DAMPIER TO BUNBURY NATURAL GAS PIPELINE

Public Knowledge Sharing Report

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1. Acknowledgement of Grant Funding

Department of **Jobs, Tourism, Science and Innovation**
GOVERNMENT OF WESTERN AUSTRALIA

The feasibility study (Study) received grant funding from the Western Australian Government's Renewable Hydrogen Fund, which is administered by the Department of Jobs, Tourism, Science and Innovation (the Department).

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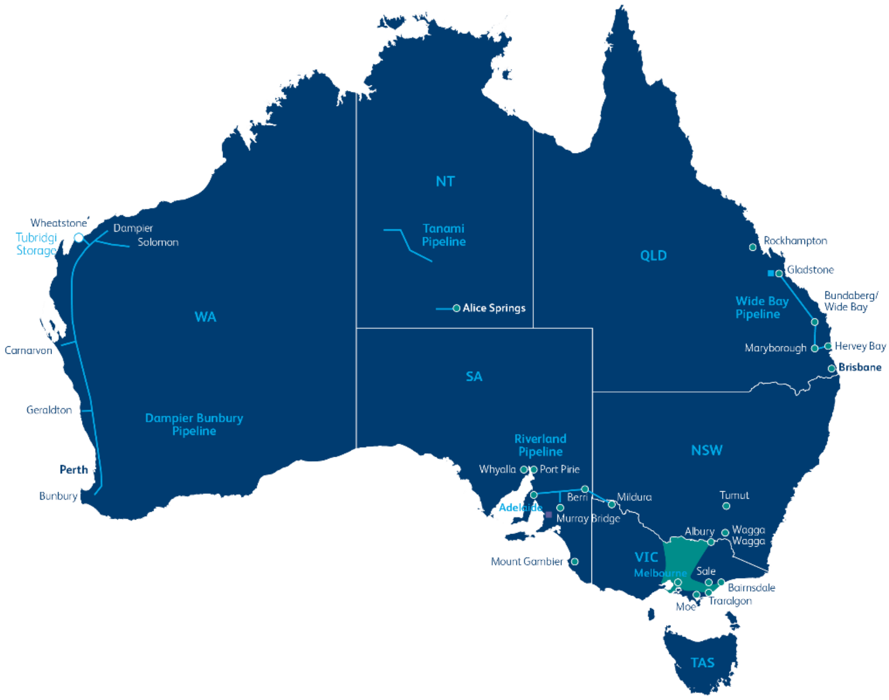
We own and operate infrastructure that delivers gas to more than two million Australian homes and businesses. We also deliver gas that supports the Australian economy – for power generators, mines and manufactures.

Our portfolio of companies delivers for customers across Australia. The combined distribution, transmission and storage assets make AGIG one of the largest gas infrastructure businesses in Australia.

While our gas distribution networks date back almost 150 years, today AGIG includes the operations of the Dampier Bunbury Pipeline (DBNGP), Australian Gas Networks (AGN) and Multinet Gas Networks (MGN). Together, we deliver for customers across the gas supply chain – with over 34,000km of distribution networks, more than 5,500km of transmission pipelines and 60 petajoules of storage capacity.

We employ approximately 315 employees across Australia with more than 1,600 contractors working on our business.

We are taking active steps towards sustainable gas delivery today, and tomorrow. In 2021 we delivered Australia's largest renewable gas production facility: Hydrogen Park South Australia.



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2 SUMMARY

AGIG as the owner and operator of the DBNGP has completed the following study:

Preparing the DBNGP as critical support infrastructure for WA's emerging hydrogen industry feasibility study

This study was part funded by the Western Australian Hydrogen Renewables Fund provided by the Minister for State Development, Jobs and Trade in association with the Department for Jobs, Tourism, Science and Innovation (JTSI).

This desktop report was designed to identify a practical pathway to enable hydrogen to be blended into the DBNGP. The scope of this study included the following:

- analysis of hydrogen's compatibility with metallic materials utilised within the DBNGP;
- analysis of hydrogen's compatibility with non-metallic materials utilised within the DBNGP;
- a gap analysis between Australia's primary standard for design and operation of natural gas transmission pipelines 'AS2885' and an international standard for hydrogen piping and pipelines 'ASME B31.12';
- a risk analysis on the methods used for determining the maximum hydrogen concentration in existing DBNGP assets;
- desktop analysis of gas measurement equipment and technology selection;
- engagement with gas users with existing connections to the DBNGP; and
- an assessment of the regulatory and approval processes that may prevent the inclusion of hydrogen into the DBNGP.
- Engagement and feedback received from original equipment manufacturers

As a result of this study, there is now a clear pathway for declaring a pipeline section as suitable for use with hydrogen/natural gas blends. This pathway includes material testing, additional operational constraints and a realignment of regulatory and commercial frameworks.

This transition will require the coordinated support of gas users, regulatory bodies, and gas policy makers.

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3 BACKGROUND

The DBNGP (Dampier to Bunbury Natural Gas Pipeline) is Western Australia's most significant gas transmission asset and provides natural gas to regional and metropolitan WA.

The DBNGP extends from Woodside's Karratha Gas Plant, in Western Australia's North West to Bunbury, 170km south of Perth. The DBNGP passes through the Pilbara, Mid-West, Wheat Belt, Peel, and metropolitan areas.

The DBNGP is made up of 42 unique pipeline sections that include the main trunkline (mainline north) from Dampier to Kwinana and an array of laterals, loop lines, extensions, and interconnects.

The DBNGP network of pipelines transport the majority of Western Australia's domestic gas. This natural gas supports the energy requirements for mining power generation, ore processing, industrial feedstock, power generation, commercial, and residential gas users.

The DBNGP has a large range of customers who are at the forefront of our decision making process when considering the blending of hydrogen into the pipeline. Furthermore, the safety of the general public and our employees is considered a pre-requisite for a change of this magnitude.

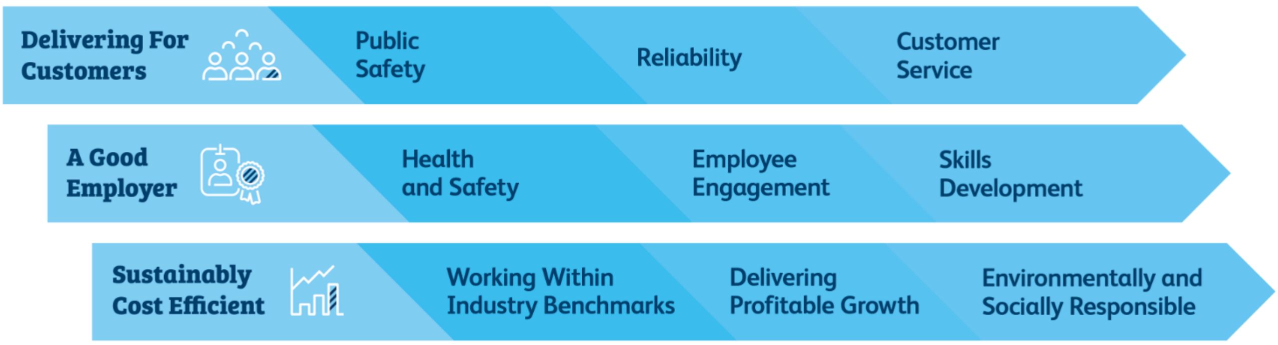
The blending of hydrogen into the DBNGP allows for significant early decarbonisation of existing energy networks. This is in line with AGIG's alignment to Gas Vision 2050 (https://www.agig.com.au/gas-vision-2050) and an internal commitment to meet net zero operations by 2040.

Australian Gas Infrastructure Group (AGIG) sees the introduction of a small concentration of hydrogen into the DBNGP as a way of offering our customers an affordable, and environmentally responsible service whilst maintaining a reliable energy supply.

This study has been undertaken in alignment with our company vision to be the leading gas infrastructure business in Australia.

Our Vision

To be the leading gas infrastructure business in Australia, aiming for top quartile performance on all our targets.



4 STUDY SUMMARY

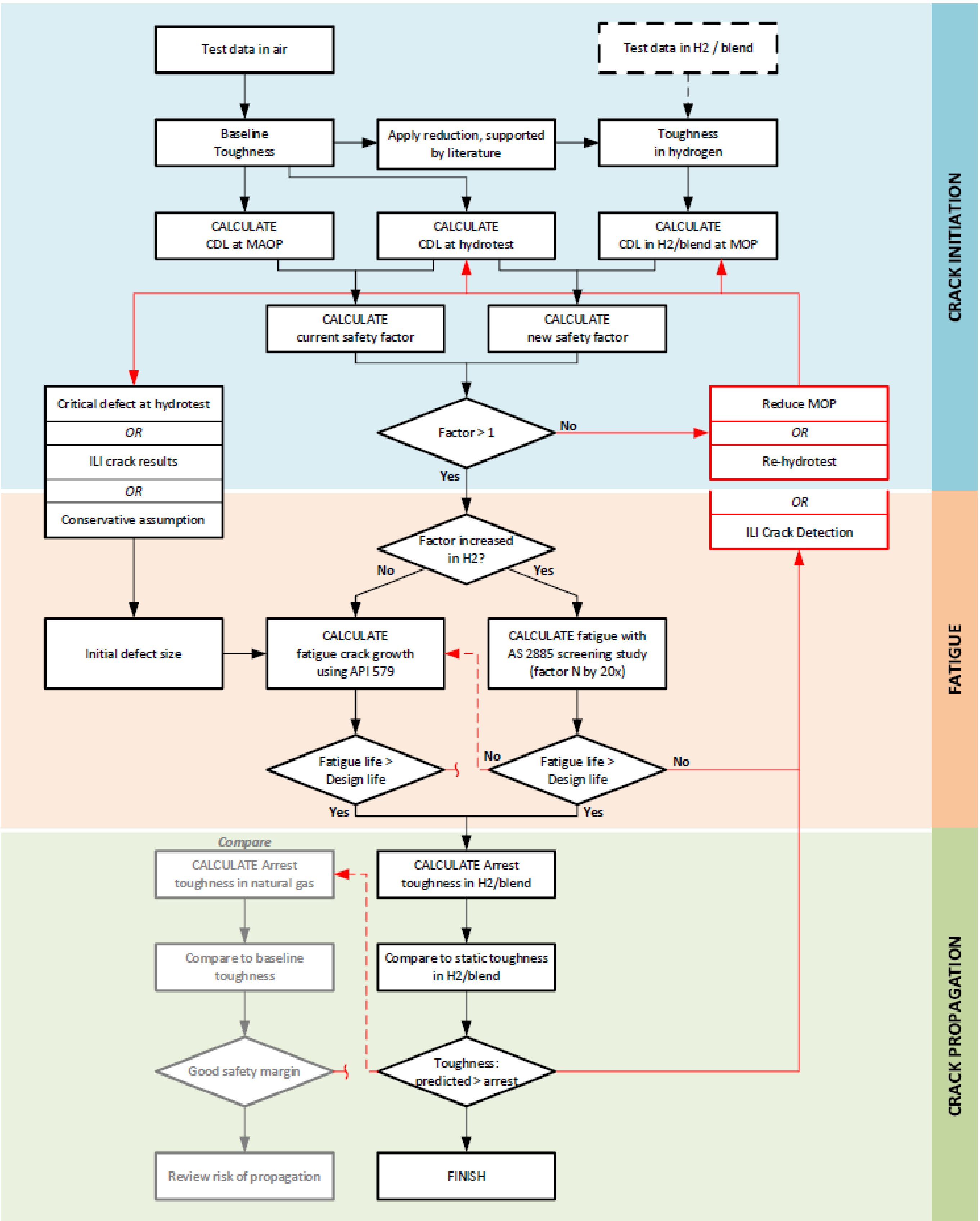
4.1 Analysis of hydrogen's compatibility with metallic materials utilised within the DBNGP

All pipeline sections within the DBNGP were assessed for their suitability for hydrogen transportation. In total, 42 independent pipeline sections were reviewed. This desktop analysis was completed using material and process data from the DBNGP.

AGIG engaged GPA engineering to complete a literature review of published data detailing the impact of low hydrogen concentration blends in steel pipelines. The purpose of this review was to identify the concentration of hydrogen that may be considered low enough that the effect of the hydrogen on pipeline safety and performance would be negligible.

The outcome of this report is a method that can be applied to approve hydrogen concentrations up to a partial pressure of 500kPag. This partial pressure represents a 9% v/v blend for many of the DBNGP sections.

This method considers factors such as pipeline design factor and fatigue life. The following flow-chart incorporating the requirements of relevant Australian and international standards was developed that can be used as a roadmap for approving a pipeline for use with hydrogen.


Test data in air
Test data in H2 / blend
Baseline Toughness
Apply reduction, supported by literature
Toughness in hydrogen
CALCULATE CDL at MAOP
CALCULATE CDL at hydrotest
CALCULATE CDL in H2/blend at MOP
CALCULATE current safety factor
CALCULATE new safety factor
Critical defect at hydrotest
OR
ILI crack results
OR
Conservative assumption
Factor > 1
No
Yes
Reduce MOP
OR
Re-hydrotest
OR
ILI Crack Detection
Factor increased in H2?
No
Yes
Initial defect size
CALCULATE fatigue crack growth using API 579
CALCULATE fatigue with AS 2885 screening study (factor N by 20x)
Fatigue life > Design life
No
Fatigue life > Design life
No
Yes
Yes
Compare
CALCULATE Arrest toughness in natural gas
CALCULATE Arrest toughness in H2/blend
Compare to baseline toughness
Compare to static toughness in H2/blend
Good safety margin
Toughness: predicted > arrest
Review risk of propagation
FINISH
CRACK INITIATION
FATIGUE
CRACK PROPAGATION

Combining the literature review study and DBNGP data resulted in the categorisation of the DBNGP into three segments:

1) **Mainline North:** This is the main trunk line that extends from the Burrup peninsula to Kwinana. This segment operates at or close to its MAOP (Maximum Allowable Operating Pressure) of 8,480kPag and utilises a large quantity of compression equipment.
2) **Mainline South:** This is the main trunkline that extends from Kwinana to Bunbury. This segment operates at pressures significantly lower than its MAOP of 6,900kPag and rarely utilises compression equipment.
3) **DBNGP Laterals:** Laterals are located along the entire length of the DBNGP and extend into mining hubs and industrial hubs. Almost all laterals operate at pressures significantly lower than their MAOP and typically operate at a stable pressure without compression equipment.

The DBNGP Mainline South and DBNGP Laterals were found to be excellent candidates for hydrogen blending and AGIG will progress with further studies to facilitate this transition.

The utilisation and operating envelope of the DBNGP Mainline North results in this section of pipeline being identified for potential future hydrogen transition. This means that DBNGP Mainline North may become a suitable candidate for hydrogen blending if utilisation declines allowing a reduction in the operating pressure. An operating pressure of 5500kPag (a reduction of 35%) would likely allow for the inclusion of blended hydrogen into the mainline north.

Pipeline sections identified as good candidates for Hydrogen Blending

4.2 Analysis of hydrogen's compatibility with non-metallic materials utilised within the DBNGP

AGIG engaged IO Consulting to complete a desktop literature review of published data concerning the impact to non-metallic materials in gas transmission pipeline systems when exposed to hydrogen and natural gas blends. The objectives for the review were:

- to identify the amount of available data concerning the performance of non-metallic materials when exposed to blending of hydrogen with natural gas; and
- to identify any aspects or components within the system that based on the available data may not be compatible with blending hydrogen with natural gas

The literature review found that there was not a comprehensive body of work that specifically addressed the situation applicable to the DBNGP, where there are non-metallic materials exposed to existing natural gas saturated environments (typical of natural gas transmission pipeline systems over long periods of time) and then exposed to hydrogen and natural gas blends. On review of the limited relevant literature applicable to gas transmission pipeline systems, it was found that most of the reports referenced the same set of data/test results.

The review did identify literature and test data that related to exposure of non-metallic materials to high pressure and high concentrations of hydrogen, reflecting the conditions that would be found in hydrogen re-fuelling or hydrogen production facilities.

The available data and literature was consolidated and applied to the non-metallic materials found within the DBNGP system and reviewed by a polymeric materials subject matter expert from The Welding Institute (TWI). TWI is a global, industry member owned research and technology organisation covering manufacturing, fabrication and whole-of-life integrity management technologies.

The conclusion from the TWI report is that no specific non-metallic materials concerns exist, however the following two areas were identified for further assessment:

1) the need to undertake a more detailed review of the specific "proprietary" non-metallic materials installed in the DBNGP system, to ensure the presence of any fillers and/or residual catalysts that could react with hydrogen were present; and
2) the gap in the literature reviewed pertaining to the fatigue performance of polymers when exposed to hydrogen blended with natural gas.

AGIG will progress with further studies into these areas of assessment to facilitate the transition pathway.

4.3 A gap analysis between Australia's primary standard for design and operation of natural gas transmission pipelines 'AS 2885' and an international standard for hydrogen piping and pipelines 'ASME B31.12'

A clause by clause comparison between the Australian Standard AS2885 'Pipelines—Gas and liquid petroleum' and ASME B31.12 'Hydrogen Piping and Pipelines' was completed.

A retrospective application of ASME B31.12 to existing natural gas transmission pipelines may enable a pipeline section to be declared suitable for use with 100% hydrogen. Whilst this declaration is subject to regulatory approvals, it is foreseeable that this method of analysis could deliver hydrogen ready pipelines in the next one to two years.

The review found that there are three significant differences between ASME B31.12 and AS2885:

1) Reduced design factors and upper limits on pressure, especially where ASME B31.12 penalises high-strength carbon steels
2) ASME B31.12 has a lower fatigue tolerance and associated reduction in weld defect limits.
3) ASME B31.12 contains a more stringent specification for weld preheat and hardness.

It is likely that no AGIG pipeline can satisfy 100% of the ASME B31.12 pipeline standard clauses. However, several Laterals and pipeline sections were identified as excellent candidates for retrospective application of ASME B31.12. AGIG will pursue this methodology where transition of these pipelines aligns with the strategic objectives and requirements of AGIG's customers, industry and end users.

4.4 Risk analysis of the methods used for determining the maximum hydrogen concentration in existing DBNGP assets

The DBNGP is designed and operated to be compliant with AS2885. In order to demonstrate compliance with this standard, a suite of risk analyses must be completed. These risk analyses must be refreshed when a change of this magnitude is being considered.

An AS2885 Safety Management Study and a fracture control plan were completed on a single pipeline section. Importantly, these risk studies were completed by the same team that undertook the metallic material compatibility assessment. This ensured that the risk studies were completed by individuals with a high level of understanding of the properties of low concentration hydrogen blends in natural gas transmission pipelines.

The fracture control plan was an input to the Safety Management Study. The Study found that all threats identified in accordance with Section 3.2 of AS/NZS2885.6 were satisfactory, subject to the following recommendations:

1) Additional controls are to be introduced, primarily relating to control of pressure cycling and associated integrity management to mitigate the risk of hydrogen-assisted fatigue crack growth.
2) The maximum operating pressure of the pipeline should be reduced for providing additional protection against some threats and to increase the level of compliance with ASME B31.12.
3) AGIG should conduct an in-line inspection of the pipeline with crack detection tools prior to introducing hydrogen.

4.5 Desktop analysis of gas measurement equipment and technology selection

A desktop analysis of gas measurement equipment and technology was undertaken. This analysis found that:

- all flow meters are suitable for use with hydrogen blends of 10% or less;
- temperature transmitters are suitable for use with hydrogen blends of 10% or less; and
- pressure transmitters are suitable for use with hydrogen blends of 10% or less when the pressure is less than 6,900kPag. Isolation diaphragms must be coated with hydrogen resistant materials at pressures greater than 6,900kPag.

Existing gas analysis equipment is not suitable for use with hydrogen. This equipment will remain in service and a parallel additional analyser will be installed for quantifying the hydrogen in the gas.

Flow computers, SCADA (Supervisory, Control and Data Acquisition) systems and gas accounting systems will require reconfiguration to enable the blending of hydrogen.

4.6 Gas user technology analysis - Identify what technology is being used by our gas users and how this is impacted by hydrogen

AGIG engaged IO Consulting to facilitate a customer engagement process aimed at understanding the usage and technologies employed by each gas user and the expected impacts and concerns under a scenario of blending 10% hydrogen by volume with natural gas in the DBNGP.

A 'request for data letter' was sent to each customer requesting a breakdown of their current gas usage. Furthermore, this letter requested feedback on whether the gas user has assessed the scenario of using 10% hydrogen blended into their existing natural gas supply.

Responses to the letter show that whilst users/customers are aware of hydrogen blending being on the wider industry agenda, the individual customers have not undertaken specific studies to assess the impact this could have on their current equipment, facilities and operations.

A significant proportion of industry customers/users utilise gas turbines for power generation. Based on current industry knowledge, it is generally accepted that most gas turbines can operate with up to 10% hydrogen and natural gas blended fuel gas without requiring major modifications. This does however need to be confirmed with each respective OEM (Original Equipment Manufacturer). This process has triggered a number of customers to engage with their relevant OEMs on this topic.

This engagement has also identified a large diversity of hydrogen compatibility amongst similar technologies. As an example, one gas turbine OEM has indicated that if the fuel gas specification exceeds 5% hydrogen then the current DLE (Dry Low Emissions) combustion chamber on the turbine may need to be changed to an SAC (Single Annular Combustor).

Another significant proportion of gas usage is attributed to thermal heat generation within the gas user's industrial processes. Equipment such as boilers and furnaces are frequently deployed for this purpose. In these scenarios, and based on preliminary assessments, the feedback has raised concerns over the burner management system for these applications. Also, where there is waste heat recovery units or HRSG (Heat Recovery Steam Generation), the additional moisture in the flue gas as a result of combustion with the hydrogen may cause some additional losses in efficiency. Again, this engagement is triggering conversations with OEMs and technical specialists.

The other major gas usage is in processes ranging from calcination to drying/dehydration kilns/furnaces. In these cases, customers have raised concerns over the impact that burning a hydrogen blended natural gas may have on the quality of their product, due its different combustion characteristics (such as flame temperature and moisture produced).

Responses to the letter consistently called for industry collaboration in order to facilitate the efficient and uniform adoption of the transition to hydrogen blending and resultant types of future operating scenarios. The general consensus was that an industry wide forum made up of industrial natural gas users, specifically looking at the adoption of blending hydrogen with natural gas, would be an ideal forum to disseminate learnings and information, and to ensure there was a common roadmap and timeline for any plan to adopt blended hydrogen.

4.7 AGIG regulatory position

AGIG anticipates a significant amount of regulatory change will be required to facilitate the blending of hydrogen into the DBNGP. The precise extent of regulatory change required will depend on the quantity of hydrogen blended.

AGIG have identified five key pieces of legislation that will (at a minimum) require some legislative amendment, each of these is addressed at a high level below.

4.7.1 Legislation requiring amendment

Legislation	Purpose of required amendment
National Gas Law; National Gas Access (WA) Act 2009; National Gas Access (WA) (Local Provisions) Regulations 2009; National Gas Rules	The current definition of gas does not contemplate the addition of hydrogen. Greater definitional specificity in the National Gas Law, and associated WA law and National Gas Rules, is required for future fuels like hydrogen to be transmitted through regulated gas transmission pipelines.
Work Health and Safety (Petroleum and Geothermal Energy Operations) Regulations (WA) (**WHS (PAGEO)R**) (*yet to be passed)	The proposed WHS (PAGEO) R will replace the existing set of eight regulations that apply with a single set of regulations. The extent to which this will change existing safety case requirements or conditions of an existing petroleum licence, including its safety case, should be considered to assess the impact of hydrogen blending.
Gas Supply (Gas Quality Specifications) Act 2009	Include capability of entities other than gas producers to be able to supply gas comprising a specified maximum percentage of hydrogen into a gas transmission pipeline (refer suggested limits as discussed for Gas Supply (Gas Quality Specifications) Regulations 2010 below).
Gas Supply (Gas Quality Specifications) Regulations 2010	**Phase 1**: Push for natural gas / hydrogen blends up until 15% or the Wobbe index low limit (whichever occurs first) to be included within the existing scope with minor changes **Phase 2**: Include additional schedule for alternative gas specifications for natural gas blends with H2 greater than 15% or a wobbe index lower than the low limit
Petroleum Pipelines Act 1969 (WA)	Amend definition of petroleum to include hydrogen.

AGIG considers that other legislation (in addition to the key legislation identified above) may require amendment, or be interpreted differently as a consequence of amendments to the legislation set out in the table above. We refer to the CRC Future Fuels Regulatory Mapping for Future Fuels Final Report and accompanying legislation database which identified that environmental regulations and planning and development regulations and policy may be affected. AGIG considers that blending of hydrogen may require changes to the relevant Australian Standards. At a minimum, we expect that AS 2885 – Transmission Pipelines will require amendment as it is the key standard applicable to the DBNGP and is referred to in the pipeline safety case. AGIG expects that industry collaboration will be required given the wide ranging impacts that changes to Australian Standards may pose to end-users, customers with various connections and appliances and industrial users, given changes to Australian Standards are likely to be treated distinctly from changes in law.

AGIG considers that blending of hydrogen may also cause significant contractual uncertainty and it is difficult to assess the impact such changes could have on particular shippers. For example, AGIG's standard shipper contract contains various relevant clauses that allow for changes in gas specification where there is a change in law. However, there may be circumstances where particular end-users or gas retailers are required to waive rights should the change in gas specification occur, and it is not possible to determine with certainty whether this will occur.

AGIG expects that regulators in WA will be required to facilitate industry and public consultation on proposed regulatory changes and departments such as DJTSI and DMIRS will be required to work collaboratively on proposed regulatory reform.

End of Document