Attachment 9.10 (1)

AGIG Network Adaptation Strategy – Renewable Gas

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Network Adaptation Strategy – Renewable Gas

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Originated by

Title	Name	Signature	Date
Senior Engineer - Low Carbon Future	Robert Davis		June 2022

Reviewed / Endorsed by

Title	Name	Signature	Date
Head of Network Strategy & Planning	Troy Praag		June 2022

Approved by

Title	Name	Signature	Date
EGM – Network Operations	Mark Beech		June 2022

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1. Document overview

1.1. Purpose

The purpose of this Network Adaptation Strategy is to articulate AGIG's approach to facilitating the introduction of renewable gas, specifically hydrogen, into the Victorian gas distribution networks (AGN Victoria and Albury and the Multinet Gas Networks (MGN)). AGIG regards renewable gas as either biogas that has been upgraded to biomethane, or green hydrogen produced through electrolysis using renewable electricity. For the purposes of network asset compatibility, biomethane is identical to natural gas and no changes are required to facilitate its blending in the network. Hydrogen, however, does require a limited number of changes to existing asset management practices to ensure high levels of reliability and safety are maintained.

This Network Adaptation Strategy articulates:

- the energy transition underway in Australia and the need to get our networks ready for renewable gas in order to meet government ambitions, and customer expectations;
- our journey to renewable gas; and
- the necessary changes to our asset management practices and processes to ensure hydrogen compatibility is addressed prior to its introduction.

Specific projects and costings for the individual networks are provided in the AGN and MGN network adaptation plans 410-PL-AM-0010 - Renewable Gas Network Adaptation Plan – AGN Victoria and MG-SP-0016 - Renewable Gas Network Adaptation Plan – MGN Victoria, which are informed by this strategy.

Key milestones are to accommodate a 10% hydrogen to natural gas blend by 2030, and operate a 100% hydrogen network by 2040. This is in line with the Victorian Government's commitment to net zero greenhouse gas emissions by 2050, with emissions reduction targets of 28% - 33% by 2025 and 45% - 50% by 2030.[1]

1.2. Scope

This strategy covers AGIG's distribution networks and assets connecting to transmission pipelines in Victoria. It outlines the component replacements, process updates, and risk assessments required prior to the injection of hydrogen at both 10% volume blends and 100% conversion for the MGN and AGN Victoria networks.

Components within the MGN and AGN Victoria and Albury networks have been assessed for hydrogen compatibly, leveraging understanding from the Australian Hydrogen Centre (AHC) network compatibility technical assessments and experience gained through the operation of the Hydrogen Park South Australia (HyP SA) blending project. Other AGIG assets such as AGN Wagga Wagga, AGN Queensland and AGN Alice Springs distribution networks contain similar equipment. However, a detailed assessment of each will be conducted before developing renewable gas network adaptation plans for these networks.

1.3. References

AGIG has relied on technical assessments completed for the Australian Hydrogen Centre by independent engineering contractor GPA:

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[1] Victoria State Government, Gas Substitution Roadmap Consultation Paper, June 2021.

- GPA. (2021). 210620-REP-001 – Piping Compatibility Issues;
- GPA. (2021). 210620-REP-002 – Component Compatibility ;
- GPA. (2021). 210620-REP-003 – Operational Issues;
- GPA. (2021). 210620-REP-004 – Downstream Considerations;

and the following technical assessment completed for AGN by GPA:

- GPA. (2021). 210827-REP-001 – Pipeline Suitability for H2 Service

2. Background and context

The energy transition

There is an energy transition happening in Australia. In all jurisdictions, governments are looking at ways to decarbonise energy systems, moving away from fossil fuels and traditional forms of energy generation and consumption. This energy transition applies equally to both electricity and gas, with both sectors inextricably linked to each other and both certain to remain an important part of Australia's energy mix for years to come.

The Victorian Government is committed to reaching net zero greenhouse gas emissions by 2050 and has set emissions reduction targets of 28% to 33% by 2025 and 45% to 50% by 2030.[2] Natural gas has been a crucial part of Victoria's energy mix for decades. Gas is used by more than 2 million residential and commercial consumers for heating, hot water and large scale manufacturing, and contributes 15.8% of Victoria's total CO_2 emissions.[3] It is clear the gas sector has a critical role to play in this decarbonisation journey.

Gas and gas networks will continue to have a major role

The role of gas going forward is the subject of considerable ongoing research and debate. Opportunities to decarbonise the gas network are being explored by a range of bodies including the COAG Energy Council[4], Australian Government[5], CSIRO[6], AEMO[7] and the Victorian Government[8], as well as the network businesses themselves[9].

While the precise nature of how gas will be used in the future has not yet been defined, a recurring theme throughout all the ongoing bodies of work is the introduction of renewable gas – most likely hydrogen and biogases – as a long-term substitute for natural gas. Indeed, the AEMC has recently gone so far as to amend current legislation to accommodate regulatory and economic consideration of renewable gas.[10]

Given this evidence, it is indisputable that renewable gas and gas networks will have a role in Australia's energy future.

> *"Switching gas appliances to electrical options and shifting to alternative gases such as hydrogen and biogas will all likely play a role in achieving net zero emissions, while promoting a sustainable, resilient and prosperous Victoria."*
>
> Hon. Lily D'Ambrosio, Minister for Energy, Environment and Climate Change (Vic)

Valuing Victoria's gas networks

Victoria has an extensive gas system that crosses the state and has significant interconnections with other states. The system includes 1,900 km of gas transmission pipelines, 32,000 km of distribution pipelines and an asset base valued at nearly $6 billion.[11] These assets are long established, reliable, and remain the primary method of gas transportation in the state.

AGIG owns two of the three main gas distribution networks in Victoria (AGN Victoria and Albury, and MGN). Combined, these networks serve more than 1.5 million consumers in metropolitan and

[2] Victoria State Government, Gas Substitution Roadmap Consultation Paper, June 2021.
[3] Including both fugitive emissions and emissions associated with the combustion of gas. Approximate estimates based on 2019 State and Territory Greenhouse Gas Inventories, AEMO and National Greenhouse Gas Accounts
[4] https://h2council.com.au/policy-regulation/government-policies
[5] https://www.industry.gov.au/data-and-publications/australias-national-hydrogen-strategy
[6] https://www.csiro.au/en/research/environmental-impacts/fuels/hydrogen/hydrogen-roadmap
[7] https://aemo.com.au/consultations/current-and-closed-consultations/hydrogen-blends-and-renewable-gases-procedures-review
[8] https://engage.vic.gov.au/help-us-build-victorias-gas-substitution-roadmap
[9] https://www.energynetworks.com.au/projects/gas-vision-2050/
[10] Review into extending the regulatory frameworks to hydrogen and renewable gases | AEMC
[11] Australian Energy Regulator (2020)

regional Victoria. There networks comprise 23,667 km of pipeline, and services, meters and associated assets.

Infrastructure to transport gas in Victoria is already in place. Its technical properties and operational parameters are understood. Industry and the broader public are aware that the gas networks exist, and how to work around them. Consumers continue to use and value the services the networks provide. The connections already exist and for the most part the network has already been paid for.

While some modification is required to the gas networks to allow them to transport renewable gas such as hydrogen or hydrogen blends safely and efficiently, it makes economic sense to modify and repurpose these existing high value assets rather than discarding them or replacing them with an entirely new gas transportation system.

Consumers want gas and support decarbonisation

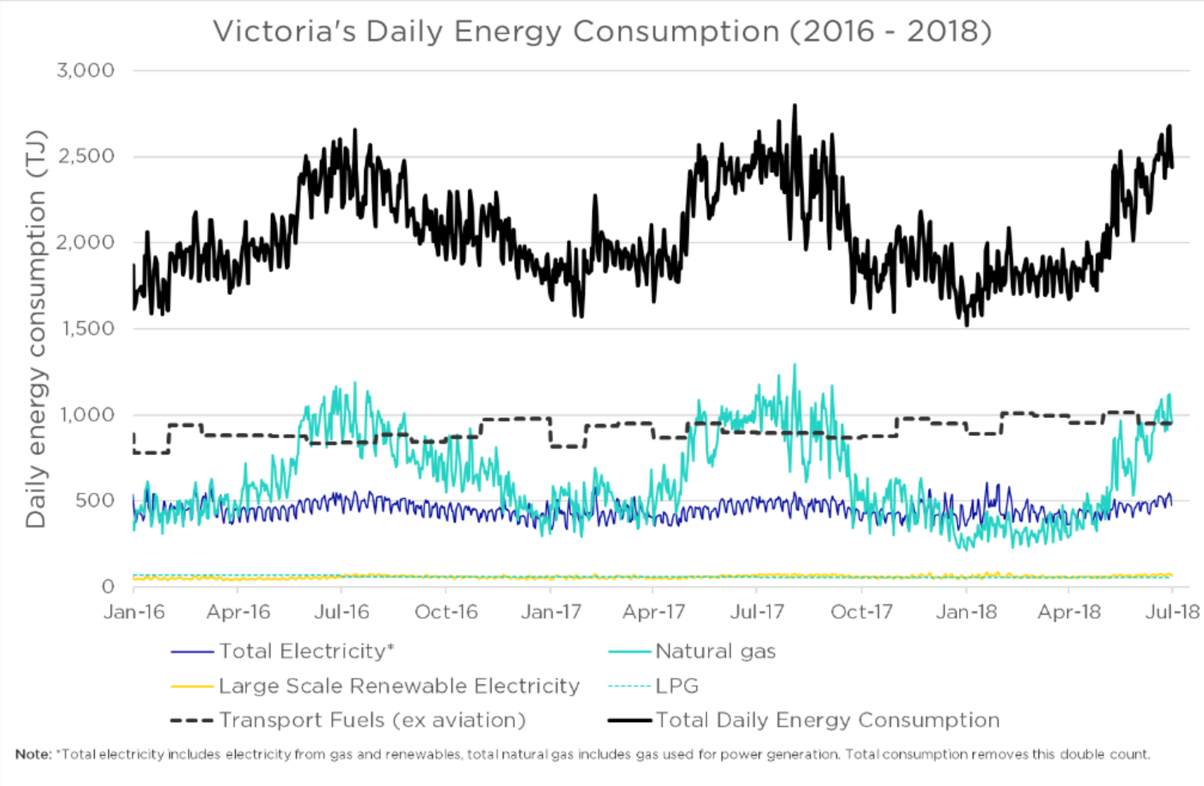
Perhaps most importantly, consumers like gas. They also support efforts to reduce carbon emissions. Research across AGIG operations to understand our customers and the communities in which we operate has led to several important insights, summarised below:

- Customers like using gas in their homes, and it is often a preferred fuel for cooking and heating;
- Customers value the reliability of gas and satisfaction levels are very high (>80% over the last 12 months), with many customers having never experienced an outage;
- Environmental sustainability is becoming increasingly important to customers and communities, with the following findings from AGIG's Voice of the Customer research:
    - ~50% of AGIG's national gas consumers rate environmental considerations as extremely important (an uplift of 5% over the last 12 months);
    - AGIG gas customers in regional NSW and Victoria score 'Cleaner for the Environment' at an 8.6-out-of-10 in terms of level of importance.
- Customers demonstrate an increased willingness-to-pay for better environmental outcomes, for example in AGIG's recent Victorian program:
    - Clean energy and reducing carbon emissions is an imperative for the majority of customers.
    - 87% of customers view climate change and reducing carbon emissions as important or very important.
    - 89% of customers support AGN's proposed approach to preparing our networks for renewable gas.

In Victoria, where natural gas is likely to remain an important part of the energy mix for years to come, hydrogen represents a significant opportunity to achieve emissions reduction targets, while making use of Victoria's extensive gas network and minimising costs.

Figure 2-1 below shows Victoria's total daily energy consumption from 2016 to 2018. It shows that during winter peaks gas provides around double the energy provided by electricity.

Figure 2-1: Victorian daily energy consumption 2016 to 2018



This chart supports the view gas has an important role in Victoria's energy mix today, and gas consumption is well entrenched in consumer behaviours. Though the type of gas consumed and overall demand levels may change over time, it is reasonable to assume gas services (natural or renewable) will remain relevant for the foreseeable future. Perhaps more significantly, the above chart also suggests it would be extremely expensive and impractical to decarbonise all existing uses of gas through electrification – there is a significant quantity of energy, it cannot all be displaced by electricity.

A proactive, conservative and efficient network transition to renewable gas

Given the ongoing energy transition, consumers' preference towards gas services for heating and manufacturing, and recent energy policy movements towards decarbonisation, it is vital get our networks ready to transport renewable gas.

The good news is that this work has already commenced. In fact, the vast majority of the network and associated equipment is already able to operate with hydrogen.

Most of our mains are capable of supporting hydrogen, and those that aren't are being replaced as part of ongoing asset management practices. Over the past two decades, we have been replacing old cast iron and unprotected steel pipes with new polyethylene (PE) pipes, which are well suited to transporting hydrogen.

Cast iron and unprotected steel are compatible with hydrogen or hydrogen blends, however, the age of these assets means they are becoming unsuitable to transport any type of gas – natural or renewable. Though we don't have to wait for all the cast iron to be gone before we can start blending hydrogen into the network, it makes sense to get them out of the ground as soon as possible.

Mains replacement is well underway across all major Australian gas distribution networks. Our AGN Victoria network will have all cast iron and unprotected steel removed by the end of 2022, with the MGN mains replacement set to be complete by 2032. Most Australian distribution pipelines will be converted to PE pipes by 2035, which will support the wide-scale, safe transportation of hydrogen gas in the medium to lower pressure distribution pipelines.[12]

Equipment manufacturers whose equipment is not currently hydrogen compatible are developing components that can accommodate renewable gas as part of their product offering. Given progress to date, we consider blending of up to 10% by volume of renewable and decarbonised gases by 2030 and full network conversion to 100% renewable gases by 2050[13], in line with Victoria's emissions reductions targets, is technically feasible. Further investigation is also underway to assess the feasibility of increased blends beyond 10% (e.g. 20% & 30%) as an additional interim step before 100% conversion.

To adapt our network to a 'hydrogen ready' state, we propose a proactive, conservative and incremental approach. Our Network Adaptation Strategy has two broad focus areas:

1. **End-of-life replacement** – the most efficient way to adapt the network for renewable gas is to do so incrementally as part of our business-as-usual asset replacement. As per the mains replacement program, we will build the introduction of renewable gas into our asset management considerations. This means that where practicable and where the cost difference is negligible, when replacing gas distribution network equipment we will purchase parts that are compatible with hydrogen and renewable gas.
   For example, our current metering fleet is already capable of supporting 10% hydrogen blends. However, as part of our regular end of life Periodic Meter Change program, we aim to transition to ultrasonic meters, which are better suited to higher blends and up to 100% hydrogen. This approach will allow us to get our metering fleet 100% ready for only the incremental cost of the newer meters.

   This incremental approach allows us to facilitate the energy policy direction to decarbonise Australia's energy sector, and to do so in an efficient manner. Given the long life of many of our network assets, this 'hydrogen ready' asset replacement program has either already commenced, or must commence during the next round of asset life cycle replacements if we are to keep pace with the energy transition.

2. **Targeted proactive replacement** – while the majority of our network is either already compatible or will be adapted through ongoing end-of-life replacement, there are some assets that will need to be changed out for hydrogen-ready components before end-of-life.

   We estimate that the assets that need to be replaced proactively (i.e. before end of life) to make our Victorian networks hydrogen ready accounts for less than 1% of the overall asset base, or around $20 million of investment. These include assets such as pressure regulating equipment, and electrical equipment in hazardous areas.

   Our strategy is to identify the relatively small volume of incompatible components early (as part of this Network Adaptation Strategy) and commence a program of proactive replacement, targeting those parts of the network that are most likely to have hydrogen introduced first. For example, the Murray Valley area in the north of the AGN Victoria network has been earmarked as an early candidate for renewable gas injection given the nearby HyP Murray Valley project. We would therefore target proactive replacement of electrical components and incompatible pressure regulating equipment in that section of the network.

We submit that this proactive approach, coupled with prudent end-of-life replacement, is a more efficient and cost-effective approach than adopting a 'wait and see' philosophy and then having to

[12] Deloitte Access Economics (Report for the ENA), *Decarbonising Australia's gas distribution networks.* See: https://www.energynetworks.com.au/assets/uploads/054496_tg_decarbonising_australias_gas_network_final.pdf
[13] Preferably by 2040 as a stretch target.

conduct more costly reactive works when hydrogen developments accelerate. All distribution network operators have a duty of care to manage and periodically replace assets, irrespective of what gas is being transported. There is sufficient evidence to suggest Victorian networks will be required to transport hydrogen in the near future, it therefore makes sense to get our network ready in the most economically efficient way

Near-term investments – 10% hydrogen

To get to 100% hydrogen, we first need to safely transport hydrogen blends. It is important to emphasise that hydrogen is already safely produced in Australia, and for AGIG, we are currently safely transporting hydrogen through the gas distribution network at a blend of 5% without significant change.

Our first renewable hydrogen blending project – HyP SA[14] – is already operational. HyP SA demonstrates the technical feasibility of production and blending technology in an Australian context and also underpins further research and business cases, which can pave the way for commercial production. For example, the HyP SA project provides a test bed for regulators in implementing safety, environmental and other regulation specifically for hydrogen.

In Victoria we are developing HyP Murray Valley, which builds on the successes in South Australia and will see us work closely with Energy Safe Victoria (ESV) and Department of Energy, Land, Water and Planning (DELWP) to provide assurance hydrogen is safe for deployment through the network and for use in appliances. We will use HyP Murray Valley to trial introduction of 10% hydrogen blends, and identify the investments we must make to introduce renewable gas into the broader networks.

The purpose of this Network Adaptation Strategy is to identify the capital works and operational activities required to adapt our network for renewable gas. Our aim is to develop a modest proactive asset replacement program for the AGIG networks, with a focus on strategically timed investment to ensure assets are replaced just before they are needed.

As discussed, the bulk of hydrogen-ready investments will be made through ongoing end-of-life asset replacement at, incurring only the incremental costs of the new assets. However, there will be some proactive investment required in the near term.

The level of investment across each network business will vary depending on each network's asset portfolio and specific needs. The individual hydrogen adaptation plans and options considered for AGN Victoria and Albury and MGN – including forecast costs – are described in 410-PL-AM-0010 - Renewable Gas Network Adaptation Plan – AGN Victoria and MG-SP-0016 - Renewable Gas Network Adaptation Plan – MGN Victoria.

[14] A 1.25MW electrolyser demonstrating the production of renewable hydrogen for blending with natural gas (up to 5%) and supply to more than 700 existing homes in metropolitan Adelaide.

3. The journey to renewable gas

3.1. The story so far

There are currently two leading types of renewable gas ready to be injected into gas networks, and blended with natural gas:

1. Biomethane created by 'upgrading' biogas
2. Pure hydrogen created through electrolysis using renewable electricity

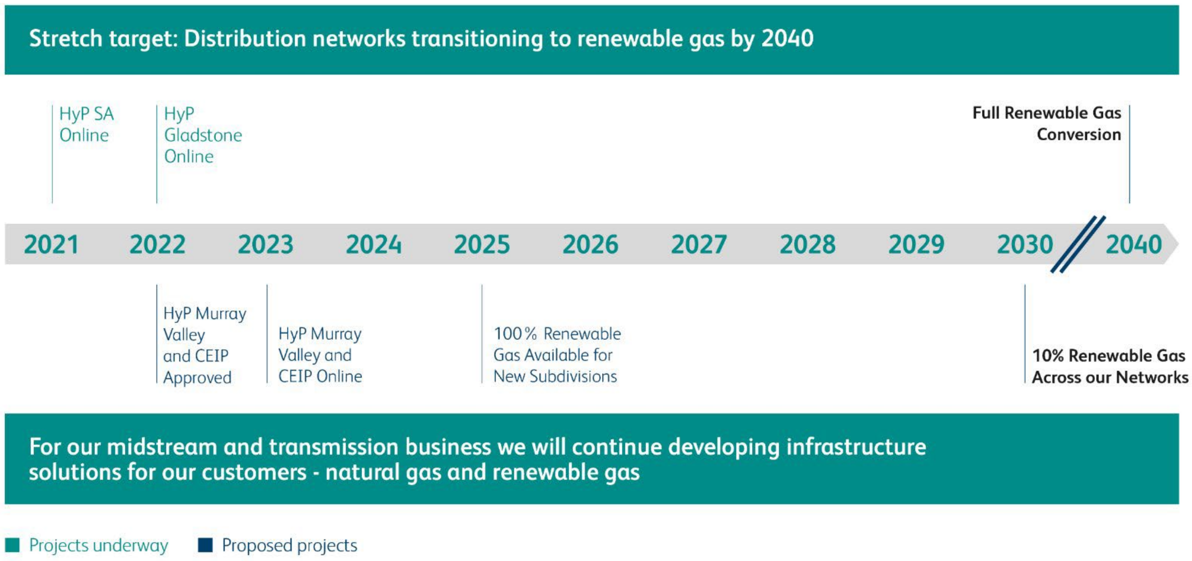
We will transition to 100% renewable gas in a balanced, conservative and incremental approach. Biomethane is an ideal renewable replacement for natural gas as it can be used without the need for any changes in transmission and distribution network assets or end-user equipment. However, there is significant uncertainty of the potential amount and location of Biogas sources that could be upgraded to Biomethane[15]. The energy sector is therefore looking to hydrogen as the next renewable gas option.

Hydrogen produced through electrolysis allows the location and scale of production to be designed to align with variation in customer demand. However, it has different properties[16] to natural gas and therefore we need to consider how best to integrate it into the gas network.

AGIG has commenced investigations and started on the pathway towards a renewable gas future. We have successfully demonstrated the operation of hydrogen blended networks, with hydrogen park in South Australia (HyP SA) operational since May 2021. HyP Murray Valley in Victoria expands upon the success of HyP SA and is planned to commence operation in 2024.

The next phase in the hydrogen journey is to facilitate 10% renewable gas by 2030, and to facilitate the transport of decarbonised gas within our Victorian distribution networks (AGN and MGN) by no later than 2050. This will involve targeting sections of our networks to adapted first and incrementally introduce hydrogen as a gas blend, with the aim of offering 100% renewable gas to new housing estates no later than 2025. Figure 3-1 shows the planned dates in relation to this transition.

Figure 3-1 - Renewable gas timeline



[15] Deloitte Access Economics (Report for the ENA), Decarbonising Australia's gas distribution networks. See: https://www.energynetworks.com.au/assets/uploads/054496_tg_decarbonising_australias_gas_network_final.pdf
[16] Refer to Appendix A for a comparison of properties between Natural Gas and Hydrogen

3.2. Next steps

Hydrogen differs from natural gas in several ways – it has reduced energy density by volume, is a much smaller molecule, has a wider flammability range and a lower ignition energy. These critical differences mean we will need to conduct detailed assessments, and where necessary modify our assets and operations for compatibility with hydrogen.

We have been working with the Australian Hydrogen Centre to undertake an assessment of asset compatibility with hydrogen and consider the changes that are required to prepare assets and operational processes for hydrogen injection. As part of this work, third party experts GPA, considered four key areas:

- piping compatibility;
- component compatibility;
- operational issues; and
- downstream considerations.

GPA found that the existing network equipment and processes can accommodate a 10% hydrogen blend with only minor modifications to specific parts of the network. Additional work would be required to safely introduce 100% hydrogen, however GPA found that much of the networks are already hydrogen ready (for example PE mains). We therefore consider that the proactive replacement of hydrogen compatible assets can be managed by prioritising those parts of the network where hydrogen is most likely to be introduced first (e.g. the Murray Valley and surrounds).

We have used these studies, together with information from our HyP projects, to determine what works need to be undertaken in preparation to accept hydrogen into the Victorian gas distribution networks (AGN and MGN)[17]. The key actions are discussed in the following sections. The resulting hydrogen adaptation plans for AGN Victoria and Albury and MGN are described in 410-PL-AM-0010 - Renewable Gas Network Adaptation Plan – AGN Victoria and MG-SP-0016 - Renewable Gas Network Adaptation Plan – MGN Victoria.

[17] The following items have not been considered in the document as they are not generally considered part of the existing distribution network. They may, however, require separate consideration as to their compatibility with hydrogen or integration into the existing distribution networks: downstream (consumer) appliances and fitting lines, electrolysers and hydrogen injection and blending units.

4. Network compatibility

This section describes the key findings of the GPA compatibility report and the key actions that must be taken to facilitate the introduction of renewable gas. It includes discussion on the compatibility of existing network assets, design standards, and integrity management processes.

4.1. Engineering design and integrity management

4.1.1. Pipelines (>1050 kPa)

The GPA compatibility review found that most of AGIG's pipelines with design factors below .04 can safely be used to transport hydrogen blends or pure hydrogen. Through engineering calculation, it was found they have effective resistance to fracture and fatigue at the relevant operating conditions, and that the original pipeline hydrotest still provides a margin of safety after hydrogen embrittlement.

In service live welding may be possible on AGIG pipelines containing hydrogen. Existing weld procedures will not be appropriate and must be re-qualified.

New hydrogen pipeline design should be completed as per AS2885 with additional guidance from ASME B31.12 as the most mature hydrogen pipeline design standard available.

Actions:

1. Hydrogen injection projects utilising AGIG pipelines that have not yet been assessed should perform hydrogen compatibility review as early as possible in the scoping stage of the project.
2. Create weld procedures as required.
3. Consider guidance from ASME B31.12 during new pipeline construction.

4.1.2. Network piping (<1050 kPa)

Piping

The distribution network has a large range of materials across four pressure categories. The compatibility review identified that steel, copper and plastic pipe materials can be retained in hydrogen service at 10% and 100%. Cast iron is not commonly considered suitable for hydrogen service, though there is little specific data available. The compatibility report concludes that low-pressure cast iron (<7 kPa) can be retained in 10% and 100% hydrogen service.

Joint types

The review concluded that all joint types in the system are suitable for use with 10% hydrogen blends, and that most connection types are suitable for 100% hydrogen also, including welded, flanged and threaded steel connections, and welded and glued plastic pipe connections.

Though flared-type tubing connections (e.g. Swagelok and similar copper pipe connection types) are acceptable and are in fact common in hydrogen systems, ongoing research at Deakin University has flagged that other mechanical joint types with a narrow leak path may have unacceptable leak rates at 100% hydrogen. These include Gibault and perfection joints, which are primarily designed for the water industry. These require closer review, including a review of the type of elastomer that is used to establish the seal in these joints.

In service live welding may be possible on AGIG distribution piping containing hydrogen. Existing weld procedures will not be appropriate and must be re-qualified.

Actions:

1. Perform further investigation into the suitability of certain mechanical joints.
2. Create weld procedures as required.

4.1.3. Meters

Due to the difference in volumetric flow rate of hydrogen and natural gas to deliver the same amount of energy, existing volumetric gas meters used almost exclusively across the distribution networks will see a reduction in capacity to deliver energy to the customer. For 10% blends, this reduction is minor and within the margin of typical over-specification of current installations.

For 100% blends, the volumetric flow rate increases by a multiple of three, the equivalent of the difference between a standard domestic meter (e.g. Email 750) and an AL1000 meter. Installing an AL1000 meter at each domestic customer is not feasible due to its size and cost.

New-to-market small ultrasonic and other flow-based meters are a promising alternative. Some domestic meters are being marketed that are compatible with both natural gas and hydrogen at the respectively required volumetric flow rates. This type of meter raises the possibility of being installed when supply is natural gas and then not requiring a change out when 100% Hydrogen is supplied.

Action:

1. Change-out existing meters with larger flow capacity ones prior to 100% hydrogen injection. Consider completing changes during normal planned meter change (PMC) program ahead of hydrogen injection.

4.1.4. Hazardous area equipment

Due to the lower ignition energy of hydrogen when compared to Natural Gas, electrical equipment installed within hazardous areas must be rated to a higher level than is required for natural gas. In summary:

- 100% natural gas requires a category IIA equipment
- At 9% hydrogen / 91% natural gas blend, the category changes to IIB
- Category IIC is required at blends above 43% hydrogen / 57% natural gas

An initial review of several AGN pressure reduction stations has shown the majority of equipment (~90%) installed across the Victorian networks is already category IIC.

Action:

1. All new hazardous area equipment installed during normal maintenance or new projects to be category IIC.

4.1.5. Network component compatibility

The introduction of hydrogen poses embrittlement concerns for certain metals, and has the potential to change the material properties of certain elastomers. While the impact of hydrogen has not yet been fully tested, Table 3-1 summarises materials that should be avoided for hydrogen service until further research confirms compatibility. Please refer to the GPA Component Compatibility report (appendix C) for more detail.

Table 3-1 - Material compatibility with hydrogen

Material	Reason
High strength steels, high carbon steels, tool steels and similar	Increased susceptibility to hydrogen embrittlement.
Martensitic stainless steel, and precipitation hardened stainless steel	Increased susceptibility to hydrogen embrittlement.
Cast iron	Generally not considered compatible with hydrogen, although lacking data at pressures and stress associated with distribution networks. Further research required.
Nickel alloys E.g. Inconel, Monel, Hastelloy C-276	These are not generally considered suitable, but may safely be used at low stress levels, subject to engineering confirmation.
Titanium	Some grades have lower performance. These need to be confirmed individually.
Natural rubber	Performance reduces in hydrogen.
Silicone	Performance reduces in hydrogen.
Fluorosilicone	Performance reduces in hydrogen.
Butadiene-Styrene SBR, Butadiene-Acrylonitrile NBR	Potential performance reduction – more investigation required.
Epichlorohydrin CH	Potential performance reduction – more investigation required.
Ethylene-propylene EPDM	Potential performance reduction – more investigation required.
Polyoxymethylene / Polyacetyl POM	Potential performance reduction – more investigation required.

Metal components

Hydrogen can cause embrittlement of some metals, leading to a reduction in tolerance to crack-like defects and an acceleration of fatigue failure. GPA has identified that components with parts made from copper alloys, most aluminium alloys, and stable austenitic stainless steels are suitable for 10% and 100% hydrogen service. Other metals with poor performance, such as cast irons, high strength carbon steels (e.g. chrome-moly), martensitic stainless steels and nickel alloys may also not be suitable and the following recommendations apply:

- components with bodies or pressure containing parts made from martensitic stainless steel or nickel alloys are not suitable for any level of hydrogen service;
- components with cast iron bodies should only be used up to a maximum pressure of 7 kPa in 10% and 100% hydrogen service, in the absence of any other supporting data; and

- components that contain materials for which no data has been identified should be replaced unless the manufacturer can endorse its performance in hydrogen.

Actions:

1. Perform further investigation into the suitability cast iron for suitability as use in components at high pressure (up to 1050kPa).
2. Replace incompatible components prior to Hydrogen blending.
3. Update purchase process to include hydrogen compatibility assessment.

Plastic (elastomer) component parts

The hydrogen effect on properties for many plastic materials is not currently quantified or reliably predicted. While commonly used Viton and PTFE are hydrogen compatible, very widely-used NBR (Buna- N) often underperforms in hydrogen (depending on the brand). There are also many instances of Acetal, EPDM and some other elastomers that may have reduced performance in hydrogen. Across all of these materials, however, the reduced performance is not expected to result in spontaneous failure of the component. The materials are generally used internally in valves and regulators as seals, gaskets, diaphragms and occasionally bearing materials. As a result, replacing the components containing these materials is not considered essential; instead, risk assessment of seal leakage and close monitoring of performance and failure rates are advised.

Actions:

1. Perform further research through FFCRC into elastomer compatibility.
2. Check high quality spare parts are specified for pressure reduction stations.
3. Update purchase process to include hydrogen compatibility assessment.
4. Confirm compatibility of transmission pipeline repair components (Plidco & Smith clamps).

Further research

Some network component areas require further compatibility research prior to a decision on whether to retain or replace the affected equipment. These include:

- Cast iron – there is limited research to support or oppose its use in the pressure range of 7 kPa to 1050 kPa. There are many regulators and valves using cast iron currently in use on the network at these pressures.
- Elastomers – further work is required to quantify the impact of hydrogen on operational performance of elastomers, noting that elastomers in natural gas also have a finite life.

Risk mitigation can be undertaken through a program of increased inspection and maintenance, particularly at lower percentages of renewable gas entering the distribution system in the first 5 years.

4.2. Planning

4.2.1. Network capacity planning

Managing the capacity of a distribution network is a key control to avoid customer supply issues due to low pressures within the network. Network capacity models have been produced for AGIG’s networks to investigate the impact hydrogen will have on network capacity.

Hydrogen has a reduced higher heating value (HHV) of 12.1 MJ/m^3 when compared to natural gas ~38.4 MJ/m^3. However, this reduction in HHV is significantly offset as hydrogen has a lower viscosity and specific gravity in comparison to natural gas, therefore flows much faster without the corresponding pressure loss.

While the increase in volumetric flow rate is directly proportional to the reduction in heating value (i.e. 100% hydrogen required roughly three times the volumetric flow compared to natural gas), the

> Worked example: The Yarra Glen network in Victoria was selected for an assessment. The current augmentation planning for natural gas was due for augmentation in 2034.
>
> - 10% hydrogen blend bought forward the requirement for augmentation to 2033.
> - 100% hydrogen would bring forward the augmentation requirements to 2027.

reduction in capacity is significantly less than the inferred two thirds. Modelling shows that 100% hydrogen is equivalent to a ~12% reduction in capacity versus natural gas whilst 10% hydrogen is equivalent to a ~2% reduction.

Services connecting the customer to the distribution mains are not included in the modelling. A future assessment will be undertaken to verify if there will be any capacity concerns at 100% hydrogen.

Actions:

1. The current network planning process should be expanded to include hydrogen related models at 10% blend now so that appropriate network upgrades can be designed in time to facilitate hydrogen blending.
2. Complete capacity assessment of small diameter services.

4.2.2. Hazardous areas

Compared to natural gas, hydrogen and hydrogen blends will require a larger minimum hazardous area size in open spaces (note actual size commonly includes significant upwards rounding, so might not change). In enclosed spaces, such as valve pits, the hazardous area is simply designated as the entire pit.

Hydrogen will require a change to the equipment group, due to the reduced ignition energy compared to natural gas. This also impacts 10% hydrogen blends.

- For 10% hydrogen, hazardous area extents may increase by about 10%, which may require changes at the higher-pressure facilities, but this is likely to fall within rounding for most facilities. Equipment group, for the limited compositions that have been analysed, increases from IIA to IIB at around 9% hydrogen. If an item of equipment is numerous in the network, the first action for this equipment would be to seek to re-certify it, rather than replacing it.
- For 100% hydrogen, hazardous area extents increase by a multiple of about three, using typical classification methodologies, which may require facility modifications if the existing area was close to a property boundary. Equipment group increases to IIC, which will require replacement of more components. Assessment of existing hazardous areas is required to determine which ones will require physical changes on site.

Investigation into typically hazardous areas equipment installed in gas networks has found that it is typically category IIC.

Actions:

1. Any new hazardous area equipment purchased should be cat IIC to prepare for eventual 10% & 100% hydrogen scenario.
2. Review and update hazardous area dossiers as part of hydrogen projects.
3. Review and update hazardous area extents as part of hydrogen projects.
4. Replace incorrect category equipment as part of hydrogen projects.
5. New facilities to be designed and specified assuming 100% hydrogen for hazardous area requirements.

4.2.3. Pressure regulating stations

When a system is converted to hydrogen there will be a corresponding increase in the flow velocity due to the decrease in energy by volume. The increase will be only marginal at 10% hydrogen, but more work will be required at 100% hydrogen.

High velocity is associated with several risks including erosion, vibration and noise (the last of which is a public nuisance threat).

The change in flow velocity after conversion should be assessed in regulator station modelling to identify any velocities that will be higher than current design norms. Related structural vibration and noise should also be assessed.

Actions:

1. Assess flow velocity, vibration and noise impacts at regulating stations as part of hydrogen projects and upgrade as stations as required.
2. New facilities to includes a 100% H2 design assessment during the design process.

4.3. Work practices

Difference in gas properties between natural gas and hydrogen results in a number of changes in characteristics that were identified to affect network operation in a number of ways, particularly in the case of 100% hydrogen service. These effects include:

- reduced energy density, requiring higher volumetric flowrates throughout the distribution network to match the current energy capacity;
- increased size of leak clouds due to higher volumetric flow rates;
- increased probability of ignition due to reduced ignition energy;
- higher explosive forces than for natural gas due to increased flame speed;
- faster dispersion in open areas due to buoyancy; and
- differences in thermal behaviour due to hydrogen having a negative Joule-Thomson coefficient at ambient conditions;

4.3.1. Leak management

For 10% hydrogen, the change in gas properties is insignificant enough that no change in either proactive, reactive, or design controls is required. This is well supported by evidence from historical town gas operation.

For 100% hydrogen, the likelihood and consequence of an ignited release may be sufficiently increased to justify a change of controls. Existing leak management plans should be reviewed and updated for 100% hydrogen prior to injection.

Action:

1. Review leak management plans with the following considerations:
    - reactive measures to place less value on the absence of ignition sources; and
    - increase of proactive leak control measures.

4.3.2. Piping and pipeline repairs

For 100% hydrogen operation, due to the increase in leak potential from hydrogen resulting from its lower molecule size, leak testing should be conducted using helium or hydrogen rather than the normal air. Similarly, mechanical joints such as perfection couplings used for certain repairs to plastic piping may have an increased leak rate on 100% hydrogen. Their use should be discontinued if 100% hydrogen service will occur on the network. Further research will confirm if a replacement program is required for mechanical joints already in the network.

The in-service welding procedure should be reviewed and updated for 10% and 100% hydrogen service.

Due to the potential for degradation in performance of certain elastomers, increased monitoring and preventative maintenance of pressure reduction station is required until certainty of performance is achieved.

Action:

1. Perform further investigation into the suitability of certain mechanical joints.
2. Create weld procedures as required.
3. Confirm compatibility of transmission pipeline repair components (Plidco & Smith Clamps).

4.4. Documentation

The following documents require updating with the changes outlined in this document to ensure ongoing management of the gas assets is conducted appropriately.

- Pipeline documentation
- Design guidelines
- Procurement specifications

5. Asset management considerations

Taking into account the network compatibility assessment and our incremental approach to introducing renewable gas, Table 5-1 outlines the key asset management considerations for our gas distribution networks.

Table 5-1: Asset management considerations for the AGIG gas distribution networks

Asset management activity	Summary
Capex works	
Network capacity planning	Assess proposed augmentations for the introduction of 10% hydrogen blend and if projects are required to brought forward into the next 5 years, or if pressure risk can be mitigated
Hazardous area equipment	Update the hazardous area dossiers and extents, adjust infrastructure for compliance to 10% hydrogen blend
Pressure regulating stations	No further work required for 10% hydrogen blend
Steel pipelines – weld procedures	Create weld procedures prior to the introduction of Hydrogen
Steel pipelines - weld hardness testing	Perform Weld Hardness testing on steel pipelines in readiness for hydrogen blends
Network incompatible parts	Replace incompatible components prior to the introduction of Hydrogen
Meters	No changes required for 10% blend
Pipeline Repair Equipment	Assess compatibility of transmission pipeline repair equipment and replace with Hydrogen ready equipment.
Operational activities	
TP compatibility assessment	Assess remaining licensed pipelines for compatibility with hydrogen blends
Hazardous areas extents	Assess hydrogen area extents
Document updates	Update documents to reflect changing product, for example pipeline defect assessments, SMS reviews, GIS blended area identification
Further assessment or investigation required	Allocation for studies to ensure a safe transition to increasing hydrogen
Service capacity review	Not required for 10% hydrogen

These asset management considerations form the basis of the specific Renewable Gas Network Adaptation Plans for each of our networks. The amount of work required to address these considerations will vary by network, however, we consider the volume of proactive asset replacement to achieve full hydrogen compatibility will be approximately 1% of the total asset base, and is predominantly a one off cost.

All the solutions proposed within the AGN Victoria and MGN hydrogen adaptation plans are deemed to be:

- a conservative and phased level of investment reflective of the locations that hydrogen will enter the network in the next five years;
- reducing the risk to an acceptable level; and
- aligned with the network vision of achieving facilitating 10% renewable gas by 2030, and to facilitate the transport of fully decarbonised gas within our Victorian distribution networks (AGN and MGN) by no later than 2050, with 2040 identified as a stretch target.

The AGN Victoria and MGN Renewable Gas Network Adaptation Plans are provided in 410-PL-AM-0010 - Renewable Gas Network Adaptation Plan – AGN Victoria and MG-SP-0016 - Renewable Gas Network Adaptation Plan – MGN Victoria.

Appendix A Gas properties

Characteristic	Natural Gas	Hydrogen
Density relative to air (d)	0.555	0.0696
Heating Value (MJ/Sm^3)	38.4	12.1
Flame Speed (m/s)	0.4	3.2
Flammability range	5% - 15%	4% - 74%
Explosive limits	5.7% - 14%	18.3% - 59%
Ignition Energy (MJ)	0.26	0.02
Flame Temperature	1875	2045
Mixture most easily ignited in air	9%	29%
Wobbe Index (MV/√d)	50	46
Visibility – Gas	Colourless	Colourless
Visibility – Flame	Blue	Translucent / Orange
Smell	Odourless	Odourless

Appendix B Supporting documents

GPA. (2021). 210620-REP-002 – Component Compatibility

Glossary and definitions

The table below is a comprehensive list of asset management terminology and acronyms commonly used at AGIG. Note not all these terms may appear in this document.

Term	Meaning
AA	Access arrangement
ACIF	Australian Construction Industry Forum
AEMO	Australian Energy Market Operator: Responsible for the administration and operation of the wholesale national electricity market in accordance with the National Electricity Code.
AER	Australian Energy Regulator: Responsible for the economic regulation of energy networks.
AGIG	Australian Gas Infrastructure Group
AGN	Australian Gas Networks
AHC	Australian Hydrogen Centre
ALARP	As low as reasonably practicable
AMP	Asset Management Plan
AMS	Asset Management Strategy
ARS	Ancillary Reference Service - Standard services offered by Multinet Gas at fixed charges
AS/NZ	Australian/New Zealand Standards
AUS EX	Australian Program for the Certification of Equipment for Explosive Atmospheres
Available testing	Testing of a non-faulty meter returned from the field less than 10 years old from purchase or repair tested in a meter testing facility before being re-installed in the field to complete its in-service life.
Capex	Capital expenditure
Cathodic protection	Prevention of corrosion by application of direct electric current to the surface of a metal.
Cathodic protection unit (CPU)	A device providing cathodic protection current, powered from an external energy source. Such energy sources include mains power, solar, etc. Cathodic protection units require permits and registration in accord with the Electricity Safety (Cathodic Protection) Regulations 2009
Cathodically protected (Distribution) area	An electrically isolated area within the distribution system, of size convenient and practicable for assessing and maintaining the effectiveness of corrosion protection
CI	Cast iron

Term	Meaning
Coating quality survey	A survey conducted by traversing directly above a coated main along its length using equipment and techniques designed to identify any defects in the coating. Methods in common use include "Pearson" and Direct Current Voltage Gradient (DCVG)
Coil (Electromagnetic coil) Survey	An electromagnetic tracing technique for locating points of failed insulation or electrical contact to other metallic structures.
Corrosion	The deterioration of metal caused by its electrochemical reaction with its environment
CP	Cathodic Protection
CPU	Cathodic Protection Units
CTM	Custody Transfer Meter. A large capacity meter installed at every injection point from the DTS to MGN's network.
Current AA period	Jan 2018 to June 2023
Data logger	Interval metering equipment that counts pulses from the mechanical meter index and records gas volume.
Direct Current Voltage Gradient (DCVG) Survey	A type of coating quality assessment survey conducted by traversing above the pipeline using equipment that applies pulsating DC electrical signals to identify coating defects.
Drainage Bond	An electrical connection via cable from a point in the distribution system to tram or train substations to prevent adverse effects from stray currents. These installations include equipment to control the direction and magnitude of current flowing.
DTS	Declared Transmission System
EDMI	Meter manufacture and supplier to MGN
EFT	Economic Feasibility Test
Electrical isolation	The electrical separation of structures to be protected from other structures and/or electrical systems. This is achieved by the installation of insulating flanges, monolithic insulating joints and insulating couplings
ESV	Energy Safe Victoria. A government body responsible for the safety and technical regulation of energy networks in Victoria.
FIRB	Foreign Investment Review Board
FLE	Field Life Extension. Alternative name for Sample Testing Program/in-service compliance testing of diaphragm meters <30m3/hr.
Flow corrector	Interval metering equipment which can correct gas flow to energy with the help of live pressure and temperature values.

Term	Meaning
FY	Financial year
Galvanic (Sacrificial) anode	A block of metal which provides protection by preferentially sacrificing itself instead of allowing the steel to corrode.
Gas meter	Mechanical device (usually) used to measure the volumetric flow rate of gas that passes the device. The volume of energy that passes through the meter is dependent on both gas pressure and temperature when the volume is measured
GDSC	Gas Distribution System Code
GFC	Gas and Fuel Corporation
GFCV	The Gas and Fuel Corporation of Victoria
GIS	Geographic Information System
GJ	Giga Joule, 1 Giga Joule = 1,000,000 Joules
GPC	Group Pressure Control
GPRS	General Packet Radio Services
GSC	Gas Safety Case
GSM	Global System for Mobile Communications
HDPE	High density polyethylene
HP	High pressure (140 to 515 kPa)
HP2	High pressure 2 (600 to 1050 kPa)
I&C	Industrial and Commercial
IEC EX	International Electrotechnical Commission System for certification to Standards Relating to Equipment for Use in Explosive Atmospheres
ILI	In line inspection
Interval meter site	Installation which is large enough (with respect to gas usage) to warrant the use of hourly metering data via a data logger of flow corrector.
IO	Input output
kPa	KiloPascals
L&G	Landis & Gyr – Meter manufacture and supplier to MGN
Large meter	Meter with capacity greater than >10 sm^3/hr.
LP	Low pressure (1.4 to 7 kPa)

Term	Meaning
MAOP	Maximum allowable operating pressure
Meter family	A group of the same meter brand and type installed in the same calendar year.
Meter type	Refers to the technique employed to measure gas flow i.e. Rotary, Turbine, Diaphragm.
MG	Multinet Gas
MGN	Multinet Gas Networks
MHQ	Maximum Hourly Quantity
MIBB	Market Information Bulletin Board
MP	Medium pressure (35 to 210 kPa)
MPE	Maximum Permissible Error
NATA	National Association of Testing Authorities
NCC	Network Control Centre
Next AA period	July 2028 to June 2028
NGL	National Gas Law
NGR	National Gas Rules
NMI	National Measurement Institute
Non-reference Service	Non-standard services offered by MGN provided at fair and reasonable cost.
OEM	Original Equipment Manufacturer
OMSA	Operational and Management Services Agreement between MGN and Service Provider
Opex	Operating expenditure
PE	Polyethylene
PIG	Pipeline Inspection Gauge
PMC	Periodic meter change
PVC	Poly vinyl chloride
RAB	Regulated asset base
RF	Radio Frequency
RTU	Remote Telemetry/Terminal Unit

Term	Meaning
Sample testing program	Annual program whereby sample meters from each meter family population are tested as per AS/NZS 4944 to determine their on-going or extension to their in-service life in the field
SAP	An Enterprise Resource Planning tool which used recording asset data and maintenance management.
SCADA	Supervisory control and data acquisition
SEPP	State Environment Protection Policy
Shared assets	Shared network assets – for example, Mains in the street
SIOS	SCADA Input Output Schematic
sm^3/hr	Standard cubic meters per hour (either Gas or Air).
Small meter	Meter with capacity less than 10 sm^3/hr. Normally used for Residential (domestic) purposes.
SMS	Safety Management Study
Spot potential reading	A measurement of pipe-to-soil potential taken at a given location at a particular point in time. Such readings can be used to assess protection status where potentials do not vary with time. However, in circumstances where potentials fluctuate due to telluric or stray current influences, recordings of potential over a period of time (usually 24 hours) are necessary
Stray current electrolysis	Is the effect of stray currents on buried metallic structures
Tariff D	Tariff D applies to customers using greater than 10,000 GJ a year or more than 10 GJ MHQ.
Tariff L	Tariff L is open to customers who consume more than 1,000 GJ per annum or less than 10,000 GJ per annum and have an MHQ demand of less than 10 GJ per hour.
Tariff V	Applies to customers using less than 10,000 GJ a year and less than 10 GJ MHQ.
Test point	A conveniently located termination point for electrical cables connecting to a buried pipeline. This allows measurement of the pipeline potential, and is the principal method of assessing the effectiveness of corrosion protection. Test points are also required for coating quality surveys and electromagnetic coil surveys to investigate losses in protection
Thyristor drainage unit (TDU)	Electrical equipment, usually installed in tram or train substations, to provide sufficient negative voltage for drainage bonds to be effective. The output voltage of TDUs is normally controlled so as to vary in accord with substation load
TJ	Terajoule
TP	Transmission Pressure (Pressure Range: Above 1050 kPa)
UAFG	Unaccounted for gas
UPS	Unprotected steel

Term	Meaning
Variable conductance drainage bond (VCDB)	Electronic equipment used to control the current in a drainage bond. The output current of VCDBs is normally controlled to maintain a set level of protection on a structure
Victorian Electrolysis Committee (VEC)	The Victorian Electrolysis Committee comprises membership of all parties affected by or causing stray current electrolysis. It is responsible for co-ordination of testing and adjustment required to maintain effective protection from stray currents and to control interference between adjacent cathodic protection systems. It is also responsible for administration of cathodic protection permits and regulations under the authority of Energy Safe Victoria.