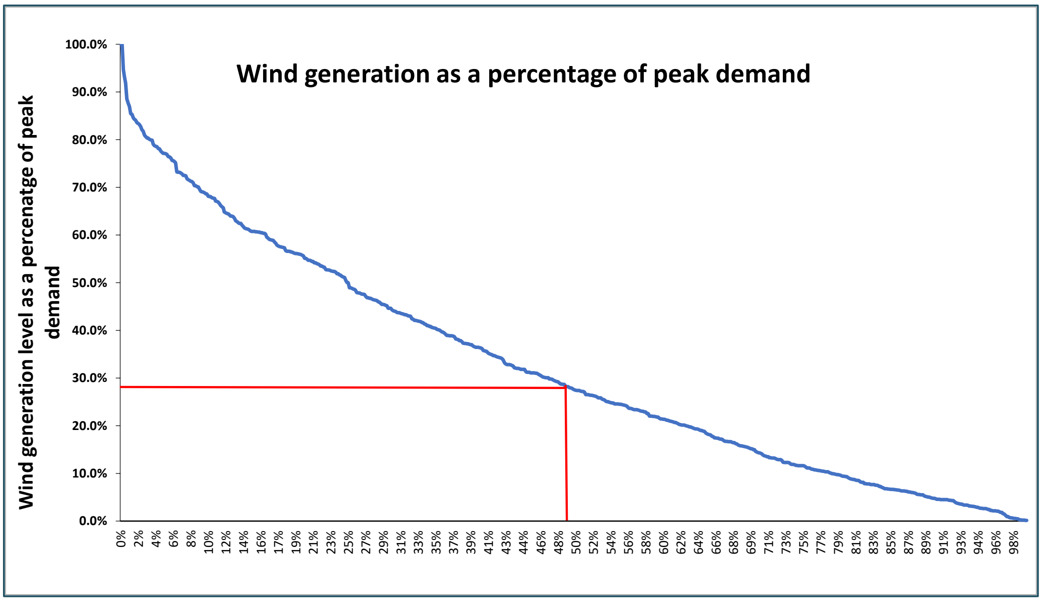
- Figure 12**Error! Reference source not found.** shows the relatively low utilisation of the Installed Wind Generation Capacity in SA with wind generating at less than 25% of its feasible output capacity for over 50% of the time, and
- Does not get above 60% of its output capacity at any time, and the average use is 26% of this period[40].
  - Wind is not a uniform source of energy as it simply does not blow consistently across the whole fleet every day for example, however
- The wind utilisation is relatively good compared to solar generation utilisation (which has much lower utilisation largely defined by daylight hours and panel positioning e.g., 17% average daily production in SA[41]).
- This explains why over the Analysis Period wind generation in SA contributed approximately 44% of the required electricity demand for customers and combined with grid connected solar just under 50%, requiring the remaining electricity to be supplied by SA Thermal Generation and Imports.

5.3.3. SA wind generation timing of peak output

The timing of the SA peak wind generation is also important in terms of the requirement for electricity generation that can be dispatched quickly to support its intermittency.

Figure 13 below shows the level of wind generation at the period of peak demand for electricity in SA as a percentage of peak demand, across the period (2019-20).

Figure 13: SA wind generation daily production as a percentage of daily peak demand (2019-20)



Source: OGW analysis of AEMO dispatch and demand data

40 Often termed the wind capacity factor, and this measure can vary a lot e.g., AEMO in its 2020 Integrated System Plan lists higher wind capacity factors for various parts of SA (not a weighted average as is the case here). I also note for completeness that there may be occasions where wind generation constraints may be applied for commercial purposes e.g., when prices in the South Australian market are negative.

41 Clean Energy Council: Solar Choice Clean Energy Council Solar PV Consumer Guide, page 4.

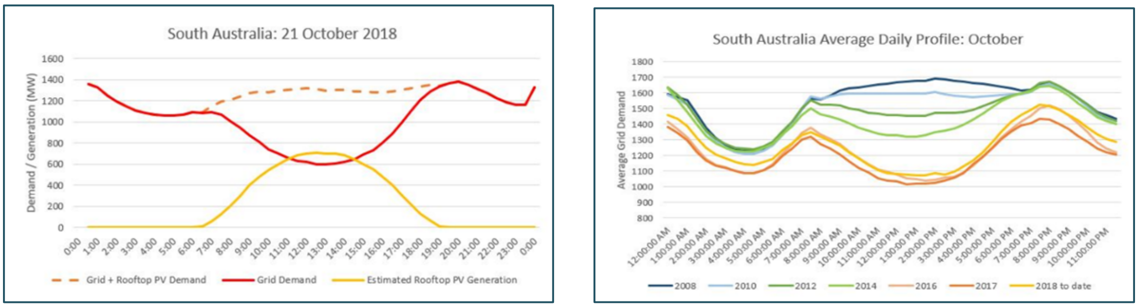
- Figure 13**Error! Reference source not found.** shows how much wind generation contributed to the peak demand daily across the period (2019-20).
- The wind generation in the period contributed less than 30% to meeting peak demand over 50% of the time (343 days over 2 years) requiring additional generation to be supplied by South Australian Thermal Generation and Imports.
- It shows that in terms of supplying 100% of the peak demand in South Australia this occurred some <1% of the time (on 2 days in 2 years).

5.3.4. Impact of rooftop solar generation on the SA demand profiles

One of the customer demand characteristics that significantly impacts in SA on the electricity generation analysis above (and across the NEM) is that generation from rooftop solar is seen as a reduction in mid-day load/demand and not as AEMO dispatchable generation.

- This has been changing the daily demand profile for dispatchable electricity with demand peaks now occurring at the beginning and end of the daytime solar generation period (often termed the solar “duck” curve). These changes can be seen in Figure 14.

Figure 14: SA rooftop solar impact on demand – the “duck” curve (2018 examples)



Source: AEMO: Swings and (demand) roundabouts in SA, 25 October 2018

- Grid connected solar generation, which is forecast by AEMO to grow substantially in SA, also does not contribute to meeting peak demand. It is instead creating these new periods of peak demand such as moving the peak back to 7 pm in this example from AEMO.
- This means any shortfall from wind generation in peak times in SA must be met by SA Thermal Generation and Imports.

5.3.5. The gas supply system has responded in SA to flexible dispatch

It is also important to understand that this form of flexible gas generation also means that the gas supply system and gas traders must also adapt to this intermittent generation by the gas plants. There can be periods where gas generation is low and where it is very high, and these variations can be for very short periods and for prolonged periods.

This requires a mix of flexible gas production capacity and gas storage capability. In particular the ability to store gas becomes critical to service fast start gas generation plants and the ability to acquire gas supply for prolonged periods at high levels requires highly flexible gas trading instruments and contracts.

The gas industry has responded to this challenge and, apart from some very innovative trading, the use of existing gas supply infrastructure to meet these new challenges has demonstrated its high level of flexibility and capability.

The ability to transport and store gas in specific storage facilities and as line pack[42] on major gas pipelines is proving to be essential if high levels of intermittent renewable generation are to be supported reliably. The WORM would also have this capability.

5.4. Looking more at the future renewable generation mix and wind droughts

The future generation mix across the NEM and including SA will see further rapid growth in wind generation, rooftop and grid connected solar generation, energy storage by way of batteries and pumped hydro, and new transmission interconnectors.

The phasing out of coal plant is also well documented so the heavy lifting for renewable generation intermittency support will move to storage options and dispatchable generation, which may well include new forms of gas generation if it is competitive (e.g., use of net-zero emission gases, existing gas infrastructure).

To examine what sort of impacts ramping up the level of renewable generation in SA may have on its need for battery storage and other forms of dispatchable generation we can use a simple overlay on the existing SA market demand profile that we have used in the previous analysis (an example of what may occur and its simplified impacts).

The following changes have been assumed, to create an example of the SA energy mix that is more representative of that conceptualised for the NEM under the ODP 2040:

- Maintain current wind capacity, as it is already close to the target level, and
- Multiply the current solar (scheduled) grid connected generation capacity by 7, and then
- Store the oversupply (supply in excess of demand) of any renewable electricity assuming no limits on the amount of battery storage capacity available[43], and
- Dispatched as per the same demand profile and dispatch patterns as in:
  - Figure 9: SA 30 day Extended Wind Drought Period (MW)**Error! Reference source not found.**, and
  - Figure 10: SA 30 day Maximum Wind Generation Period (MW).
- The modelling assumes the generation is built in South Australia and displaces imports, for simplicity[44].

5.4.1. SA Modified Extended Wind Drought Period example

Figure 15 below shows the changing dispatch for the Extended Wind Drought Period example with changes made to the generation mix and introduction of large levels of energy storage. Negative dispatch is when the oversupply is filling the battery.

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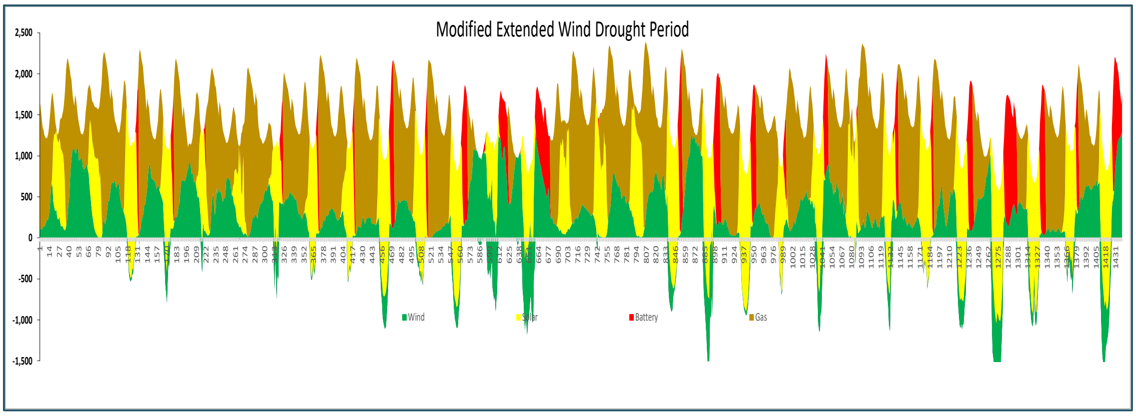
42 Linepack is the ability to store gas in pipelines as gas can be compressed. This form of gas storage is sold as a service on many major gas transmission pipelines and is sometimes called “Park and Loan Services” or “Imbalance Accounts”. This is form of storage is used everyday in Australia for managing gas generation, and some pipelines have been built specifically to optimise the storage that is available, by making the pipeline a lot bigger than needed (e.g., Colongra Power Station in NSW).

43 If more pumped hydro was to become available, the oversupply on renewable electricity could be similarly used to pump water ready for generation when required. If there was the ability to use an interconnector to achieve storage in another regional aera that would also have similar effects.

44 Interconnectors that are built will have the same issues with renewable electricity generation intermittency and storage but may bring some regional diversity that could assist with supply and any storage capability interstates that would replace the end for this capacity to be built in South Australia. These are economic decisions about location.

Figure 15: SA Modified Extended Wind Drought Period example (MW)



Error! Reference source not found. below sets out the results for the **Modified Extended Wind Drought Period** example in terms of the resultant amount of electricity supplied by each type of generation, including how much dispatchable capacity is required in its various forms.

- This includes the amount of energy storage that can be dispatched, and associated total storage required, and
- The level of gas generation capacity that would still need to be available for dispatch.

Table 2: Results of SA Modified Extended Wind Drought Period example

Dispatchable Capacity Requirements	MW
Installed Wind Generation Capacity	2,141
Installed Solar Generation Capacity	2,730
Max Gas Gen Capacity Needed	2,946
Max Storage Dispatch Capacity Needed	2,141
Total Capacity	9,958
Peak Demand	3,000
Total Capacity/Peak Demand	**332%**
Max Energy Storage Capacity Needed - MWh	11,471
Electricity Production %	
Wind Energy	25%
Solar Energy	27%
Gas	48%

- It can be seen that in the case of the Modified Extended Wind Drought Period example gas generation continues to play a substantial role in meeting supply (48% of energy in that period).

- This is because even with the assumptions in this simple example of major growth in solar PV there is not enough oversupply of renewable energy in such periods to allow the battery storage to fill the gaps.
- The storage cannot be refilled sufficiently, and the gas generation must still run to meet the demand.

5.4.2. SA Modified Maximum Wind Generation Period example

Figure 16 below shows the changing dispatch for the Maximum Wind Generation Period example with changes made to the generation mix and introduction of large levels of energy storage. Again, negative dispatch is when the oversupply is filling the battery.

Figure 16: SA Modified Maximum Wind Generation Period example (MW)

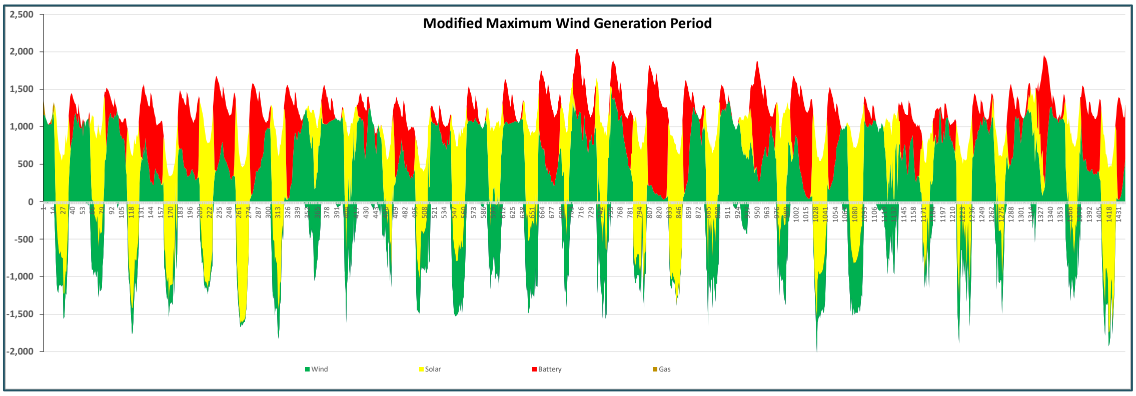


Table 3 below sets out the results for the **Modified Maximum Wind Generation Period** example in terms of the resultant amount of electricity supplied by each type of generation, including how much dispatchable capacity is required in its various forms.

- This includes the amount of energy storage that can be dispatched, and associated total storage required, and
- The level of gas generation capacity that would still need to be available for dispatch.

Table 3: Results of SA Modified Maximum Wind Generation example

Dispatchable Capacity Requirements	Capacity
Installed Wind Generation Capacity	2,141
Installed Solar Generation Capacity	2,730
Max Gas Gen Capacity Needed	200
Max Storage Dispatch Capacity Needed	1,703
Total Capacity	6,774
Peak Demand	3,000
Total Capacity/Peak Demand	**226%**
Max Energy Storage Capacity Needed - MWh	42,210
Electricity Production	

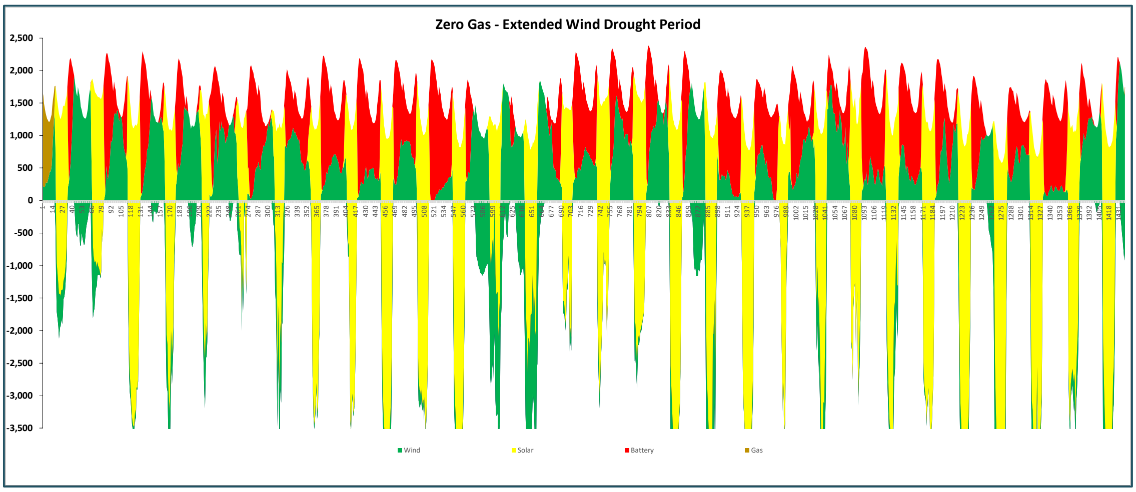
Wind Energy	59.2%
Solar Energy	40.8%
Gas	0.0%

Table 3 shows that the material increase in solar generation combined with the installation of large levels of dispatchable storage result in there being no gas required during the Modified Maximum Wind Generation Period.

5.4.3. The SA - Zero Gas Generation - Extended Wind Drought Period example

Figure 17 below shows a scenario where the amount of wind generation is increased until virtually no gas generation is in the mix during an Extended Wind Drought Period in SA. This required the Installed SA Wind Generation Capacity to be doubled, and the total amount of solar to increase to be 18 fold.

Figure 17: SA - No Gas Generation – Modified Maximum Wind Generation Period example (MW)



- Figure 17 highlights the high level of solar generation which is stored to fill the shortfalls in wind generation. There is excess generation which in a closed system would be curtailed.

Table 4 below sets out for the (virtually) Zero Gas Generation - Extended Wind Drought Period example in terms of the resultant amount of electricity supplied by each type of generation, including how much dispatchable capacity is required in its various forms.

- This includes the amount of energy storage that can be dispatched, and associated total storage required.

Table 4: Results - No Gas Generation – Modified Maximum Wind Generation Period

Dispatchable Capacity Requirements	MW
Installed Wind Generation Capacity	4,282
Installed Solar Generation Capacity	7,020
Max Gas Gen Capacity Needed	< 1.0
Max Storage Dispatch Capacity Needed	2,159

Total Capacity	13,461
Peak Demand	3,000
Total Capacity/Peak Demand	**449%**
Max Energy Storage Capacity Needed - MWh	214,818
Electricity Production	
Wind Energy	42%
Solar Energy	58%
Gas	<1%

Table 4 shows that to virtually remove the gas generation plant and operate an electricity supply system configured of wind and solar generation, and dispatchable storage requires:

- A lot more investment in additional renewable generation capacity (approximately 3 times the renewable generation capacity where gas is supporting the growth in renewable energy), but more significantly
- A massive investment in dispatchable storage to store the additional wind and solar generation produced (19 times the example where gas generation was doing the major support).
  - At some 214 GWh this is equivalent to about 1,100 Hornsdale Power Reserve energy (battery) storage systems in South Australia.
  - For this level of grid connected, large scale battery storage, the current lowest projected costs are reported[45] at US$137,000 MWh (A$175,000 MWh), moving to US$100,000 MWh (A$135,000 MWh) by 2023.
  - This means the investment in battery storage would be of the order of A$30 billion under this example (in 2023).

5.5. Net zero emission gases as a form of renewable energy storage

The renewable electricity generation in South Australia is dependent currently on (natural) gas generation but in the future if battery costs come down further (considerably further) then it may be possible to install a massive level of battery storage as the simple example modelling shows.

It will though need to compete with zero emission gas that can use existing gas infrastructure (or even new purpose-built gas infrastructure).

- The key zero emission gases in this regard are **biomethane and renewable methane**, as these can use the existing gas infrastructure without any modifications being required. They would be produced to the current gas pipeline specification.
- To a lesser extent it could well be **hydrogen or a hydrogen blend** (up to say 10%). This is yet to be proven in terms of the ability to repurpose high pressure gas transmission systems entirely, but they could still be used to some effect.

45 BloombergNEF's Annual Battery Price Survey, December 2020.

- In this case the zero emission gases potentially represent an efficient way to store renewable electricity.

5.5.1. Net zero methane gases

This can be:

- Various forms of renewable or net zero emission methane produced by:
  - The methanation of hydrogen using carbon dioxide drawn from the air through direct air capture technology (DAC), which is very well know technically, and
  - Early cost modelling undertaken by OGW (with support from a major German group) has shown this to be only a marginal cost above the costs of producing hydrogen, or
  - By the development of close coupled methanation reactors. This is a technology that has been through very early demonstration in Europe and now starting in Australia.
    - More details on these technologies can be seen at Appendix B.
- Biomethane produced from:
  - Biogas from wastewater treatment plants that employ anerobic digesters - which is a major source in its own right.
  - Food waste anaerobic digesters that take clean food waste streams and produce biogas.
  - Landfill gas collection.
  - Specific agricultural waste stream collection to ensure high quality feed to an anerobic digester plant.
  - Dedicated agricultural production to fed into anerobic digesters.
  - Use of the separated carbon dioxide from the anerobic digester (when cleaning up the biogas to be biomethane at pipeline specification) to use in the methanation of hydrogen, thereby doubling the anerobic digester biomethane output.

5.5.2. Hydrogen

Hydrogen can be produced and stored at scale and there is considerable work being undertaken to study the costs of this option. This has major policy (and financial) backing at both Commonwealth and State levels.

Hydrogen use in existing gas infrastructure is considered more problematic than zero emission methane based gases but this does not mean that it's necessarily uneconomic.

- Plastic gas distribution systems can be repurposed for use with hydrogen.
- Use in gas transmission pipelines is more concerning at high pressures due to material of construction issues but this is also being studied and solutions tested.
- There may well also be a solution that has new, purpose-built, high-pressure hydrogen gas pipelines (and storage systems) that then feed into the existing gas transmission systems at lower pressure than they operate now but can still feed the distribution systems.
- There is also analysis being undertaken to either improve the linings in existing gas transmission assets or to use a form of regular pigging systems to apply certain coatings (as done in some oil pipelines for example).

Solutions in this space are driven by the economics of having sunk gas infrastructure assets and the imperative of having to solve new technical problems, and competitive outcomes should not be discounted yet.

Hydrogen would be a very elegant solution for storing renewable electricity over time if it proves commercially feasible but is just one such potential solution in the mix.

5.6. Key learnings from the SA case study

This analysis shows several key learnings:

- The development of renewable generation requires significant levels of dispatchable generation (storage) to support that development.
  - This is not a surprise as there needs to be ways to smooth out the renewable generation intermittency.
- The operation of electricity supply systems that have high levels of renewable generation (storage) will need to use that dispatchable generation (storage).
  - The need does not go away once high levels of renewable generation capacity is installed.
- There are various forms of dispatchable generation (storage), but gas can and does currently play a very key role due to its flexibility for dispatch.
  - Gas is forecast to be able to continue to play that role if it is cost effective.
  - The SA Case Study shows that the ability to transport and store gas in specific storage facilities and as line pack on major gas pipelines is currently proving to be essential if high levels of intermittent renewable generation growth are to be supported reliably.
- If this gas was a net zero (renewable) form of gas this would complete the cycle and SA would be at net zero for its generation send out with high levels of reliability (game over).
  - Ideally that renewable gas would be zero emission methane based, as no changes to infrastructure would then be required, but it could also be hydrogen based or a mix of both.
  - This indicates that the gas infrastructure (not the natural gas as such) could be critical to supporting the development of full net zero generation outcomes for SA, it is a key sunk asset in that strategy.

In the end, it is a distinct option that renewable gas could play a major role in a net-zero solution in SA (and the NEM) and should not be foreclosed through the running down of gas infrastructure due to a perception it is linked to the longer term use of natural gas.

- The key here is that it is the gas infrastructure that allows this pathway to develop and this needs to be recognised - pipelines, compressors, storage and gas generators are critical to getting to net zero – as fast as possible.
- Battery technology may well reduce in costs sufficiently to compete with the costs of zero emission gas options, but in some of those cases repurposing the existing gas infrastructure (and gas consumer and business appliances and end use) could also tilt the economics significantly.

6. Relevant submissions and project consistency

In my Letter of Instruction, I was requested to:

Please review the submissions and consider and respond to any energy policy issues raised.

We note for your assistance that submissions 1-7, 14 each raise concerns about:

- *the strategic value of the project due to climate change;*
- *the strategic value of the project and impacts that gas infrastructure may have on climate change; and*
- *investment in renewable energy projects as opposed to gas infrastructure.*

You should also specifically address:

- *Submission 12*
- *Submission 15*
- *Submission 16*
- *Submission 17*
- *Submission 20*
- *Submission 21*
- *Submission 25*

I have tried to take from these submissions the key themes that need to be considered in relation to energy policy, noting the concerns outlined in the Letter of Instruction for the noted submissions.

6.1. Key themes that should be addressed

I have distilled the submission objections related to policy matters into the following key themes (or subjects) that I consider address these objections and to my mind explain why investments in the WORM are needed and not prejudicial to particular policy objectives of concern such as reaching net zero emissions in the Victorian energy supply system.

- "Gas" versus "Renewable Electricity"
- "Gas" Type and Gas Infrastructure
- Economics of Gas versus Electricity
- Gas Power Generation Issues

The following table outlines the noted submissions and their relationship to the key themes I address, based on relevant quotes from those submissions.

6.1.1. Submission key theme allocation table

Table 5: Submission objections matched to key themes

Submission	"Gas" vs "Renewable Electricity"	"Gas" Type and Gas Infrastructure	Economics of Gas vs Electricity	Gas power generation issues
1. - 7.	*A new gas pipeline has no place in a zero carbon future. It is a huge waste of resources that could instead be channelled into providing renewable energy to Melbourne.*	*The proposed gas pipeline cannot provide a long term solution compatible with climate change renewable promises and environmental obligations.* *I am against so much time effort and money being put into trying to source, extract and transport such a finite type of fossil fuel. I would like this effort to go into a more sustainable less damaging more climate friendly product.* *I have no specific objection to the proposed new pipeline. Rather, the problem is that extracting, circulating and burning methane ("Natural Gas") should be phased out as soon as possible, because we have entered the period of catastrophic climate change.* *There is no business or environmental case for new investment in the distribution or mining of new gas.* *This proposal will simply add to the amount of stranded "assets" that taxpayers have funded.* *Instead of investing in pipework infrastructure that enhances the availability of gas, that money should be directed to driving a reduction in gas demand, which is in line with the move towards net zero.*	*With the Bass Strait Gas fields running out of gas in the next few years, I believe gas will continue its increasing price.* *On top of that reason for not pursuing gas as a fuel of the future is the overwhelming move to electrifying everything because of climate change and health benefits enjoyed through using electricity.* *Gas can be replaced now by electricity economically because of the decreasing price of heat pumps and similar appliances.*	
12.			*These days I help Victorians to get their homes off gas, and to save money! Gas infrastructure need not and should not be expanded. Gas demand should be rapidly reduced* *A key piece of work was our 2015 research at the University of Melbourne showing how Victorians can save money by heating with their air cons.*	

14.		*They reflect the same set of irresponsible beliefs and practices that have brought about the rapid climate change that presents an existential threat to not just grasslands, or humans, but to the rich panoply of life on earth.*		
15.		*Building gas infrastructure will serve to reduce the ability of the Victorian Government to achieve its emissions reduction target by 45-50% by the end of 2030 and Net Zero Emissions by 2050.* *The project should be looking beyond the status quo, to reducing our carbon intensive energy supply in favour of more sustainable options.*		
16.	*Ensuring the availability of gas in winter is identified as a critical reason for the WORM project. Winter availability can be assured by either reducing demand for gas or by increasing supply of gas on peak days (aided by this project).* *With demand-side measures, we can greatly reduce the very real risk of gas supply running out on one or more days of high demand in winter. Demand-side management has begun in earnest in electricity markets, and there is huge potential in the case of gas. Ever lower costs of renewable electricity increase opportunities for electrification of many functions - such as industrial processes and residential use - that currently rely on gas.*	*We note that there is growing consensus that if we are to have a hope of averting catastrophic global warming, we must stop investing in new fossil fuel infrastructure.* *Building a new gas pipeline will be an investment in the energy of the past and potentially create a stranded asset. As a non renewable resource that has already peaked, the cost of fossil gas will only go up, so creating a new pipeline will not support residential, commercial or industrial consumers. Any sort of infrastructure that facilitates the use of fossil gas would also be at odds with the Victorian government's commitment through the Climate Change Act to reach net zero emissions by 2050 via a series of Emission Reduction Targets ERTs.* *The future contribution of hydrogen production to the Victorian economy does not depend on mixing it with fossil-based gas in the gas transmission and distribution network.* *Onsite production for industry or distribution in dedicated pipelines will be the solutions.* *The technology of incorporating hydrogen into our existing network is still being researched, and at best 20% hydrogen can now be included. As the graph by Ketan Joshi shows, the remaining 80% of gas will contribute massively to emissions by comparison to the alternatives.*		
17..	*Electrification will steadily reduce gas use, and gas now used by households and commercial*	*Evidence is increasingly showing that use of fossil-based gas contributes greatly to greenhouse gas emissions, and this is a focus of the recent IPCC*	*Demand for gas is declining as gas prices are now at parity with global*	*According to AEMO, gas use in gas-powered generation (TWh) is*

	businesses will be available for industry for which gas is a more critical use. *There is no 'optimal' use of the gas infrastructure in the sense of optimising social welfare or the public good (the goal of economics).* *Optimising the reduction in carbon emissions requires a managed wind-down as rapidly as possible.* *The economics of electrification and energy storage mean that this can be achieved rapidly, with government paying attention to adverse effects on particular consumers of energy as well as energy sector workers.*	*sixth assessment report which is shocking people around the world. There are severe climate impacts from continuing to invest in gas infrastructure, and in its Roadmap report the International Energy Agency has called for new investment to cease.* *If action is taken to reduce peak demand, then security, efficiency and affordability do not depend on the WORM project.*	*pricing, which causes industry to relocate when facilities are at end-of-life, and costs of electrification fall, especially of heating.* *Ramped-up government programs like the Victorian Energy Upgrades will hasten this decline.*	*declining and this trend is set to continue.* ***Even though GPG capacity might increase (GW).*** *The trend is set to battery and other storage technologies and capacities improve.*
20.		*However,* ***our greater concern is that the project will further entrench gas as a fuel source for Victoria into the future****. The recent IPCC report leaves no doubt that securing a safe environment for future generations requires a very speedy transition away from all fossil fuels.* *We believe that it is time for the Victorian government to commit to* ***no further fossil fuel infrastructure.***		*The EES makes the claim that "More efficient gas transmission would … facilitate the development of the renewable energy sector. …. The intermittent nature of these renewables [wind and solar] will require … firming capacity, via gas powered plants or storage to support energy reliability and security." It further states that "Gas will play an important role between 2030 and 2050 as the renewable energy sector expands in line with VRET and broader climate change policy." We reject these claims and point to the evidence presented in our recent submission to the "Help Build Victoria's Gas Substitution*

			Roadmap" Consultation Paper, which is appended, that there is no need for gas to play this role. [Appears to advocate for battery storage]
21.		*Since gas is a significant contributor to increasing levels of greenhouse pollution and global warming this alone should mean the Project is not permitted to proceed.* *The pipeline is proposed to deal with a projected problem dealing with periods of peak demand for gas. But given the problems gas entails it is probably better to prioritize using existing systems more efficiently while simultaneously moving from using gas appliances to equivalent systems using electricity.*	
25.	*We must address the drivers of climate damage, including use of fossil fuels, which includes gas.* *All consultations are ongoing, but overwhelmingly they have rightly identified that Victoria must end its reliance on natural gas as an energy source and explore other options if we are to meet our net zero emissions targets and effectively address climate damage.* ***Therefore, investing in new gas infrastructure at this point in time is illogical and baffling.***	*Investing in such significant gas infrastructure currently, is a poor economic decision unless it was specifically created to also accommodate alternative gases such as hydrogen (at higher concentrations), biogas and biomethane, AND these had been selected as alternative energy sources as part of our roadmap to net zero emissions.* *As we move towards alternative sources of energy in the short-to-medium-term, this infrastructure will become obsolete and the company responsible for building it will likely require compensation to recoup their costs at taxpayers' expense.*	
26.		*…the project has some conflicting statements regarding predicted consumption and greenhouse gas emission reductions. It is recommended that the project properly considers how it will assist with meeting the net zero greenhouse gas emissions target and assist suburbs in transitioning away from gas supply*	

6.1.2. "Gas" versus "renewable electricity"

A few of the submissions make the claim that not using gas and instead using renewable electricity as a form of energy is preferable as Victoria seeks to move to a net zero emissions outcome. Some also recognise that this is not always possible for some businesses, and that a level of natural gas may still be needed for these hard to abate industries.

In a straight comparison of natural gas emissions associated with its end use as a fuel and that of renewable electricity this is a factual enough claim, and it is understandable how this may well seem an easy solution. But the issue is with the timing and economics (affordability) of this option and other options that will compete over time.

Under the current electricity greenhouse intensity, it is well recognised in Victoria this ambition of net zero emissions has actually a long way to go and will be associated with massive investments in the electricity supply industry and by customers.

- Any early movement of energy demand from gas to electricity in Victoria will significantly increase greenhouse gas emissions.

Therefore, there needs to be consideration of several key transitional and system operational issues when contemplating this claim or objective, and in the next section how its linked to gas infrastructure.

- The issue is the complexity of moving toward a zero emission outcome in Victoria and not foreclosing at this stage on what may well be much needed infrastructure to achieve these outcomes.

In terms of the direct comparison of "gas" with "renewable electricity" there also needs to be serious-minded consideration of the more critical displacement of natural gas with zero emission gases. This too is a complex matter in its infancy analytically.

There needs to be balance in our thinking, without losing sight of the agreed goals of achieving net zero emission outcomes – just more a case of how to get there affordably and with high levels of supply reliability.

- There is actually a major transition required to move from the current relatively low level of renewable electricity in the east coast grid mix and that required to become totally renewable.
  - This point cannot be trivialised.
- That transition and indeed the end point operation of a very high intensity renewable electricity generation grid does require large amounts of dispatchable generation (storage) in order to back this intermittent generation and deliver the electricity supply reliability currently enjoyed by all customers – as we can see in the SA Case Study, and
  - At a cost that is affordable for residential and business customers.
- Additionally, the electricity grid does not just have to be decarbonised itself but will literally have to double its output if:
  - Gas is replaced by electricity (taking no account of new electricity load from electric vehicles), and
  - Will also need to add significant renewable electricity generation to deliver zero emissions gases if that route is taken, or even a mix of both.
  - There is no escaping the need for major investment in renewable electricity generation under any case (zero emission gases, renewable electrification, or mix of both) – but it has to be firmed, has to be reliable and has to be affordable.
- To put this task into perspective for Victoria:

  - The 200-230 PJ/year of gas currently used in Victoria as outlined is some 54 TWh.
  - Electricity consumption (2019-202) was 44.3 TWh – gas is some 20% higher on a simple like for like basis[46].
  - This 54 TWh is equivalent to the entire power consumption annually of Queensland being added to Victoria, and.
  - Some 2 million residential gas customers will have to make decisions about replacing appliances with electricity or zero emission gas as a fuel by 2050.
  - Similarly, many businesses will have to invest in conversions to electricity or zero emissions gas as a fuel or feedstock by 2050, and
  - Some will not be able to make this conversion and solutions for them will have to be provided if they are to stay in business in Victoria.
- The timing of this transition will invariably be quite long without massive Government support financially (and even then, it may struggle to get done by 2050).
  - This issue was explored in Section 4.2.
- It is also not clear yet that electrification is the best economic solution and it may well prove to be an expensive option to adopt, particularly with no gas available for generation support (lots of renewable energy storage investment as we see in the simple examples in the SA Case Study).
  - It may well be better to pursue zero emission gas production for a range of reasons – mainly related to being able to repurpose the existing gas infrastructure – which is a lot more than pipelines – and includes large quantities of existing energy storage and gas generation assets, and
  - This decarbonisation pathway would also support other industries such as manufacturing, hard to abate industries and energy exports (e.g., green LNG – circa $50 billion/year market).
  - Zero emission methane for example, produced from renewable electricity, would be able to be stored in huge quantities in existing gas storage systems and fully support a very high level of renewable generation in the electricity system. It could be the largest and cheapest way of storing renewable electricity - reusing existing gas infrastructure - as well as used for direct gas supply to all existing gas customers.
  - Early modelling shows the cost of the methanation of hydrogen to be remarkable low cost (marginal cost over hydrogen production) and that technology development here shows significant economic promise.
  - Biomethane may also be a much bigger contributor to the energy mix in the future than is currently anticipated. Often discounted due to a perception that there is not a major bioenergy resource available to the market in Australia, this assumption is now being tested and found to not necessarily be the case. For example, the ability to use the renewable carbon dioxide produced in the biomethane process to make more biomethane (with hydrogen) is not yet well appreciated but would double the output from most digester technologies. This resource may well be very significant if properly considered, which will also take time, and should be given that time.

46 This does not account for other things such as electricity losses, the efficiency of appliances such as air conditioners that have high coefficients of performance, gas used in power generation, etc.

- There is also a major policy drive to develop a hydrogen export industry in Australia and this cannot be simply ignored at this time.
  - It has significant commercial and technological challenges as some have pointed out in their submissions, but it is already being used in household testing overseas, and
  - Major research is being undertaken to repurpose existing gas infrastructure as much as possible and this work is showing promise - although a lot more is yet to be done, and again such work should not be discounted too early.
  - I also note that the WORM is intended to be built to a design that will allow hydrogen use[47].

The key message here is that there is a great need to not foreclose on "gas" infrastructure as a key decarbonisation ally, as zero emission gases shown major economic promise when all costs are considered.

- Even at face value it makes no economic sense to place all the reliance on doubling or trebling the size of the renewable electricity sector integrated with battery or hydro storage based on views of future pricing trends, and abandoning the economic optionality that zero emissions gases can provide for consumers and business, and of course our export markets.
- The OGW SA Case Study is very instructive in this regard.
  - If that market currently had a zero emissions gas production system the SA grid would be at net zero very quickly.
- I would also note that in my career I worked with the old "towns gas" which was some 60% hydrogen, and was a gas we manufactured (not from under-ground), mostly using steam reforming of coal, naphtha and natural gas.
  - This gas was the back stay for many decades in Australia and originally lit the streets of Melbourne I understand (certainly Sydney).
  - I assisted in the design and construction of many new gas assets but critically worked in the conversion from towns gas to natural gas in the NSW economy and can attest this was no easy task and was hugely expensive (and luckily customer numbers were low at the time).
  - The dislocation for customers was also considerable, and expensive.
  - Conversion from gas to electricity will have similar ramifications over time depending on what appliances are switched in and out (how many houses will need new internal electricity wiring and power boards for example if induction cooking is used), as would conversion to 100% hydrogen. Zero emission methane forms of gas will require no such conversions. The economics are not simple in this trade off of solutions.

So having separated the concept of "gas" being just a fossil fuel version of itself and questioning if in fact electrification will prove to be the economic best case, the really major objection received was that investing anything into gas infrastructure would give a life to natural gas and/or end up with stranded gas assets and costs to the community from that stranding.

47 APA Technical Note No. 29 - Pipeline Design - Response to RFI Item 4, page 2.

6.1.3. Separating the type of "gas" from the gas infrastructure investments

I think in fact this is an easier issue to deal with as the gas infrastructure needs to be separated in this debate from the actual type of gas running through that infrastructure.

For example, if all the gas in Victoria was in fact a zero emission type of gas then this argument would not even be put forward.

Similarly, as outlined above, the SA Case Study shows if SA had zero emission gas available, they would be able quickly to move to net zero for their energy sector and again using the existing gas infrastructure to achieve this outcome.

In Victoria it has to be recognised that the main energy supply system is actually currently the gas network and storage assets, and that gas generation is also currently a valuable asset in terms of system reliability. This artery of energy delivery should not be abandoned without an overarching reason if it can contribute to addressing zero emission outcomes.

- The WORM upgrade will yield the ability to improve the use of gas storage to meet peak demands in Victorian for heating.
  - It may well be that reverse cycle air conditioning can do more of this duty over time but that is certainly not the case currently, and the analysis will take time to be undertaken properly.
  - If increased use of reverse cycle air conditioning is to be a viable solution, displacing natural gas, the investment in the renewable electricity supply side will be a massive undertaking and at current rates of development would take a lot longer than the 2050 timeline.
- There may well appear to be conflicting policy objectives – zero emission by 2050, and development of reliable and affordable gas supplies. This is really though more of a timing issue not a direct conflict as such.
- Investment in the WORM is a security of supply issue, where the peak demand for heating using gas can be met and for other strategic outcomes such as more flexibility in the gas infrastructure which we can see in the SA Case Study is currently proving to be essential in development of the renewable electricity supply (especially once coal retires as it has in SA).

In completing this theme I note that several of the submissions have referenced the *International Energy Agency (IEA[48]) Net Zero by 2050, A Roadmap for the Global Energy Sector Report (July 2021).*

Therefore, it is interesting to examine what is said in that report, and it shows that gas still does continue to play a key role but does not need to develop more resource globally to play that role:

> *Beyond projects already committed as of 2021, **there are no new oil and gas fields approved for development in our pathway**, and no new coal mines or mine extensions are required. The unwavering policy focus on climate change in the net zero pathway results in a sharp decline in fossil fuel demand, meaning that the focus for oil and gas producers switches entirely to output – and emissions reductions – from the operation of existing assets. Unabated coal demand declines by 98% to just less than 1% of total energy use in 2050. **Gas demand declines by 55% to 1,750 billion cubic metres** and oil declines by 75% to 24 million barrels per day (mb/d), from around 90 mb/d in 2020. [page 21]*

48 Australia is a member country.

This would seem to indicate assumptions about being able to transport gas (as LNG) around the globe to even out supply restrictions in some countries – making the best use of existing gas supplies.

> *No new natural gas fields are needed in the NZE beyond those already under development. Also not needed are many of the liquefied natural gas (LNG) liquefaction facilities currently under construction or at the planning stage. Between 2020 and 2050, natural gas traded as LNG falls by 60% and trade by pipeline falls by 65%. [pages 102 and 103]*

- Presumably this would mean for Victoria ensuring there is a capability to take imported LNG supplies, and this is an issue currently under consideration by several investors with the LNG import facilities seen (in AEMO GSOO modelling) as critical to meeting peak gas demand and overall gas supply in the 2020 to 2030 timeframe at least.
- Such terminals in Victoria if approved would also need to use the existing gas infrastructure.

In the IEA Report most of this gas appears to be earmarked for hard to abate industries and end uses.

The IEA report also explored the electrification scenario:

> *The rapid electrification of all sectors makes electricity even more central to energy security around the world than it is today. Electricity system flexibility – needed to balance wind and solar with evolving demand patterns – quadruples by 2050 even as retirements of fossil fuel capacity reduce conventional sources of flexibility.* ***The transition calls for major increases in all sources of flexibility: batteries, demand response and low-carbon flexible power plants,*** *supported by smarter and more digital electricity networks. Governments need to create markets for investment in batteries, digital solutions and electricity grids that reward flexibility and enable adequate and reliable supplies of electricity. [page 23]*

The IEA report indicates that there will be a need for low-carbon flexible power plants, much as we see in the SA Case Study, and as the ESB is also advising the policy makers, a need to create a market that gives the incentive to invest in dispatchable generation capacity.

- Again, the key issue here is to try and repurpose as much of the existing gas infrastructure as possible as decarbonisation pathways reveal their economics.

Interestingly the IEA Report also has **nuclear power generation** as one of the corner stone forms of generation supporting the massive growth required in renewable power generation (as base load).

> *Our pathway calls for scaling up solar and wind rapidly this decade, reaching annual additions of 630 gigawatts (GW) of solar photovoltaics (PV) and 390 GW of wind by 2030, four-times the record levels set in 2020. For solar PV, this is equivalent to installing the world's current largest solar park roughly every day. Hydropower and nuclear, the two largest sources of low-carbon electricity today, provide an essential foundation for transitions. [page 14]*
>
> *By 2050, almost 90% of electricity generation comes from renewable sources, with wind and solar PV together accounting for nearly 70%.* ***Most of the remainder comes from nuclear.*** *[page 19]*

- It is again just another option for decarbonisation and will have to compete with storage options and zero emission gas options, particularly in Australia as we currently have no appreciable nuclear power to dispatch. And this seems to be recognised in the IEA Report:

> *The relative contributions of nuclear, hydrogen, bioenergy and CCUS vary across countries, depending on their circumstances. [page 29]*

Noting here that if nuclear is not available all the other options will require gas pipelines and storage infrastructure.

In the IEA Report there are also calls for new pipelines to be built (or existing ones to be repurposed) to transport CO2 (for CCUS), hydrogen and biogas.

This includes new pipelines to transport captured CO2 emissions and systems to move hydrogen around and between ports and industrial zones. [page 15]

One of the key advantages of bioenergy is that it can use existing infrastructure. For example, biomethane can use existing natural gas pipelines and end-user equipment…[page 78]

Notes: Infrastructure includes electricity networks, public EV charging, CO2 pipelines and storage facilities, direct air capture and storage facilities, hydrogen refuelling stations, and import and export terminals for hydrogen, fossil fuels pipelines and terminals. [page 81]

The IEA report also notes the massive investment required in renewable electricity generation assets and similarly a massive investment in hydrogen, in its modelling.

…annual investment in hydrogen, including production facilities, refuelling stations and end-user equipment, reaches USD 165 billion in 2030 and over USD 470 billion in 2050. [page 82].

This hydrogen needs to be transported and again repurposing existing gas infrastructure would be an economic step to seriously examine before foreclosing on such valuable infrastructure.

6.1.4. The economics of gas and electricity use by gas customers

Some submissions indicated that gas is already not competitive with electricity reverse cycle heating, and particularly if customers have solar PV on their rooftops.

This means customers with reverse cycle air conditioners installed do have a simple option of switching it on or using their gas heating systems. The decision-making issues include:

- How much difference in costs do customers perceive exists in today's electricity market offers between gas and electricity for heating end use?
- How they perceive this decision will be affected by solar PV on their rooftop, and
  - How many customers have Solar PV and the timing of their heating needs – which does tend to be well outside the solar PV generation timeslots in winter (an all day and night need for cold days),
  - Even if the solar PV they have has excess capacity at those times.
- Is there actually a willingness to pay for gas heating if they perceive that it is an appreciably superior form of heating in what can be a very cold climate?
- How do they perceive the costs of gas or electricity for heating will move appreciably in the future – what are their views on price volatility?
  - Will a transfer of the heating load onto the electricity supply system actually end up causing higher electricity costs?
  - Will the removal of coal generation increase electricity costs in Victoria (as it did last time)?
- How do customers perceive the relative emissions from gas and electricity currently?
  - The reality is transferring heating load from gas to grid based electricity would inevitably at the moment increase emissions in Victoria.

- Many of the submissions advocated a rapid move to electricity away from gas but this would currently mean a lot more coal and gas would be inevitable dispatched to supply that electricity.
  - This brings in again the timing issue of investments, how long will it take to build enough renewable electricity generation to take up this new demand?
  - This will take decades at the current investment rates and gas use in that transitional period would yield lower greenhouse emissions in Victoria (the classic "unintended consequence" issue)

These are all market-based questions and can only be understood currently by either very detailed customer research or by looking at historical trends of how the heating demand is being met.

- AEMO has made it very clear in its extensive analysis in its 2021 GSOO and VGPR that they currently expect gas to be the prime fuel used for winter heating (this aspect is discussed at the beginning of this report), and
  - Have deep concerns about meeting those peak demands and that the WORM will play a key role in that regard in the next 10 years.
  - AEMO have assumed the WORM is being built in its scenario analysis, as has the Victorian Gas Substitution Roadmap and the National Gas Infrastructure Plan, and it has been approved by the Australian Energy Regulator based on rigorous regulatory tests.
  - I note though that the AEMO 2021 GSOO Central Case did not consider a scenario with greater electrification of residential heating (or other heating alternatives to gas) to drive down Victoria's maximum daily demand for gas, and
  - AEMO's *Inputs, Assumptions and Scenarios Report* (IASP), which was published in July 2021, 4 months after the GSOO, did, in particular, detail how AEMO

    …will model the future in its forecasting and planning publications for the rest of 2021 and into 2022.
  - AEMO is going to scenario test the potential impacts for example of a significant shift (50%) of the heating demand in Victoria from gas to electricity by the mid-2030s.
- Therefore, changes to this position may well occur as noted in some submissions but the issue is that the barriers to switching back and forth between the fuels are very low (if customers have reverse cycle air conditioning) so there is no guarantee that gas for peak winter heating will get displaced by electricity use in any permanent way unless this were for example mandated by a policy shift.
  - In fact, the worst of both worlds may occur with customers using their reverse cycle air conditioners for heating during the day (drawing on their rooftop solar PV) and dropping in their gas heating after daylight hours.
  - The issues here are about risk and timing, and these are issues that need to be recognised and managed in the near term (over the next 10 years) and investments such as the WORM (and other additional incremental supply enhancements) then become critical to both supply security in that period and over the longer term depending on customer preferences and policy changes.

The strategy here for at least the next decade appears to be to let these market forces (and policy) play out, particularly as the Victorian Government seeks to decarbonise the energy sector through a combination of support for electrification and zero emission gas production.

- The message also seems clear to not foreclose too early through the regulatory system on the options that may be required to achieve net zero by 2050.

There is also a need to recognise at the policy and regulatory level that the massive investment that will be needed to achieve the forecast growth in renewable electricity supply will need to come from the private sector, as it is highly unlikely it will come from the public purse, and this will inevitably take a lot of time.

In the meantime, supply has to be maintained of essential heating fuel delivery capacity – be it gas or electricity – and the WORM is recognised as being integral to that outcome.

6.1.5. Gas power generation and renewable electricity

There was in the submissions some (but not much) consideration given to the critical issue of gas power generation and its support role over time for electrification of the gas demand in Victoria (or the NEM generally).

This is not surprising as there has yet to be a serious-minded focus on this issue in terms fo every detailed analysis, but this is starting to occur, and it is a lot more complex analysis that originally thought, so will take some time to work through all the options.

This is one of the key reasons I have added the OGW SA Case Study as it does provide a lot of insight to what is occurring in a jurisdiction with already very high levels of renewable electricity generation. In fact, this is a world class example of such a jurisdiction, but the fact it is in the Australian context makes it even more compelling to study.

Without reiterating too much of what this report has already outlined about that case study it is sufficient to say that gas infrastructure is intrinsically linked to the development of zero emissions energy outcomes in that state, and that with zero emission gas it would be able to reach zero emission status.

6.2. Project consistency

In conclusion it appears that:

- The WORM project is currently consistent with the policy developments at both the State and Commonwealth level.
  - It is also seen in the AEMO analysis that the WORM construction is a given in that analysis, a base line assumption, and
    - Yet Victoria will still face challenges in meeting peak demand before 2025.
  - The Australian Energy Regulator has approved its construction after a rigorous review of its prudency.
- While the approval of gas infrastructure may seem at odds with a policy goal of decarbonisation there are good reasons what this is not the case.
  - The timing of decarbonisation is driven largely by the ability for private sector investors to develop the required infrastructure or repurpose that which is already existing.
  - The pace of this investment currently may seem very fast, but it would need to be considerably increased to meet the 2050 timeline based on the SA Case Study and the ambition to also decarbonise gas in Victoria (and this does not even allow for the implementation of electric vehicles).

  - This construction planning timeline and level of investment analysis will also take some period of time to really complete and form any meaningful views (or more importantly for the investor market to have confidence in those views).
- Whilst this is in progress there is a need to maintain a reliable supply of both electricity and natural gas (as recognised by the Victorian Government).
  - Customers of both gas and electricity across the economy need to have confidence that during the transition period to net zero emissions they can have reliable and affordable options (zero emission gas and electricity).
  - This is even more critical for business consumers, and hard to abate industries that operate in Victoria.
- It is also very important given the options for decarbonisation involve significant renewable electricity generation and a critical need for effective very deep storage of renewable electricity not to foreclose too early on any of those options.
  - The WORM expansion would materially assist for example, in most cases, a zero emission gas solution, which is still very much in contention competitively and being actively supported by all policy makers at this time.
  - The WORM has the strong support it seems from the market system operator and the major energy retailers that carry a lot of the commercial risk associated with energy supply failures.

The period 2021 to 2030 will be very informative as to the economics of the potential solutions and it seems clear that gas infrastructure will not be completely abandoned unless there is a very compelling case to do so and is most likely to be repurposed in some form to support the net zero initiative.

The WORM enabling greater access to and use of gas storage appears to me to be a well justified investment for consumers and the industry at this time, and potentially a valuable future asset in the push to decarbonise our economy.

6.3. Inquiry RFI Responses

I have also been asked to provide some brief commentary on the following RFIs.

Table 6: RFI brief commentary

RFI	Project Type	Item	Question	Comment
RFI1	Project description	Project rationale	Expand on the practical costs and disbenefits of continuing to use the existing low-pressure pipeline system to transfer gas to the east of the State.	It constrains the ability to use the valuable underground gas storage system at Iona to assist meet peak demand in the winter for gas heating, and in the future storage of zero emission gas The APA EES also outlines how the WORM will assist reduce operational costs and greenhouse gas emissions.
RFI2	Project description	Project rationale	Explain the extent to which the Project and the pipe sizing are intended or expected to	The Iona Underground Storage will materially be able to increase its storage

RFI	Project Type	Item	Question	Comment
			facilitate or generate increased gas supply and demand, in addition to improving supply efficiencies. The Pipeline Licence Application notes possible future market expansion.	utilisation (faster refill capacity and reinjection capacity) as the Bass Strait supply starts to run down. It will allow greater flows east and west across the gas transmission systems and assist with delivery and storage of gas from interstate.
RFI91	Waste management	Greenhouse gas	Provide advice on the consistency of the Project with emerging initiatives including the: • Draft Gas Substitution Roadmap by DELWP • Draft Gas Infrastructure 2050 report by Infrastructure Victoria.	This is addressed in my report.

Appendix A: Qualifications and experience of James Arthur Snow

I am an Executive Director of Oakley Greenwood based in the Brisbane Office. I have been an Executive Director since its founding in November 2008 and have been in the energy industry since 1979 (some 40 years). I have worked in this sector in Australia, New Zealand, the USA, Middle East and across South East Asia.

I hold an Honours Degree in Chemical Engineering from the University of Newcastle and am a Graduate of the Australian Administrative Staff College (Mt Eliza, Melbourne) and a graduate of the Australian Institute of Company Directors.

I have also held the positions of the Chairman of the Australian Chemical Engineering College and Board Member of Engineers Australia and received Fellowship status from Engineers Australia and the Institution of Chemical Engineers (UK). I was also conferred the honorary title Adjunct Professor in the UQ Energy Initiative on the 1st July 2016 by the University of Queensland.

I have held in the past senior managerial and operational positions in the energy sector in management; commercial strategy, acquisitions and negotiation and arbitration of major gas contracts; development of major projects and new markets; marketing and public relations; professional engineering; and economic regulation and competition policy and related compliance matters.

In my career I have worked in the gas and electricity sectors and been involved in such matters as:

- The design and construction of major gas and electricity assets – gas pipelines, Compressed Natural Gas (CNG) assets, Liquified Natural Gas (LNG) asset, gas production assets (hydrogen based gases), gas fired electricity/power generation systems, low and high voltage power lines and substations, metering systems, control systems, etc.
- Energy marketing and senior management of retail operations, negotiation of major gas agreements (GSA's, GTA's, gas storage arrangements), contractual arbitration procedures.
- Mergers and acquisitions including complex commercial modelling, completing acquisitions, providing key advice on strategy and undertaking due diligence for asset acquisitions and sales.
- Energy pricing, complex energy market modelling and forecasting, stakeholder projects, NEM and Gas Law Rule changes, demand side response.
- The efficient use of energy by end users, greenhouse gas emission mitigation and regulation.
- Design of and review of energy markets (including the Victorian Declared Wholesale Gas Market) and associated regulation.
- I have also consulted within the energy sector for some 27 years in an expert capacity across hundreds of projects - noting I have undertaken projects in recent times that are likely relevant as they include:
  - Engaged in a prosecution matter (20220/21) in the NEM focused on gas fired power station issues (ongoing matter).
  - Engaged in 2020/21 on a major gas related litigation as a leading gas market expert in the Supreme Court of Victoria (submitted 7 expert reports, matter was settled by the parties).
  - Engaged on a major gas price arbitration matter in 2021 (now complete).

- Expert advice in the first Part 23 Gas Arbitration undertaken in Australia.
- Due diligence for the purchase and sale of major energy assets (gas and electricity).
- Principle gas advisor to the Tasmanian Energy Security Taskforce.
- Led multiple consulting assignments for the Council of Australian Governments (COAG) via the Federal Department of Energy and Environment (Canberra) across several major, recent gas matters (long-term gas market investment, gas transmission regulatory reform, gas shipper stakeholder surveys as part of the current Part 23 Regulatory Impact Assessment review, the landmark Gas Price Trends Review reports in 2015 and 2017, review of gas transmission providers information reporting requirements in real time for the Australian Energy Market Operator Gas Bulletin Boards on the east and west coasts of Australia (including a cost benefit analysis) and a detailed review of the energy and power generation requirements for North and Central Queensland for their Underwriting New Generation Investments program.
- In 2012/13 I was engaged by Hydro Tasmania to undertake due diligence work related to the GSA and GTA aspects of their potential and actual acquisition of the AETV Power Stations (Bell Bay) from Aurora Energy in Tasmania. This involved extensive DD and advice regarding these agreements and how best to mitigate the liabilities they would impose if the station was not used (which was highly likely and became the case).
  - One key aspect of this assignment relevant to this matter was the work I undertook to examine, to cost model, and then to assist negotiate converting the gas transmission throughput entitlements to gas storage service entitlements on the Tasmanian Gas Pipeline (TGP). This work involved the detailed analysis of existing gas storage options and costs such as other relevant linepack services (e.g. the Colongra Lateral in NSW), Iona and LNG services. His work led to TGP investing in their assets to be able to provide these services independently of the Hydro Tasmanian GTA.
  - I also examined and implemented the on-sale of the Hydro Tasmania GSA entitlements into the Victorian DWGM in the winter of 2014. This was gas and injection capacity entitlements at Longford and a successful deal was completed, on-sold to as I understand it to three Retailers.
  - I have since been re-engaged to assist with the Tasmanian Gas Strategy.
- Multiple assignments in 2021 for the Victorian Department of Environment, Land, and Planning (gas market support mechanisms for hydrogen, options for increasing the take up or renewable gases in Victoria, renewable hydrogen commercialisation pathways fund review panel).
- Projects for APT (APA) - related to gas, the forecasting for the Victorian Transmission System regulatory review (examining the potential impacts of energy policy as part of this work).

A.1 General gas industry experience

- I spent 12 years in the natural gas industry with AGL holding several senior executive positions involved with the technical end use of energy, regulations and tariffs, contract pricing, wholesale gas procurement, analysis of energy projects investment for Board submission, gas price reset arbitrations, growth strategies – including developing and implementing mergers and acquisitions and extensive retail management.

- I have deep gas industry expertise in terms of gas supply options, transmission, distribution, pricing, contracts and end use. I have for example in the past developed gas supply options for a number of power station developments (on and off grid) including piped gas, LNG and CNG supplies. I have also built gas transmission and distribution systems and small-scale LNG and CNG facilities.
- I have related expertise in the economic regulation of gas supply systems and processes and have developed, built and implemented complex, bespoke economic and commercial models related to gas use and developments.
- I also have hands-on senior executive experience running a major Business Development and Construction business for listed entity Energy Developments Ltd (Executive General Manager Development reporting to the Managing Director). This encompassed Coal Seam Gas, CNG and LNG power station developments – remote and embedded, production and trading of greenhouse gas credits and certificates, and CNG and LNG facility developments in Australia. I developed detailed financial models for all the investment opportunities for EDL over a 2-year period and reported these to the Board at each Board meeting. I was responsible for these developments and if approved their construction and commissioning.
- I have extensive project development and implementation experience (including construction management) and am often engaged to undertake bespoke modelling and pricing assignments; retailer new entrant strategies and implementation, business restructuring and improvement; greenhouse emissions matters and demand side management.
- My expertise and standing in the energy sector were recognised in June 2016 being conferred the Honorary Title of Adjunct Professor by the University of Queensland, Energy Initiative.

A.2 Other gas industry background

Some relevant projects include:

- Leading the recent project to assist the Federal Department of Industry, Science, Energy and Resources (was the Department of Environment and Energy) to develop the Technology Roadmap covering renewable gas targets (hydrogen), energy storage and other technologies. This involved providing advice to Australia's Chief Scientist (Dr. Finkel), the Chairman of the Australian Energy Market Operator (Mr Clarke, AO), the head of the Business Council of Australia (Mr King) and other leading experts selected by the Minister.
- Leading a major review of the strategic energy requirements for North and Central Queensland for the Department of Environment and Energy (Canberra). This work involved detailed analysis of the commercial and industrial demand now and into the near future and what level of synchronous generation or system support is required, integration issue and what will this cost, and other policy or regulatory options that should be considered. This project also involves an extensive stakeholder engagement process with some 40 direct interviews being undertaken. OGW had a team of 6 working on this project.
- Leading the Gas Bulletin Board (GBB) Scoping Study 2018/19, AEMO on behalf of the Commonwealth Government Minister for the Environment and Energy – this project examined in major detail the options for improving the data and information on the GBB from Producers and Pipeline operators with a focus on real time provision of data and information to increase market transparency, and included extensive stakeholder interaction, assessment of regulatory impacts, economic policy analysis and a full cost benefit analysis of the key options. It covered both the east and west coast GBB's.

- Economic and Commercial Advisory – Gas to Market Project 2019, Queensland Department of State Development, Manufacturing, Infrastructure and Planning – much of this report remains confidential, but it examined the issue of gas pricing in the State and east coast and related policy options and decisions.
- Gas Price Trends Review Report 2017/2018 - for the Dept of Environment and Energy. This report was an update to the original (2015) report completed by OGW and was commissioned by the GMPIT, COAG Energy Council. The reports examined in detail (jurisdictional, segment, supply chain) the price trends in gas in Australia from Producers through to Retail, for large and small consumers over the last 10 to 12 years and is now a major reference report for the industry and Government.
- Gas Transmission Arbitration 2018 – provided expert testimony and opinion through papers and reports, and reviewed submitted expert reports, on behalf of Hydro Tasmania when it sought access to the Tasmanian Gas Pipeline on reasonable terms (that reflect workable competition) through a form of enforced commercial arbitration undertaken under Part 23 of the National Gas Rules.
- I was also engaged as the gas expert engaged to advise the Tasmanian Energy Security Taskforce in late 2016 and provided extensive advice on complex matters related to gas supply, use and energy security for Tasmania to the Chairman.
- Extensive gas market review for a large offshore (Japanese) investor 2018 – the OGW gas team, led by me, completed a very extensive market review of the gas markets in Australia for a Japanese company that has major investments in LNG facilities in Australia and internationally and wanted to understand the Australian market and related investment opportunities in more detail. This work also involved extensive forecast modelling examining the likely interaction of gas and power wholesale markets under current State and Commonwealth emission and renewable generation policy trajectories to 2040. It was landmark work for a major investor and was delivered at Board level in Japan.
- LNG use in Papua New Guinea 2018 – OGW gas team led by me undertook a major assignment for an international mining company related to the potential for them to use LNG for powering their mining works in PNG. This assignment included analysis of the price of internationally traded fuels, including LNG, and involved engaging with international LNG traders and producers.
- Gas Power Stations for Miners – the OGW gas team led by me has completed several major gas repowering projects for leading miners in Australia and continues to undertake such work e.g. South32, Tronox, Anglo Gold Ashanti, Rio Tinto, Adani. This work also involves placing a commercial value on gas reserves, and extensive integration of solar and energy storage. I have also completed major power station prefeasibility assessments and implementation of new plant for miners.
- Interview with Seoul Economic Daily on LNG and Gas Markets in Australia – OGW was approached by Kogas the Korean state-owned gas supplier – one of the biggest buyers of LNG in the world with investments in LNG production internationally – in my Adjunct Professor role to be interviewed by this leading Korean newspaper as a recognised Australian expert on gas markets and regulatory issues (and gas related investments) in Australia.

- Prior to 5 years ago I had long term engagements with major gas power station developers (all have existing stations – in total projects were in excess of 2,000 MW) working as part of their project teams on modelling of the financial viability of the projects, providing detailed information to support funding, assisting with the strategic development of the project and working extensively on gas supply agreements and power off taker arrangements and market price forecasting. I no longer assist in the procurement of gas contracts as it conflicts with other wok that I have been engaged in over the last 5 years.
- I worked for two years (2005 and 2006) with Energy Developments Ltd as their lead business development Executive General Manager (EGM) reporting to the MD and regularly reporting to the Board on development matters, opportunities and projects. This included major power station developments and potential merger and acquisitions.
  - While at EDL I developed a detailed financial modelling approach to project investment analysis and embedded a process of MD and Finance Director sign off prior to Board sign off based on this modelling approach. I also was responsible for the construction and commissioning of all major projects once they were signed off by the Board and their on-going economics on completion. He then handed them over to the Operations side of the business.
  - As part of his Executive role I also worked closely with the Auditors of the business to verify and have signed off the holding values of the various on-going assets and facilities (mostly power stations), and the work in process, for the annual accounts.I also pitched the development of an LNG peaking and fuelling plant at Newcastle, NSW to AGL while at EDL. AGL subsequently went on to develop this plant after I left EDL (A$310m).
- Acted for a major Queensland industry on the potential purchase of 20 PJ of gas from either Timor Sea or PNG for self-generation, some 15 years ago.
- Examined the role of gas-fired generation in Australia and the subsequent opportunities that arise in the market for new developments and market entry.
- Led a major market review of renewable energy and gas fired electricity generation of the Asia Pacific region for a major US Utility with detailed work on the opportunities in China.
- Pioneered the long-distance trucking of CNG to fuel remote power stations (Yulara) and was heavily involved in the development of CNG and LNG supply, storage and dispensing facilities for transport and power use across Australia.
- Led the development of LNG use for mine haul trucks (circa 200 tonne) with the options of using drainage gas at coal mines as the fuel (formed venture of CAT, Xstrata, EDL and Westport from Vancouver). This was while at EDL and was subsequently taken up by CAT and Westport after I left EDL.

A.1: Prior professional history

2016 -	Adjunct Professor, University of Qld, Energy Initiative
2008 -	Executive Director, Oakley Greenwood
2006 - 2008	Senior Advisor, Charles River Associates - International
2005 - 2006	Energy Developments Ltd, Executive GM Development
2001 - 2004	Charles River Associates, Asia Pacific/Vice President
1993 - 2001	Energetics, CEO Consulting/CFO/General Manager
1991 - 1992	Hunter Electricity (Newcastle), CEO
1990 - 1991	Energetics Pty Ltd (Newcastle), Marketing Director
1978 - 1990	AGL, Manager Sales and Marketing (1986-90) / Manager Regulation 1990/ Manager Commercial and Industrial Sales (1983-86) / Project Engineer (1980-83) / Works Engineer (1978-80)

A.2: Education

- Adjunct Professor, University of Queensland Energy Initiative (Honorary appointment)
- B.E. (Chemical) Honours, Fellow IChemE, past Fellow IEAust.
- Graduate Australian Administrative Staff College, Mt Eliza, Melbourne.
- Graduate Australian Institute of Company Directors.

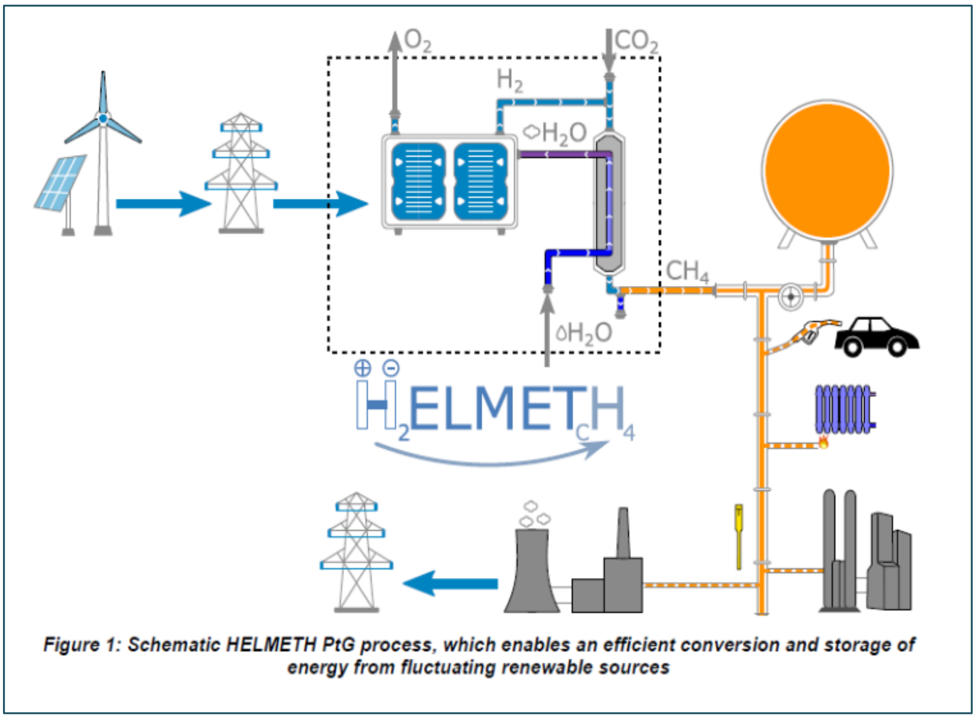
Appendix B: Zero emission methane gases

The development of this technology has commenced in Europe and Australia. Europe has a road map for this development as renewable methane can utilise existing infrastructure which is a major issue in Europe, and they have huge gas storage capacity = 1,131,000 GWh - with 22 GWh/day delivery. Demand is some 16,000 PJ/annum (4,400 TWh) for gas.

B.1: HELMETH Power-to-Gas Prototyping (Europe)

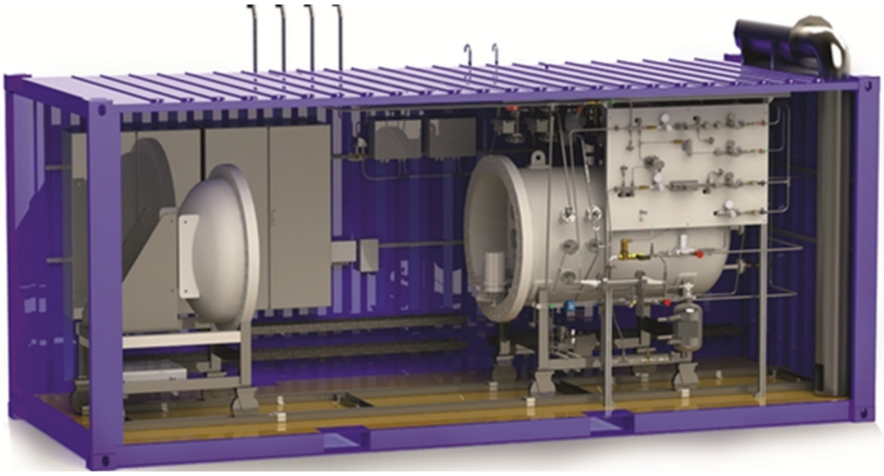
- The European technology development includes HELMETH which is classified as being Technology Readiness Level 4 to 5 (TRL 4-5).
  - They targeted a conversion efficiency of >85% of renewable electricity to methane in close reactor design, or fully integrated reactor design.
  - There has been an initial high-efficiency HELMETH Power-to-Gas (PtG) process prototype developed, that combines pressurised high temperature steam electrolysis with a carbon dioxide methanation module. The main efficiency gains are in the hydrogen production at these high temperatures and pressures, recognising that the methanation reaction can provide a lot of heat to the process.
  - This demonstrated the technical feasibility of a conversion efficiency of some 75% to 80% was achievable at this level of TRL.
  - This produces a renewable methane (or as they term a synthetic natural gas (SNG)) compatible with existing natural gas infrastructure.
- A significant advantage of the HELMETH PtG technology in contrast to PtG plants with low temperature electrolysis modules is its higher efficiency resulting in considerably lower electricity demand per unit of output.

Figure 18: HELMETH Power-to-Gas high efficiency methanation process



Source: http://www.helmeth.eu/

Figure 19: HELMETH prototype reactor

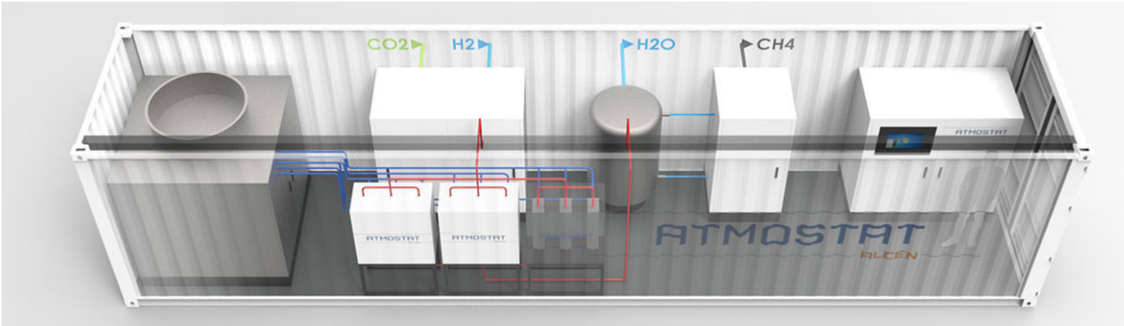


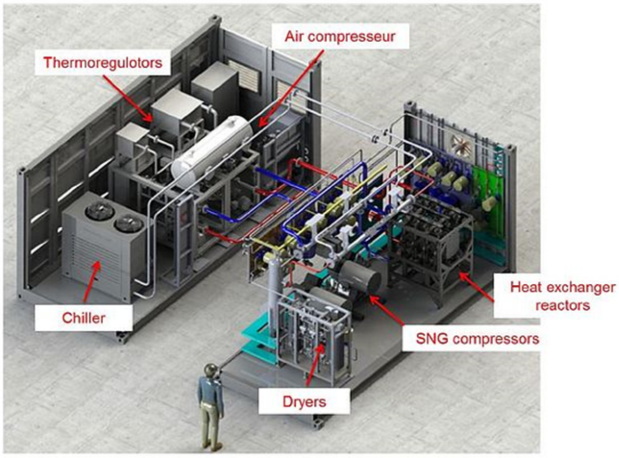
B.2: Store&Go trials of renewable methane production technologies (Europe)

Some 27 partner organizations and companies from all over Europe collaborated in the STORE&GO project to integrate Power-to-Gas technology into the future European energy system. The project life span was 48 months, starting from March 2016 to end of February 2020. It was funded by the European Union's "Horizon 2020 research and Innovation programme".

- The STORE&GO project tested different available power-to-gas technologies in three different European countries - Germany, Switzerland and Italy, and thus under different regulatory frameworks.
  - Germany - isothermal catalytic honeycomb reactor technology - converting renewable energy with reactor enabled methanation processes with improved heat management.
  - Switzerland - biological methanation - waste water conversion through biological methanation.
  - Italy - modular milli-structured catalytical reactors - converting purified water through milli-structured methanation and capturing carbon dioxide from air and liquify the resultant gas to LNG.

Figure 20: Store&Go Technology prototypes





Source: https://www.storeandgo.info/

B.3: Southern Green Gas methanation unit (Australia)

The APA group and ARENA have co-funded a renewable methane pilot project in Queensland for the production of renewable methane at Wallumbilla (a major has hub). The development partner is an Australian start up, Southern Green Gas (https://www.southerngreengas.com.au/).

The demonstration plant will produce approximately 320 kilograms of hydrogen per year, converting it into 32 gigajoules of methane which will then be injected into APA's gas engine fuel line at Wallumbilla, and is expected to be operational by late 2021.

The collaboration on this project aims to demonstrate the technical and commercial benefits of an integrated hydrogen electrolysis and renewable methane production system. The project will generate cost and technical data to be used to assess the feasibility of larger, commercial scale, renewable methane production.

This unique project is the first step in testing whether it is possible on an industrial scale to create methane using solar-generated electricity, water and CO2 from the atmosphere in Australia.

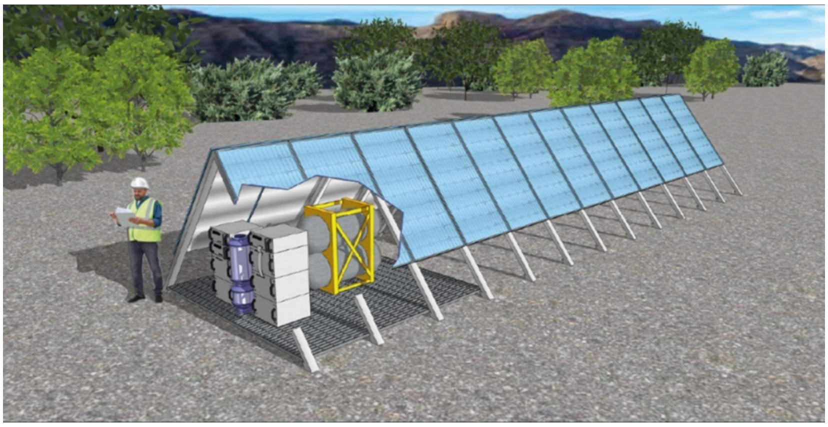
ARENA CEO Darren Miller said:

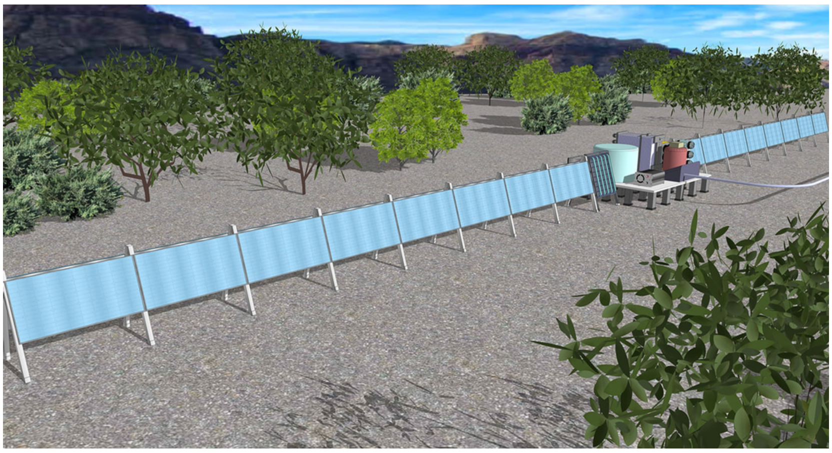
"Renewable methane is in effect indistinguishable from the methane that currently fills our natural gas pipelines. The gas network is expected to play a key role in supporting the decarbonisation of Australia's energy system."

Commenting on the initiative, SGG's Managing Director Rohan Gillespie stated:

"The reason we have chosen methane as the carrier for renewable energy is the ability to utilize the existing gas infrastructure system. The existing gas pipeline network allows us to access customers here in Australia, as well as export customers such as Japan and South Korea, through the existing liquefied natural gas (LNG) system. We believe renewable methane offers the best solution to creating a major new export industry for Australia, leveraging its globally competitive advantage in solar energy."

Figure 21: Southern Green Gas renewable methane demonstration project





Southern Green Gas and the University of Sydney are also developing modular direct air capture units (DAC) to be produced in Australia.

Figure 22: Southern Green Gas modular DAC units