31 October 2022

Submission: National Electric Vehicle Strategy Consultation

The Australian Pipelines and Gas Association (APGA) represents the owners, operators, designers, constructors and service providers of Australia's pipeline infrastructure, connecting natural and renewable gas production to demand centres in cities and other locations across Australia. Offering a wide range of services to gas users, retailers and producers, APGA members ensure the safe and reliable delivery of 28 per cent of the end-use energy consumed in Australia and are at the forefront of Australia's renewable gas industry, helping achieve net-zero as quickly and affordably as possible.

APGA welcomes the opportunity to contribute to the Department of Climate Change, Energy, the Environment and Water (**DCCEEW**) consultation on the National Electric Vehicle Strategy (the **Strategy**). APGA supports the inclusion of hydrogen electric vehicles within the Strategy and highlights the role which hydrogen pipelines can play in securing least cost refuelling infrastructure for Australia's network of major highways.

APGA supports a net zero emission future for Australia by 2050[1]. Renewable gases represent a real, technically viable approach to lowest-cost energy decarbonisation in Australia. As set out in Gas Vision 2050[2], APGA sees renewable gases such as hydrogen and biomethane playing a critical role in decarbonising gas use for both wholesale and retail customers. APGA is the largest industry contributor to the Future Fuels CRC[3], which has over 80 research projects dedicated to leveraging the value of Australia's gas infrastructure to deliver decarbonised energy to homes, businesses, and industry across the nation.

Hydrogen electric vehicles are anticipated to play a valuable role in the long-distance haulage and rural private vehicle sectors. Compared to battery electric vehicles, hydrogen electric vehicles are lighter in weight, have greater range and faster refuelling capabilities, and can address some of the uptake challenges for electric vehicles in these settings. Key to the rise of Australia's hydrogen electric vehicle fleet will be the availability of reliable, cost-effective hydrogen refuelling, and APGA appreciates the focus which the Strategy applies to this challenge.

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[1] APGA Climate Statement
https://www.apga.org.au/apga-climate-statement

[2] Gas Vision 2050, APGA
https://www.apga.org.au/sites/default/files/uploaded-content/website-content/gasinnovation_04.pdf

[3] Future Fuels CRC Website
https://www.futurefuelscrc.com/

APGA is confident that hydrogen refuelling networks supplied by hydrogen pipelines can provide a high availability, cost effective supply chain model for hydrogen refuelling. This opportunity is predicated on the following four concepts:

- Predominant hydrogen refuelling supply chain models;
- Advantages of the hydrogen pipeline transport and storage model;
- Case Studies focused on Australia's two busiest highways; and
- No-regrets hydrogen infrastructure.

APGA hopes that the National Electric Vehicle Strategy will consider hydrogen pipeline supply chain economics within its hydrogen refuelling station strategy on this basis.

Predominant hydrogen refuelling supply chain models

Development of hydrogen refuelling stations will need to consider five macro energy supply chain aspects: renewable energy production, renewable energy transport, and renewable energy storage, renewable energy conversion, and refuelling. While there is little variability in renewable energy production, conversion (electrolysis) and refuelling options, there are a number of different approaches to renewable energy transport and storage (aka supply chain) which are likely to determine the relative reliability and cost effectiveness of a hydrogen refuelling network.

Hydrogen refuelling supply chain models considered in the Australian context to date have relied upon one of three models:

- **Model 1:** Transmission of renewable electricity via the NEM to an electrolyser and hydrogen storage located at a refuelling station;
- **Model 2:** All-in-one renewable electricity generation, electrolysis, storage and refuelling in locations without energy transmission; or
- **Model 3:** A hub and spoke model utilising lower cost bulk hydrogen production at a centralised location, which is stored at refuelling stations once delivered by hydrogen tube trailer.

Each of these models solves one of three problems which occur in the other two models:

- Model 1 avoids the land requirements and variability of generation of Model 2 and the high cost of tube trailer energy transmission of Model 3[4];
- Model 2 avoids the energy transmission costs of either Model 1 or Model 2;
- Model 3 avoids the higher cost per unit hydrogen of small electrolyser deployment capacity in Model 1 & Model 2 and the land requirements of Model 3[5].

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[4] Reddi et al 2018, Techno-economic analysis of conventional and advanced high-pressure tube trailer configurations for compressed hydrogen gas transportation and refueling, *International Journal of Hydrogen Energy* 43 (9) pp. 4428-4438 https://doi.org/10.1016/j.ijhydene.2018.01.049

[5] United Kingdom Department for Business, Energy and Industrial Strategy, 2021, *Hydrogen Production Costs 2021*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011506/Hydrogen_Production_Costs_2021.pdf

These differences make each supply chain model approximately competitive with the other two. APGA wishes to flag a fourth opportunity which improves upon all challenges experienced by each of the predominant three models – refuelling stations supplied by hydrogen pipeline.

Advantages of the hydrogen pipeline supply chain model for hydrogen refuelling

The hydrogen pipeline supply chain model for hydrogen refuelling is uniquely suited to hydrogen refuelling along Australia's network of major highways, each of which require in the order of 10s of terajoules (1000s of kilograms of hydrogen) per day worth of energy to facilitate long distance haulage. Hydrogen pipelines are able to provide low-cost hydrogen transport and storage within one piece of infrastructure, allowing for lower cost refuelling stations and lower cost centralised hydrogen production.

The cost of hydrogen production or refuelling apparatus is out of APGA's scope of expertise. As such, APGA is unable to provide the full energy supply chain costs for any of the above refuelling supply chain models. APGA is however well placed to comment on the advantages of using pipeline infrastructure to transport hydrogen and provides the following in the hope that this information may be added to hydrogen production and refuelling cost information by those who understand costing of these supply chain components.

The cost for transporting hydrogen with and without hydrogen storage across a distance of 500km can be seen in Table 1 below. APGA anticipates that these transport and storage costs are highly competitive in comparison to electricity transmission via the NEM, hydrogen transport via tube trailer, hydrogen storage in on-site hydrogen storage vessels, or any form of electricity storage.

Table 1: Hydrogen pipeline transport and storage costs across a distance of 500km[6]

Refuelling Energy Requirement	Pipeline Transport Cost	Pipeline Storage Cost (4hrs storage)	Pipeline Storage Cost (12hrs storage)	Pipeline Storage Cost (24hrs storage)
10TJ/day or 1,420kgH2/day	$4.64 per GJ	$6.47 per GJ	$2.16 per GJ	$1.08 per GJ
	$0.66 per kgH2	$0.92 per kgH2	$0.31 per kgH2	$0.15 per kgH2
50TJ/day or 7,100kgH2/day	$2.16 per GJ	$0.00 per GJ	$1.50 per GJ	$1.54 per GJ
	$0.31 per kgH2	$0.00 per kgH2	$0.21 per kgH2	$0.22 per kgH2

Note: The referenced material also includes data for distances as short as 25km and transmission volumes as high as 500TJ per day (71t hydrogen per day), all of which demonstrate similar cost competitiveness relative to electricity transmission infrastructure.

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[6] Pipelines vs Powerlines: a summary
https://www.apga.org.au/sites/default/files/uploaded-content/field_f_content_file/pipelines_vs_powerlines_-_a_summary.pdf
Pipelines vs Powerlines: A Technoeconomic Analysis in the Australian Context
https://www.apga.org.au/sites/default/files/uploaded-content/field_f_content_file/pipelines_vs_powerlines_-_a_technoeconomic_analysis_in_the_australian_context.pdf
Pipelines vs Powerlines: Appendix 3A and 3B Results Summary
https://www.apga.org.au/sites/default/files/uploaded-content/field_f_content_file/appendix_3a_and_3b_results_summary.xlsx

Using a hydrogen pipeline to deliver hydrogen to refuelling stations would also minimise refuelling station cost, with refuelling stations only required to compress hydrogen out of the pipeline rather than produce or store hydrogen locally. Additionally, supplying refuelling stations via hydrogen pipelines would enable motorists to access least hydrogen supply as hydrogen would be able to occur in wholesale quantities within in any renewable energy zone (REZ) which the pipeline traversed. APGA anticipates that each of these aspects combined can provide a more reliable and cost-effective hydrogen refuelling supply chain compared to the other models identified above.

Case Studies: The Hume and Pacific Highways

The Hume and Pacific Highways are two of Australia's busiest trucking routes. Including the Pacific Motorway, these major roads span the 1700km between Melbourne and Brisbane and facilitate between 1,000 and 3,000 ,truck movements each day. Combining data available via the National Freight Data Hub and Victorian ARCGIS accessible databases, with a hydrogen truck fuel use estimate of 20kg hydrogen per 100km, provides the following hydrogen demand potential for average daily trucking movements on the Hume and Pacific Highways.

Table 2: Potential hydrogen demand estimate for all truck movements by highway

Highway	**Hydrogen Demand (kgH2/day)**	**Hydrogen Demand (GJ/day)**
Hume Highway (Sydney – Melbourne)	6,590	46,408
Pacific Highway (including the Pacific Motorway) (Sydney – Brisbane)	4,362	30,717

Both highways also benefit from a REZ being located approximately at the halfway point. The Wagga Wagga REZ is located halfway between Sydney and Melbourne on the Hume Highway, and the New England REZ is located around 150km west of Raleigh, the halfway mark of the Pacific Highway. Each REZ provides the opportunity for low-cost wholesale production of renewable hydrogen.

This information combined with data from the *Pipelines vs Powerlines* study can be used to undertake high level macroeconomic analysis of hydrogen transport and storage pipelines to supply refuelling stations along each highway.

Case Study 1: The Hume Highway

The Hume Highway has the opportunity to be supplied by two connected 500km hydrogen transport and storage pipelines. These pipelines can be supplied with hydrogen from the Wagga Wagga REZ, as seen in Figure 1. The maximum trucking demand for each hydrogen pipeline would be in the order of 23.2TJ/day, or 3,300kgH2/day. Note that the Hume Highway is already subject to the Hume Hydrogen Highway joint initiative between the Victorian and New South Wales Governments which seeks to support the Hume Highway becoming one of Australia's first hydrogen transport ready freight corridors.

Pipeline development could take one of three approaches:

- Conservative initial deployment of a pipeline designed for 10TJ/day (1,420kgH2/day) throughput capacity;
- Anticipate future hydrogen demand along the highway as well as in Melbourne and Sydney, targeting 50TJ/day (7,100kgH2/day) throughput capacity; or
- Somewhere in between.

Pipeline development could also incorporate hydrogen storage for 4hrs, 12hrs or 24hrs of throughput capacity.

The hydrogen transport and storage costs for development of such a hydrogen refuelling supply chain would be as seen in Table 3. In comparison to tube trailer costs of $1.30 to $3.15 per kilogram of hydrogen delivered, the pipeline energy transport model becomes cost effective from a transport perspective at 9 to 22 per cent of total trucking volume for the 20TJ per day (2,840TJkgH2 per day) configuration. This percentage will reduce once a comparison between on site hydrogen storage costs and pipeline storage costs are considered, however APGA was unable to find relevant on site hydrogen storage cost data to undertake this comparison.

Table 3: Hydrogen transport and storage costs for Hume Highway hydrogen pipeline refuelling supply chain

<table>
<tr><th>Pipeline Design Case</th><th>Total Refuelling Capacity</th><th>Transport Cost</th><th>24hr Storage</th><th>Max VRE Serviceable</th></tr>
<tr><td rowspan="2">2x 10TJ/day
1,420kgH2/day</td><td rowspan="2">20TJ/day
2,840kgH2/day
43% Truck Demand</td><td>$4.64 per GJ</td><td>$1.08 per GJ</td><td rowspan="2">5.6GWh per day</td></tr>
<tr><td>$0.66 per kgH2</td><td>$0.15 per kgH2</td></tr>
<tr><td rowspan="2">2x 50TJ/day
7,100kgH2/day</td><td rowspan="2">100TJ/day
14,200kgH2/day
215% Truck Demand</td><td>$2.16 per GJ</td><td>$1.54 per GJ</td><td rowspan="2">27.8GWh per day</td></tr>
<tr><td>$0.31 per kgH2</td><td>$0.22 per kgH2</td></tr>
</table>

*Max VRE Serviceable: Maximum REZ Variable Renewable Electricity generation quantity to align with full hydrogen pipeline throughput capacity based on 50% electrolyser efficiency.

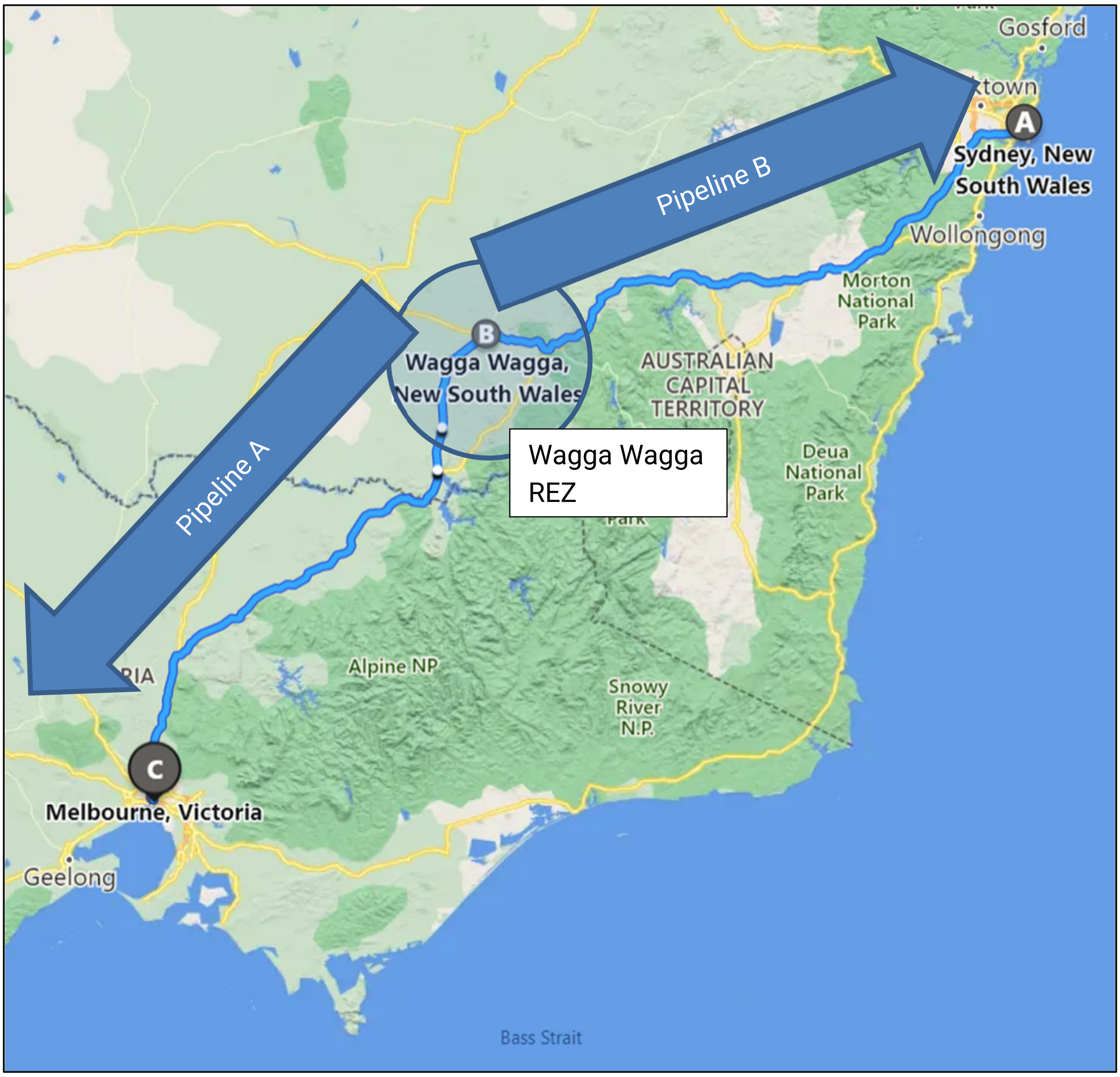

Figure1: Hume Highway hydrogen pipeline refuelling supply chain

Case Study 2: The Pacific Highway

The Hume Highway has the opportunity to be supplied by two connected 500km hydrogen transport and storage pipelines supplied with hydrogen from the New England REZ via a feeder pipeline as seen in Figure 1. The maximum trucking demand for each hydrogen pipeline would be in the order of 15.4TJ/day or 2,200kgH2/day.

Pipeline development could take one of three approaches:

- Start conservatively with the deployment of a pipeline designed for 10TJ/day (1,420kgH2/day) throughput capacity;
- Anticipate future hydrogen demand along the highway as well as in Melbourne and Sydney, targeting 50TJ/day (7,100kgH2/day) throughput capacity; or
- Somewhere in between.

Pipeline development could also incorporate hydrogen storage for 4hrs, 12hrs or 24hrs of throughput capacity.

The hydrogen transport and storage costs for development of such a hydrogen refuelling supply chain would be as seen in Table 4. In comparison to tube trailer costs of $1.30 to $3.15 per kilogram of hydrogen delivered, the pipeline energy transport model becomes cost effective from a transport perspective at 18 to 44 per cent of total trucking volume for the 20TJ per day (2,840TJkgH2 per day) configuration. This percentage will reduce once a comparison between on-site hydrogen storage costs and pipeline storage costs are considered, however APGA was unable to find relevant on-site hydrogen storage cost data to undertake this comparison.

Table 4: Hydrogen transport and storage costs for Hume Highway hydrogen pipeline refuelling supply chain

<table>
<tr><th>Pipeline Design Case</th><th>Total Refuelling Capacity</th><th>Transport Cost</th><th>24hr Storage</th><th>Max VRE Serviceable</th></tr>
<tr><td rowspan="2">2x 10TJ/day
1,420kgH2/day</td><td rowspan="2">20TJ/day
2,840kgH2/day
65% Tot. Truck Dem.</td><td>$6.23 per GJ</td><td>$1.08 per GJ</td><td rowspan="2">5.6GWh per day</td></tr>
<tr><td>$0.88 per kgH2</td><td>$0.15 per kgH2</td></tr>
<tr><td rowspan="2">2x 50TJ/day
7,100kgH2/day</td><td rowspan="2">100TJ/day
14,200kgH2/day
325%Tot.TruckDem.</td><td>$3.20 per GJ</td><td>$1.54 per GJ</td><td rowspan="2">27.8GWh per day</td></tr>
<tr><td>$0.45 per kgH2</td><td>$0.22 per kgH2</td></tr>
</table>

*Max VRE Serviceable: Maximum REZ Variable Renewable Electricity generation quantity to align with full hydrogen pipeline throughput capacity based on 50% electrolyser efficiency.

The additional cost for the Pacific Highway system over the Hume Highway system is due to the need to transport hydrogen to Pipeline A and Pipeline B from the New England REZ. This incurs additional pipeline costs of around $0.48 - $2.18 per GJ ($0.07 - $0.31 per kgH2). Due to pressure loss across the feeder pipeline, compression may be required at the intersection near Raleigh at an additional cost of $0.50 per GJ ($0.07 per kgH2).

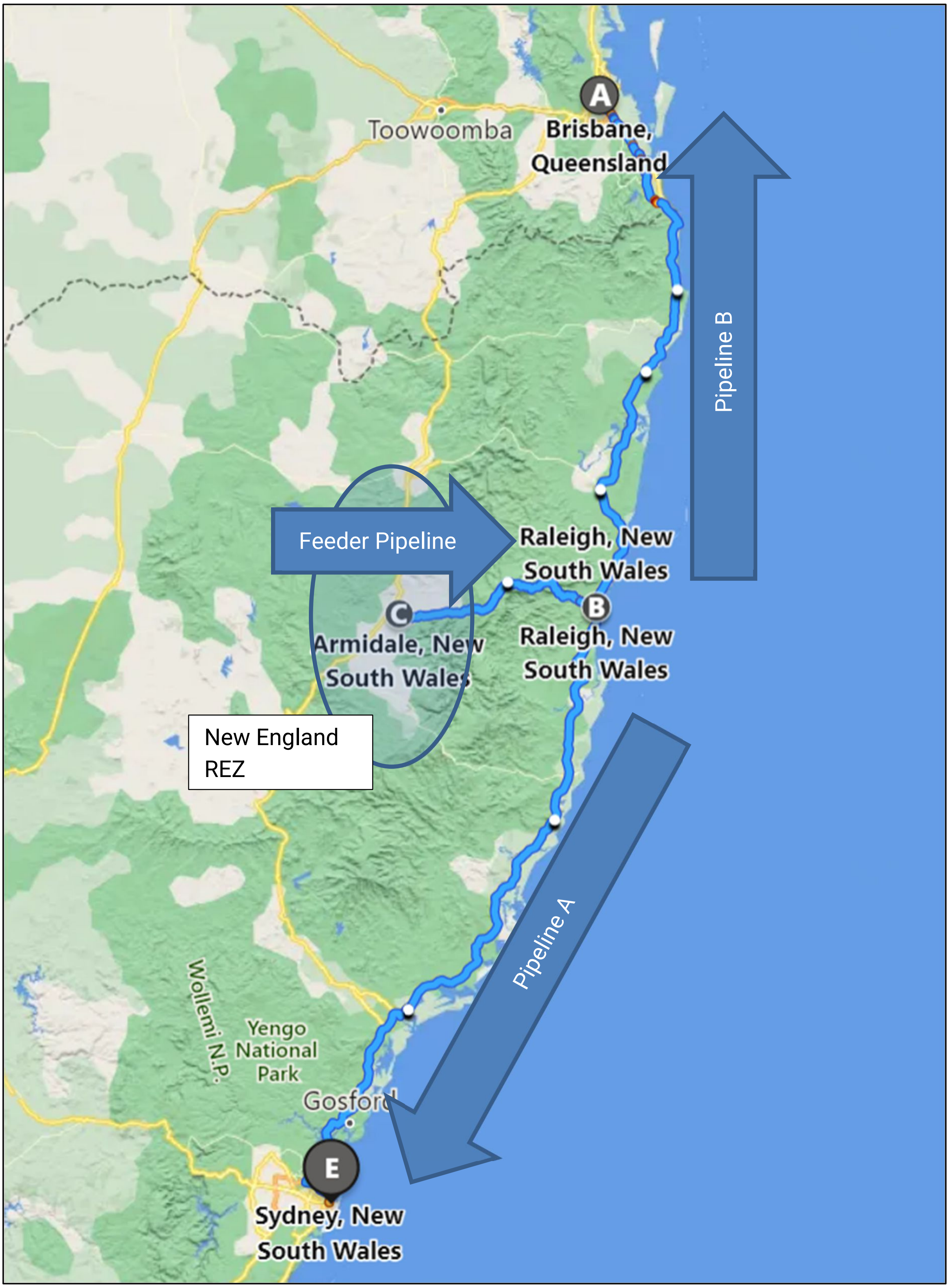

Figure 2: Pacific Highway hydrogen pipeline refuelling supply chain

No regrets hydrogen infrastructure

Hydrogen infrastructure proposed within the above case studies represents no regrets hydrogen infrastructure. Hydrogen uptake is broadly recognised as a necessary component of achieving net zero emission in Australia. If a hydrogen electric vehicle fleet does not arise despite the development of this infrastructure it can be used just as effectively to deliver the hydrogen to three of Australia's major manufacturing and industrial hubs at equal or greater volumes than proposed within this submission.

With this potential for alternative capital city demand cases in mind, the 50TJ per Day (7,100kgH2 per day) alternative become particularly interesting in each scenario. Due to the reduced per unit cost of larger hydrogen infrastructure compared to smaller hydrogen infrastructure, it makes greater economic sense to design these pipelines to be able to supply manufacturing and industry in the three capitals as well as supplying hydrogen to refuelling stations along these major highways.

This infrastructure is also future proofed in the event that either refuelling or capital city hydrogen demand increases. If a pipeline is designed with storage capacity, this storage capacity can be repurposed for throughput capacity at a later date. For example, a 500km pipeline capable of flowing 10TJ per day (1,420kgH2 per day) which is capable of storing full throughput capacity for 24hrs would need to be 32-inch in diameter. A pipeline of this size is capable of flowing well over 500TJ per day (71,000kgH2 per day) when leaving no room for storage capacity, or 50TJ per day (7,100kgH2 per day) while maintaining 4 hours' worth of storage capacity.

If hydrogen vehicle use falters, or hydrogen vehicle and/or industrial use sores, the hydrogen pipelines proposed within these case studies are able to either be repurposed in and of themselves or up-purposed through duplication as either source of demand increases.

Supporting hub and spoke model for remote rural communities

As an amendment to hydrogen refuelling supply chain Model 3, hydrogen pipelines can support an extended hub and spoke, or corridor and spoke, model for supplying hydrogen for more remote communities. Tube trailer filling stations can be strategically located along the length of each pipeline proposed in the above case studies, greatly increasing the coverage of hydrogen refuelling without a requirement for more medium scale hydrogen production facilities. This would support greater democratisation of hydrogen access across Australian society while also avoiding the cost of smaller wholesale hydrogen production models.

Building on existing state policy

The case studies proposed within this submission also align with the joint Hume Hydrogen Highway initiative by the Victorian and New South Wales Governments. This initiative recognises the value of hydrogen trucking along the Hume Highway by facilitating the first four hydrogen refuelling stations. These are just the beginning, being sufficient to refuel the proposed fleet of 25 long haul trucks. Once this proof of concept initiative successfully demonstrates the commercial viability of hydrogen trucking along the Hume, both state governments will need to consider the most cost effective approach to allow mass expansion of hydrogen refuelling infrastructure along this route – a challenge which Case Study 1 of this submission may be able to support.

Through the consideration of these concepts and more, it is hoped that broader context around the opportunity of hydrogen pipelines, combined with the department's greater knowledge of hydrogen production and refuelling facility costs, could help support the least cost, most reliable hydrogen refuelling network for Australia. To this end, APGA invites the Department and anyone who reads its submission to contact APGA for further information.

To discuss any of the above feedback further, please contact me on +61 422 057 856 or jmccollum@apga.org.au.

Yours Sincerely,

JORDAN MCCOLLUM
National Policy Manager
Australian Pipelines and Gas Association