Pipelines vs Powerlines: a summary

Least-cost energy transport and storage in a net zero future

Pipelines vs Powerlines: Reviewing Energy Transmission

256 case map

Transmission distances
25km → 500km

Throughput capacities
10 TJ/day → 500 TJ/day

Storage scenarios
4hr, 12hr, 24hr

Hydrogen Pipeline | Natural Gas Pipeline

Vs.

HVAC Powerline | HVDC Powerline

A techno economic comparison of Australian energy transmission infrastructure, covering natural gas pipelines, gaseous hydrogen pipelines, HVAC and HVDC power lines.

Reliability of supply

39,000 km of high pressure gas pipelines

0.03 events per 1000km a year loss of supply

43,000 km of high voltage power lines

0.42 events per 1000km a year loss of supply

Energy Storage

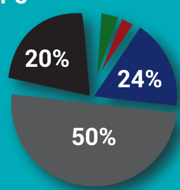
Electricity
0.017 TWh

Gas Pipelines
2.3 TWh

Underground Gas Storage
64.3 TWh

End Use Energy

Electricity 858 PJ
- renewables 194 PJ
- coal & oil 485 PJ
- gas 179 PJ



Coal 102 PJ

Gas 1,012 PJ

Renewables 170PJ

Refined Products 2,125 PJ

Energy transport through **pipelines** is up to **5 times more cost effective** than **energy transport** via **high voltage powerlines**

4hr energy storage often comes at **no additional cost** when using typical pipeline construction principles

Energy storage in **pipeline linepack** can be **100s** of times more **cost effective** than **utility scale battery** and **pumped hydro energy storage**

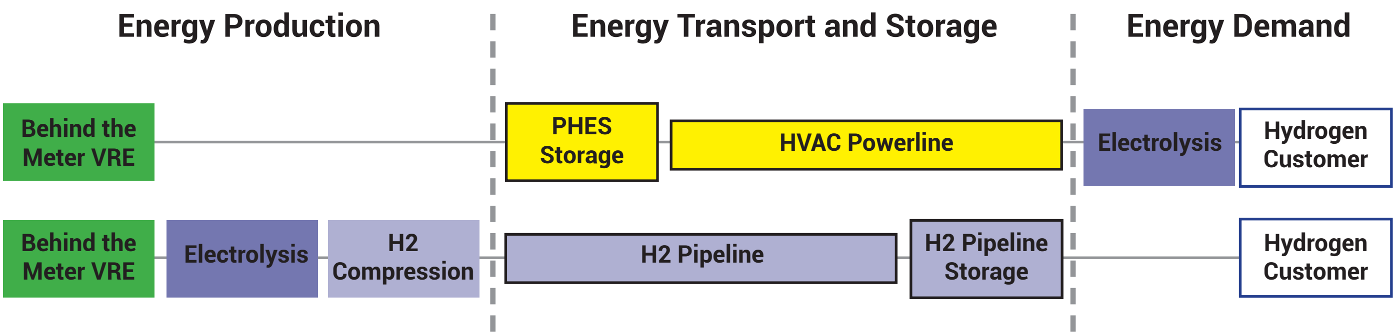
All cases modelled in this report show that energy transport and storage via hydrogen or natural gas pipeline is more cost effective than electricity transport and storage in all scenarios.

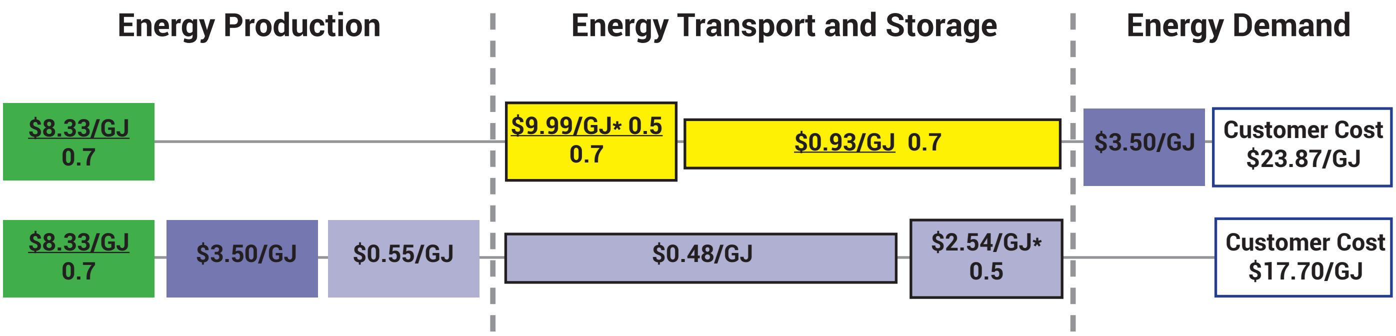
Introduction

The cost and reliability of energy transport and storage infrastructure is a crucial issue in the energy industry, with implications for energy access, affordability, the environment and public safety. APGA commissioned GPA Engineering to produce a report to analyse the cost of energy transport and storage across a range of different gas and electricity infrastructure options. This summary document uses data from the full report (available here [link]) to provide the information in a way that can inform all readers.

As part of the GPA analysis says, to date, pipelines have been a lower cost form of energy transport compared to powerlines. The track record of pipeline infrastructure shows that it is more reliable and more environmentally friendly than electricity infrastructure.

As the Australian transition to net zero-energy ramps up, a sound understanding of the whole energy system, including energy transport and storage infrastructure, will ensure the least cost decarbonisation outcomes for the nation. Recognising this, APGA sought technoeconomic analysis looking at the historical and anticipated costs of pipelines and powerlines over a range of energy capacities, distances and quantities of energy storage. Cases span distances of 25km to 500km, energy throughput of 10 terajoules a day (TJ/day) to 500TJ/day, (equal to 116 megawatts (MW) a day to 5800MW/day or 70 tonnes of hydrogen a day to 3520t H2/day). Also studied were energy storage quantities of 4 hours, 12hr and 24hr of transport throughput capacity.





Through this analysis, GPA Engineering has identified that energy transport via hydrogen pipeline costs up to four times less than via powerlines when comparing like for like distance and capacity scenarios. Further, energy storage in hydrogen pipelines costs up to 37 times less than battery energy storage systems (BESS) and up to 10 times less than pumped hydro energy storage (PHES). These figures are even greater for methane pipelines, making energy transport and storage or renewable sources of methane more cost effective than renewable sources of hydrogen.

From the perspective of a hydrogen customer, these cost improvements aren't the only advantage of hydrogen pipelines. Hydrogen production can be collocated with the energy producer enabling access to lower cost energy to power electrolysis. This also allows for the energy consumed by electrolysis to be consumed before energy transport and storage, additionally reducing the cost of hydrogen to customers by around 30 per cent.

APGA acknowledges that different renewable gases are produced at different pressures and, as such, require different compression solutions. Different compression solutions will increase hydrogen production costs by different amounts relative to the production process in much the same way as experienced in natural gas production today. Neither this nor the cost of HVAC inverter connection were covered in broad detail in this study, instead they were considered within production scope as is the standard when costing energy production today.

Despite this, the gas infrastructure solution delivers hydrogen at 20 percent lower cost than the electricity infrastructure solution. This helps to demonstrate that customer outcomes are highly dependent on a range of costs and efficiencies spanning production, energy transport and storage, as well as end use. The opportunity for pipeline infrastructure and, in particular, hydrogen infrastructure, to provide a lower cost energy transport solution could play a significant role in Australia's least-cost net-zero energy future.

In publishing this information, APGA and GPA Engineering do not seek to make a case for all energy to be transported via hydrogen pipelines in a net-zero future. Instead, we seek to open the conversation about least-cost energy infrastructure to create a future in which a blended energy infrastructure system of pipelines and powerlines can deliver least-cost net-zero energy for Australian households, businesses and export industries.

For more information, please contact apga@apga.org.au

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Australia's complementary energy infrastructure systems

Australia has two parallel and complementary energy infrastructure systems supplying energy to households and businesses. The National Energy Market (NEM), Western Energy Market (WEM) and other electricity infrastructure deliver a combined 20 per cent of all end-use energy consumed in Australia. Australia's gas infrastructure builds on this, delivering 28 per cent of all end-use energy consumed in Australia, including fuel for the gas power generators (GPG) supplying 21 per cent of electricity demand.[1]

These systems work hand in hand. Today's gas system supplies cheap, reliable energy to households and businesses across the nation, it absorbs the seasonal variations in energy demand which reach far above total NEM capacity and it supports the NEM in periods of short-term high demand through providing GPG fuel supply.

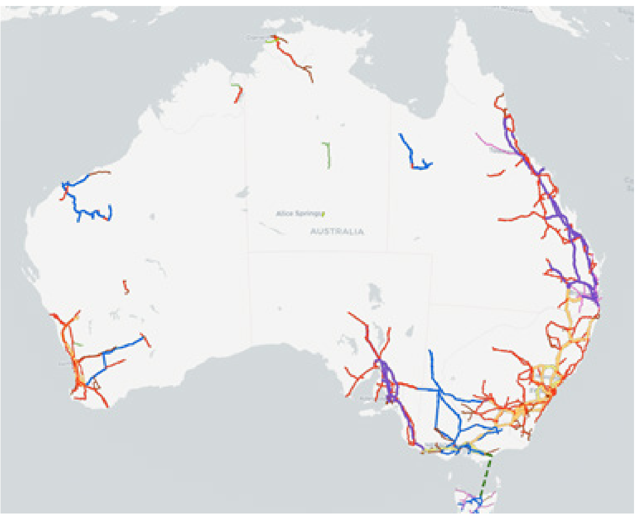
A range of applications are suited to using energy in both electrical and gaseous forms, and there are some applications more suited to one or the other. Both energy systems are on a decarbonisation journey. While the electricity system is more advanced in its journey at this point, Gas Vision 2050 sets out the ways that Australia's gas system is set to achieve net-zero emissions by 2050.

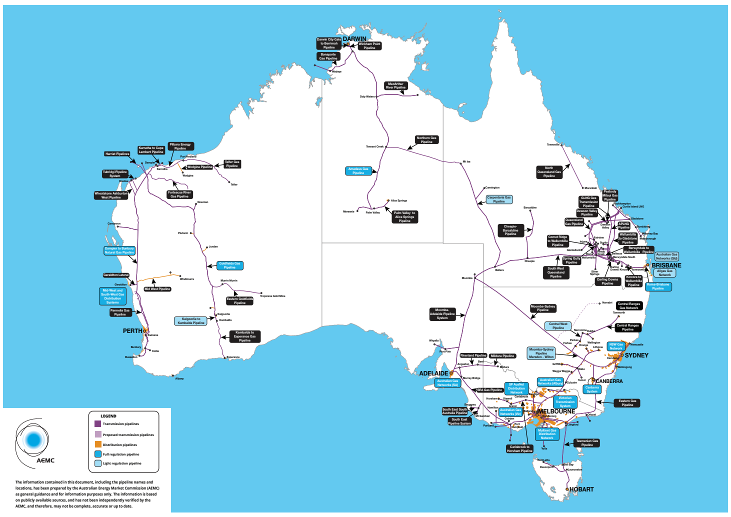
The role and advantages of gas infrastructure are critical to Gas Vision 2050 being achieved. Gas infrastructure is resilient, experiencing far fewer outages than electricity infrastructure. Gas infrastructure is buried underground, making it less likely to be impacted by weather.

Today, in Australia, more energy is transported and stored through gas infrastructure than through electricity infrastructure. This is predominantly due to gas infrastructure's ability to deliver energy transportation and storage services flexibly, reliably and at a comparatively lower infrastructure cost.

How does gas infrastructure do this?

Pipelines can move and store energy due to the physical characteristics of gas molecules. These physical characteristics are the same for all gases, while gas is often used interchangeably with natural gas, the term applies to all gases. Gases have no fixed shape and no fixed volume, they expand freely to fill whatever container they are in. They are highly compressible, meaning you can increase pressure and fit more in – this makes them easy to move and store. Gases are stable, making them easy to store over long periods of time. Pipelines, being long tubes, can hold large quantities of gas. By pressurising the pipeline, very large quantities of gas can be moved and stored relatively simply.





Lower historical cost of energy transport via pipeline than via powerline

Pipelines have long been used as a low-cost way to get energy to customers, with infrastructure extending directly to homes and businesses. Power stations are positioned relative to electricity infrastructure and demand to minimise electricity transmission costs, with pipelines used to transport fuel to GPG within the NEM.

Directly comparable examples of pipelines and powerlines are rare. However, one example is the comparison between regulated electricity and gas transmission and distribution infrastructure in the Victorian energy market.

Table E2: Costs and deliveries of Victoria's energy infrastructure (2019)

Transmission and Distribution Infrastructure	Regulated Asset Base ($m)	Actual Annual Revenues ($m)	Actual Energy Delivered (GWh)	Max Demand Capacity (MW)
Electricity	17,329	2,825	41,480	8,864
Gas	5,631	774	64,722	23,250

In comparing the regulated asset bases (RABs) of these parallel energy infrastructure pathways, we find the following:

- Victorian gas infrastructure delivers a third more energy than Victorian electricity infrastructure.
- Victorian gas infrastructure can support peak demand 60 per cent higher than Victorian electricity infrastructure.
- Victorian gas infrastructure generates only 27 per cent of the revenue from customers compared to Victorian electricity infrastructure.
- Victorian electricity infrastructure RAB value (the value of infrastructure) is three times more than Victorian gas infrastructure RAB.

While not a perfect like-for-like comparison, this example provides an indicative example of cost effectiveness of electricity and gas infrastructure with similar levels of energy demand within a specific region. In this example, gas infrastructure is clearly a more cost-effective form of energy transport than electricity infrastructure.

Pipelines are more reliable and have less local impact than powerlines

Reliability

Energy reliability is a key challenge faced by decarbonising energy markets, with variable renewable electricity (VRE) generation introducing new sources of instability in decarbonising electricity networks. While NEM reliability impacts of VRE have been minimal to date, Australian gas pipeline infrastructure has been more reliable than Australian electricity transmission infrastructure over the past decade.

The reliability of energy infrastructure can be considered in terms of loss of supply incidents per 1000km per annum. Over the past decade, gas pipelines demonstrate superior reliability when compared to high voltage transmission lines on this basis.

Table 3: Loss of Supply Comparison between Gas Transmission Pipelines and Electricity Transmission Powerlines

Infrastructure	Period of Review	Approximate length	Loss of Supply Events	Event per annum (average)	Events per annum per 1000 km installed
Gas pipelines	9 years (2009-2018)	39,000	10 (9 leaks, 1 rupture)	1.1	0.03
HV Powerlines	9 years (2010-2019)	43,000	164	18.2	0.42

Impact on local habitats, landholders, and communities

Pipelines also have lower impacts on the local habitats, landholders, and communities where they are installed and operate. The bushfire risk, land use impacts and visual pollution brought by above-ground powerlines is much greater than that of pipelines.

This is because the Australian gas pipeline industry buries its pipelines, increasing safety and visual amenity, and allowing a greater level of land use opportunities for landholders and communities with pipeline right of ways passing through their land. As a result, pipeline infrastructure is afforded greater social licence than powerlines, generally going unnoticed once installed.

The impact of above-ground powerlines can be greatly lessened by installing below-ground powerlines. Unfortunately, below-ground powerlines cost more than overhead powerlines, having been estimated at around five to six times the cost of above-ground powerlines in a recent study[2]. Due to this, only costs of above-ground powerlines have been considered in the GPA Engineering report in order to avoid unnecessary additional cost influencing the results of the report.

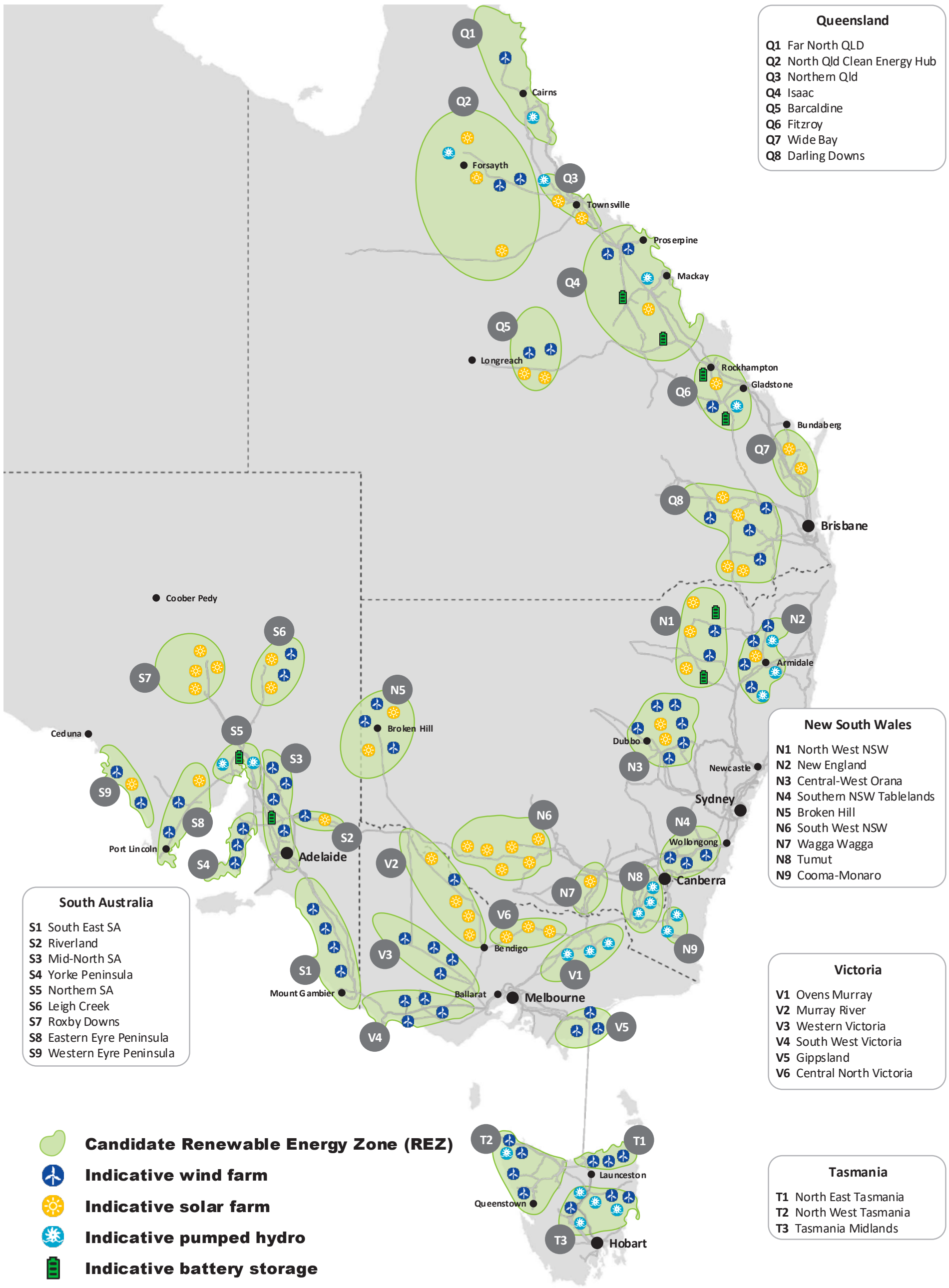
Powerline ROW, Pipeline ROW, Farmer's paddock with pipeline running through

Australian ramp up towards a net zero-energy system

The Australian energy industry has seen in increasingly rapid pace of change towards a net zero energy future. This has been recognised by the Australian Energy Market Operator through use of its Step Change scenario as the central scenario in the 2022 Integrated System Plan and responded to by the federal government through the creation of Renewable Energy Zones.

AEMO anticipates an accelerated decarbonisation of Australia through its Hydrogen Superpower scenario, forecasting that a full-scale hydrogen industry can deliver a net-zero NEM a decade earlier and with greater economic growth than options without hydrogen.

These hydrogen plans, alongside many others, consider energy transport and storage only via electricity. This is despite the fact there are many characteristics of gas infrastructure that suggest its the wide-spread use can deliver a lower cost renewable gas industry and pathway to decarbonisation.



REZs from 2022 Draft ISP (© statement) [3]

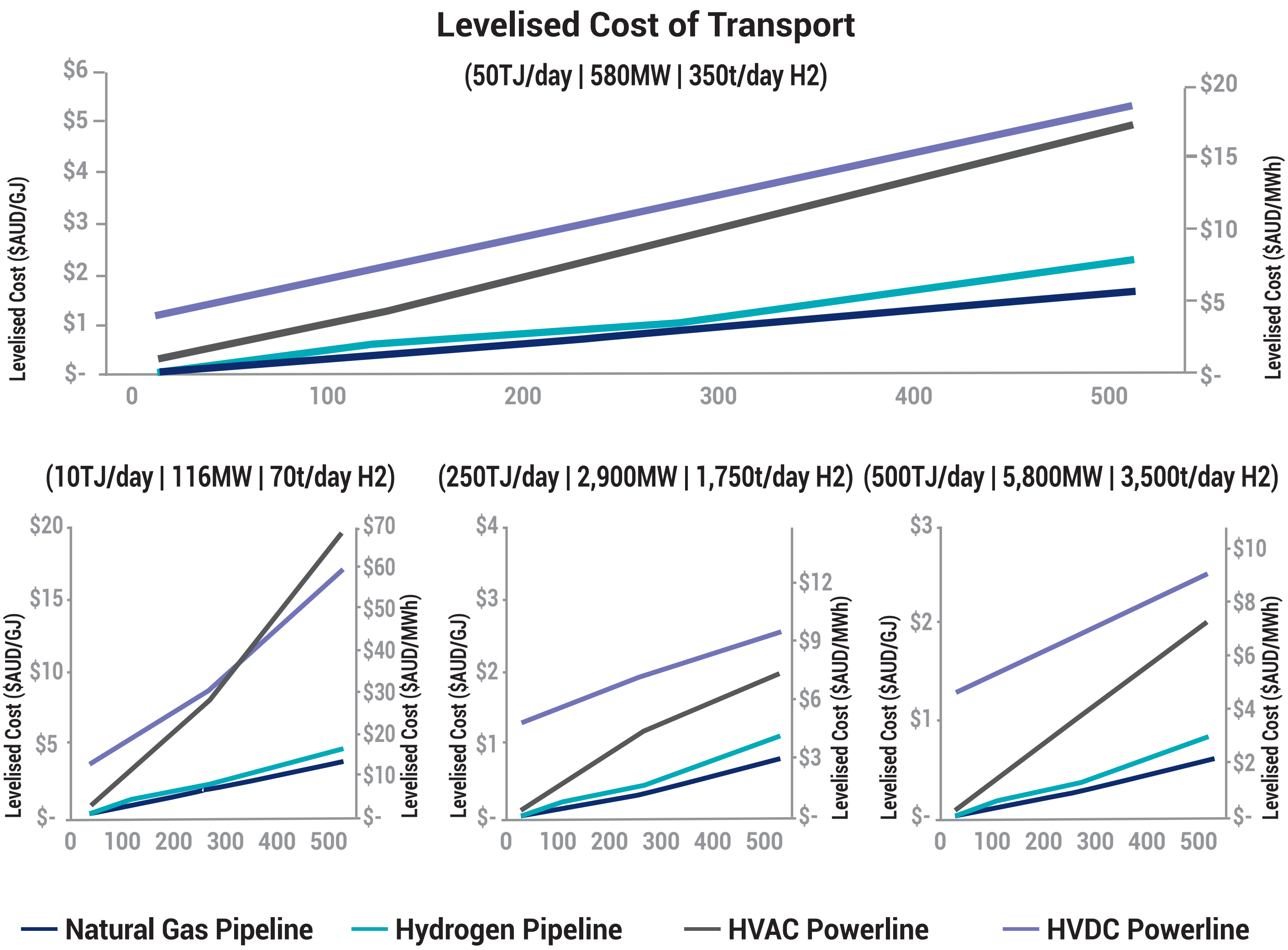
To consider this possibility, APGA commissioned GPA Engineering to deliver Pipelines vs Powerlines – A Technoeconomic Analysis in the Australian Context. In this report, technoeconomic comparisons of the cost of energy transport and storage were undertaken for natural gas (NG) pipelines, hydrogen (H2) pipelines, high voltage alternating current (HVAC) powerlines, and high voltage direct current (HVDC) powerlines. A summary of the results of this report can be seen in the following pages.

Energy transport via new pipelines costs less than energy transport via new powerlines

Technoeconomic analysis by GPA Engineering shows that while hydrogen pipelines do cost more than natural gas pipelines, both cost significantly less than energy transported via either HVAC or HVDC powerlines.

This result was seen across all modelled scenarios. The study considered energy transport distances between 25km and 500km, and energy transport capacity as low at 10 terajoules per day to 500TJ/day, 9equal to 116 megawatts (MW) a day to 5800MW/day or 70 tonnes of hydrogen a day to 3520t H2/day).

APGA had expected to observe a crossover point over the distance and capacity ranges where powerlines may have become more cost-effective than powerlines, but this was not observed. This implies that if a crossover does exist, it is outside of the range of distances and capacities modelled. HVDC costs appear to converge with H2 PPL costs with increased distance in the 10TJ/day scenarios, but the trajectory from cases analysed puts the crossover well above the maximum end of study range.



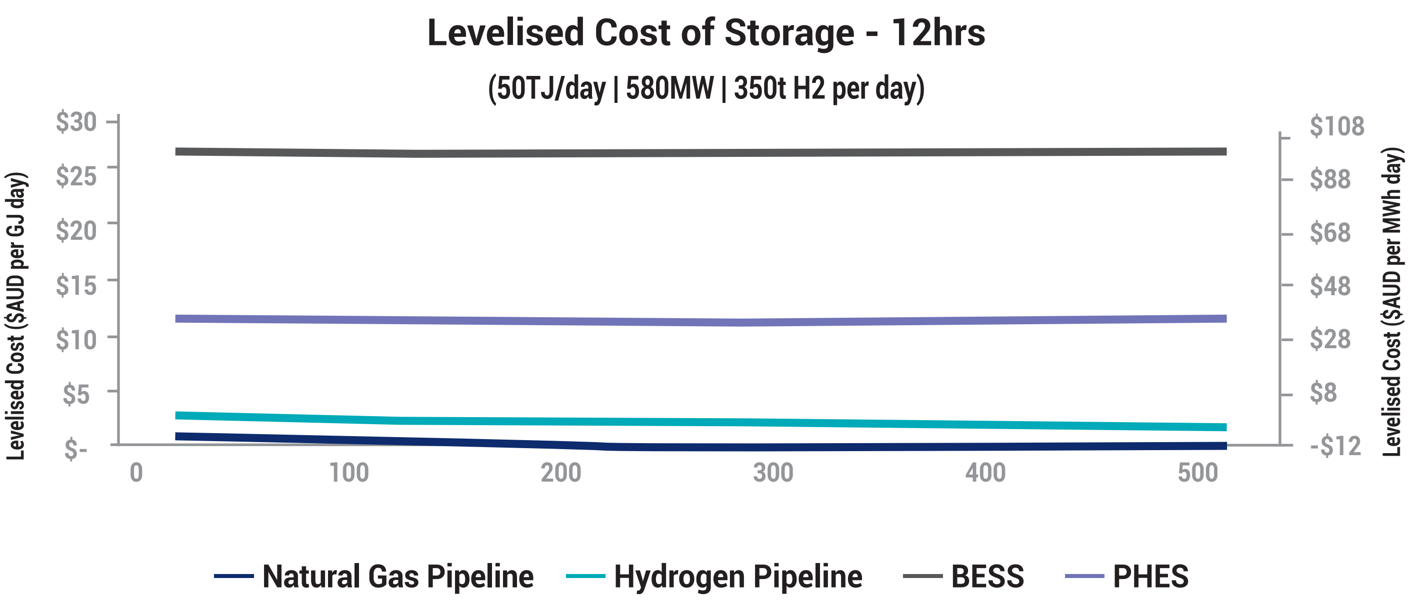
Energy Storage in new pipelines costs less than energy storage in BESS or pumped hydro

Due to the compressible nature of gases, pipelines transporting gases such as hydrogen and methane can store gas in the same pipeline at the same time as it is used to transport the gas to customers.

Designing a new pipeline to store a quantity of gas simply requires an increase in pipeline diameter once the pipeline diameter required to transport the gas is known. The additional cost of increasing pipeline diameter is the cost attributable to energy storage in pipelines, making the costs significantly less than bespoke energy storage technologies.

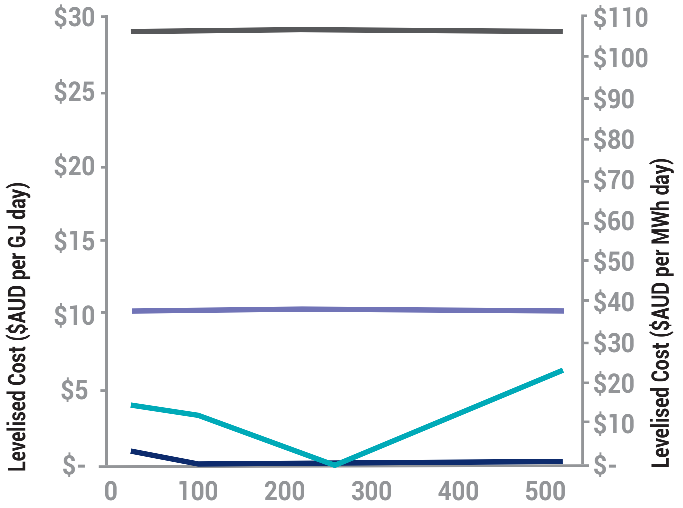
To compare the cost of pipeline energy storage with battery energy storage systems (BESS) or pumped hydroelectric energy storage (PHES), the additional cost to increase pipeline diameter was analysed over a range of energy storage cases. Storage cases were designed relative to energy transport capacity, targeting 4hrs, 12hrs and 24hrs of storage.

Non-zero pipeline energy storage costs span between $0.03 and $6.47/per GJ per day, or $0.11 to $23.29 per MWh per day. This is compared to PHES costs as low as $5.80 per GJ per day or $21 per MWh per day, and BESS costs as high as $29.23 per GJ per day or $105 per MWh per day. This makes energy storage costs in pipelines10s to 100s of times lower than electricity storage in BESS (x) and PHES (y). In some cases, 4hr energy storage in pipelines reaches $0 per gigajoule as typical pipeline size increments are already large enough to enable 4hrs worth of gas or hydrogen storage.



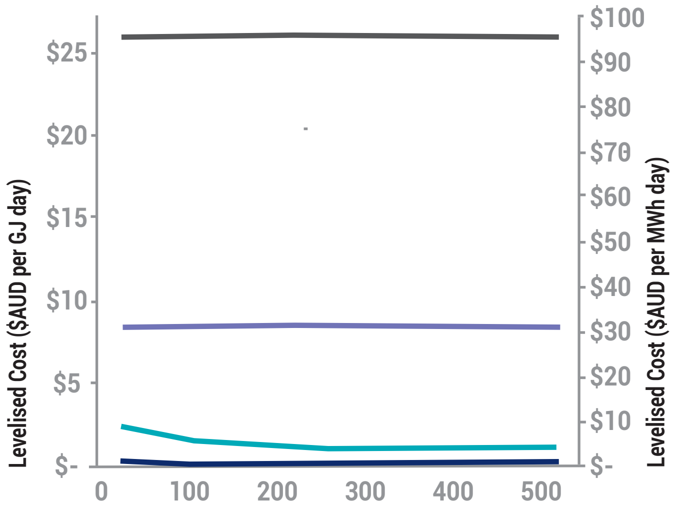
Levelised Cost of Storage - 4hrs

(10TJ/day | 116MW | 70t/day H2)



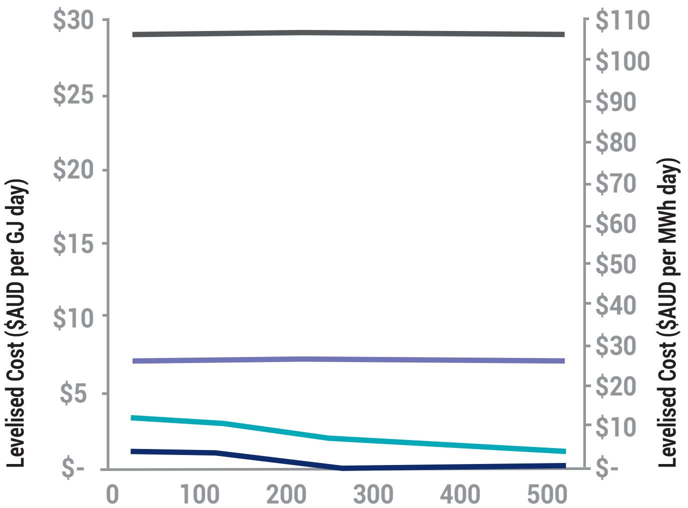
Levelised Cost of Storage - 4hrs

(500TJ/day | 5,800MW | 3,500t/day H2)



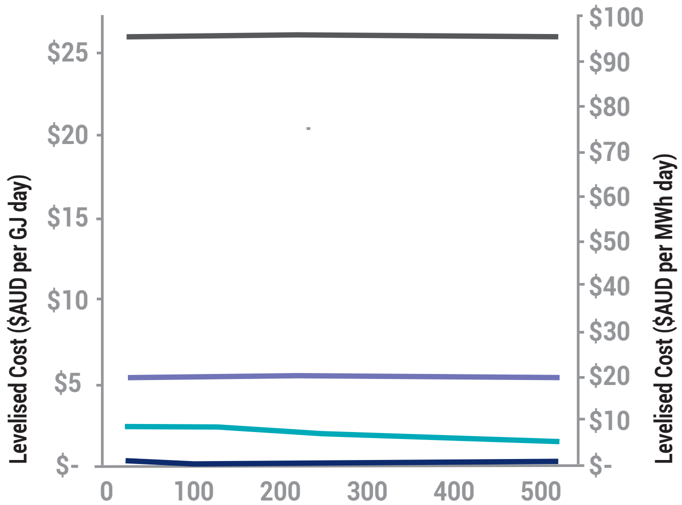
Levelised Cost of Storage - 24hrs

(10TJ/day | 116MW | 70t/day H2)



Levelised Cost of Storage - 4hrs

(500TJ/day | 5,800MW | 3,500t/day H2)



— Natural Gas Pipeline — Hydrogen Pipeline — BESS — PHES

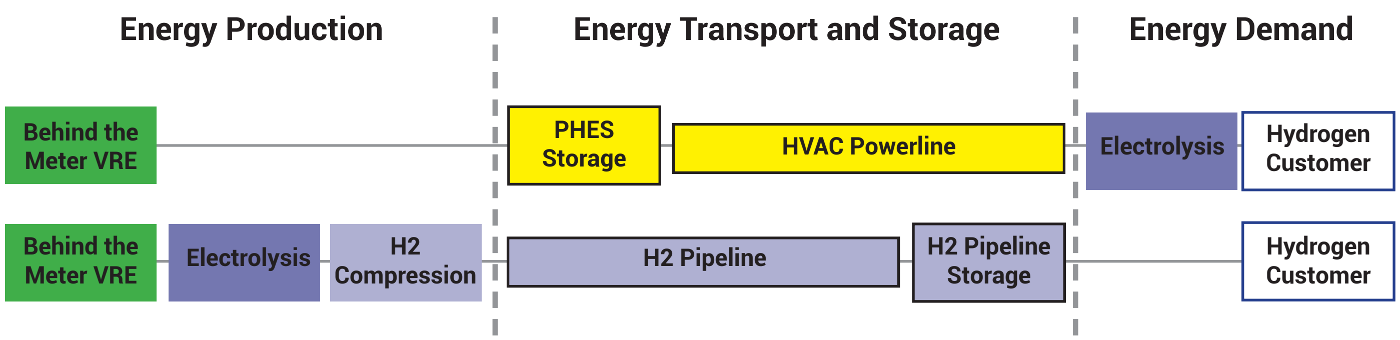
Hydrogen customer benefits greater than lower transport and storage cost alone

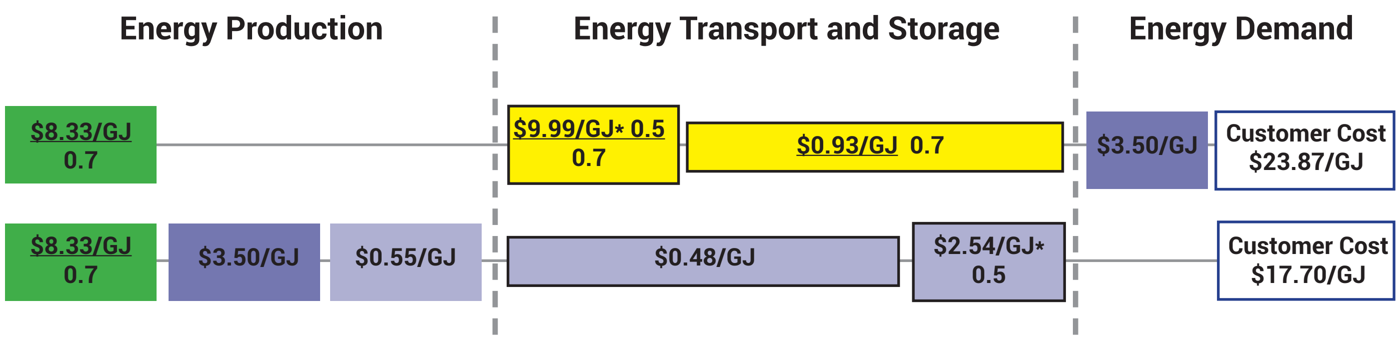
From the perspective of the hydrogen customer, the benefits of receiving hydrogen via pipeline are greater than the reduced transport and storage costs alone. Assuming that energy needs to be transported, transporting and storing energy after electrolysis rather than before electrolysis means that the energy consumed by electrolysis (typically 30 per cent) doesn't need to be transported.

This reduces the throughput capacity of energy transport and storage infrastructure, resulting in a lower cost of hydrogen for customers. This also opens the opportunity for hydrogen customers to access low-cost behind the meter solar PV and wind generation for hydrogen production.

An indicative hydrogen supply chain comparison undertaken by GPA Engineering can be seen below. Through this example, the expense of transporting the energy lost through electrolysis can be seen as significantly contributing to the cost of hydrogen for customers.

While this is a one-for-one comparison, the opportunity of network economics applies to electricity and gas infrastructure alike, meaning that networks of hydrogen pipeline are expected to deliver energy at a lower cost than electricity networks as well. The full value created through hydrogen networks relative to electricity networks or individual hydrogen pipelines requires further analysis.





How you can use this data

When undertaking energy value chain analysis, an understanding of energy production and use technologies alone are insufficient to understand the entire value chain. It is possible for one energy production technology to produce more expensive energy than another, but for energy infrastructure to result in equal or opposite costs for customers.

APGA commissioned the Pipelines vs Powerlines study to be undertaken in such a way which would allow anyone interested in a hydrogen or renewable gas future to consider pipeline infrastructure alongside powerlines infrastructure options.

Prior to this report, little robust Australian data existed comparing the costs of new pipeline and powerline infrastructure, and even less considering the opportunity of hydrogen pipeline infrastructure.

Using the data available in the Pipelines vs Powerlines report, energy transport and storage costs per unit energy can be estimated and inserted in high-level value chain cost estimates such as the one seen on the previous page. Where distances longer than 500km are required, this can be estimated by adding pipeline lengths together and adding an estimate of midline compressor cost also available in the report.

It is hoped that with these high-level cost estimates, developers, policy makers and climate advocates alike can come to informed conclusions about the potential for a renewable gas future delivered via renewable gas infrastructure.

APGA intends to build on this study by considering where such a renewable gas future could take the nation, and by integrating this data with the growing body of renewable gas industry analysis being developed around the globe.

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1 Australian Energy Update 2021, Australian Federal Government Department of Industry, Science, Energy and Resources 2021
https://www.energy.gov.au/publications/australian-energy-update-2021

2 Western Victorian Transmission Network Project High-Level HVDC Alternative Scoping Report, Moorabool Shire Council 2021
https://www.moorabool.vic.gov.au/files/content/public/about-council/large-projects-impacting-moorabool/western-victoria-transmission-network-project/wvtnp-high-level-hvdc-alternative-scoping-report.pdf

3 2020 ISP Appendix 5. Renewable Energy Zones, Australian Energy Market Operator 2020
https://aemo.com.au/-/media/files/major-publications/isp/2020/appendix--5.pdf?la=en