Australian Government

COAG Energy Council

NATIONAL HYDROGEN STRATEGY

Issues paper series

This issues paper explores the benefits, risks and barriers to using hydrogen as a transport fuel in Australia by 2030. The COAG Energy Council Hydrogen Working Group seeks feedback on the potential role of national policies and actions in realising these opportunities.

A list of questions is presented at the end seeking further input from interested stakeholders.

Hydrogen for transport

This paper has been informed by submissions to the *Request for Information* released in March this year, as well as:

- targeted visits to countries that have already started to develop hydrogen technologies and markets
- the stakeholder roundtables that were held throughout May and June.

The COAG Energy Council Hydrogen Working Group would like to thank industry and community members for their engagement in the strategy development process.

In this paper, unless otherwise indicated, 'hydrogen' refers to 'clean hydrogen,' defined as being produced using renewable energy or using fossil fuels with carbon capture and storage (CCS). This definition reflects the principle of technology neutrality set by COAG Energy and Resources Ministers when they commissioned a comprehensive and ambitious strategy for the development of an Australian hydrogen industry.

Background

Transport is Australia's second largest source of greenhouse gas emissions.[1] Vehicle exhaust is a known carcinogen and accounts for around 1500 premature deaths in Australia each year.[2] A hydrogen fuel cell electric vehicle (FCEV) only emits water, making FCEVs an emerging zero-emissions alternative for the transport sector.

Australia imports 90%of the liquid fuel we use.[3] International markets provide competitively priced fuels for Australia, but relying on imports introduces some energy security risks. In a separate but related issue, Australia does not currently meet the 90-day net oil import stockholdings required by the International Energy Agency to facilitate global oil security, though it has a plan to return to compliance.

There are a range of options for reducing fuel consumption to improve air quality, reduce carbon emissions and strengthen energy security, including FCEVs, battery electric vehicles (BEVs) and hybrids (internal combustion engine (ICE) or FCEV hybrids).[4, 5] The consumer experience and merits of these options varies and all could play complementary roles in the future transport system.

California, a state with around twice as many new car sales per year as Australia, has an established market for hydrogen cars and associated refuelling infrastructure.[6, 7] China, Japan and South Korea all have national hydrogen strategies and are manufacturing hydrogen vehicles.[8, 9, 10] Hydrogen is being used for all modes of transport, including trucks in North America, passenger trains in Germany, ferries in the United Kingdom and buses in China.[11, 12, 13, 14, 15]

The transport sector includes road, rail, aviation, and maritime sectors for both passenger transport and freight. This paper focuses on transport sectors that are expected to include a hydrogen-fuelled variant by 2030 – aviation has therefore not been included for further discussion.

Benefits

Fuel security

Some public commentary has suggested Australia lacks resilience in the supply of liquid fuels and that this constitutes an energy security risk. The Australian Government announced a Liquid Fuel Security Review in 2018.[3]

Submissions to the Working Group have reinforced the importance of considering this risk, as noted by the Institute for Integrated Economic Research Australia in its submission:

> *'Reliance on supply chains is an inherent vulnerability, and an Australian hydrogen industry would mitigate some of the risk of liquid fuel insecurity in the future.'*[16]

Genevieve Feely, from the Australian Strategic Policy Institute echoed these risks in her submission, and reinforced hydrogen's potential to strengthen Australia's strategic position and maximise energy resilience.[17]

Using hydrogen as one of the new technologies to fuel transport would help diversify energy sources and reduce reliance on current liquid fuels. FCEVs can also support energy security by reducing total demand, as FCEV vehicles use much less fuel than petrol or diesel equivalents (half as much compared to a conventional ICE, and around a quarter less than an ICE hybrid).[18] In addition, replacing consumption of imported liquid fuels with domestic energy production would improve Australia's terms of trade. The Australian Government has noted potential opportunities for domestic energy sources to improve transport energy security in the Interim Report on the Liquid Fuel Security Review.[3]

Air quality and lower emissions

Unlike ICE vehicles, FCEVs produce no tailpipe emissions and offer one solution to reduce local air pollution, especially in urban areas.[19] Hyundai calculates that driving an FCEV for an hour could potentially remove 99.9% of fine particles from 26.9 kilograms of air; enough for 42 adults to breathe for an hour.[20] Switching to zero-emissions alternatives like FCEVs would reduce health costs to the entire community.

Reducing carbon emissions from the transport sector by encouraging greater deployment of zero-emission vehicles like FCEVs would also contribute to meeting Australia's international commitments on climate change.

Familiarity of use, range and payload

FCEVs could be refuelled with a similar consumer experience to incumbent ICE vehicles – for example, at a service station or fuel depot, and at similar speed to refuelling with petrol or diesel. Hydrogen enables additional zero-emission choices without compromising on trip plans or use cycles. This will give more options to light vehicle users without access to off-street parking or dedicated battery charging space.

FCEVs have strengths where alternatives like BEVs are weakest: range, weight and refuelling times. While BEV charging speeds for light vehicles are falling quickly, trucking and commercial vehicle operators in particular perform tasks where electrification faces more significant constraints.[21 24] Because fuel cells have much higher energy densities than lithium-ion batteries, they may be more readily scaled to bigger vehicles, heavier loads and longer distances.[21 24] FCEVs can be an effective alternative for residents of regional and remote communities who could drive long distances with a single short refuelling stop, assuming hydrogen refuelling stations are located along desired routes.

Fuel cells vehicles could also reduce emissions without compromising range or payload capacity which means they may be deployed in vehicles that place a premium on these attributes, such as freight and mass transit. This could include trucks, buses, mining vehicles) and non-road freight and transit vehicles such as trains, ships and ferries. Rapid refuelling is also a more critical factor for service vehicles like buses, mining trucks, commercial freight or forklifts, where reducing downtime is a major factor in purchasing these assets.[21 24]

Analysis by the US National Renewable Energy Laboratory found the total cost of ownership for FCEV forklifts was less than BEV equivalents due to refuelling time benefits. Using hydrogen to fuel forklifts instead of electric avoids the need for long charge times (or hoists, racks and charging stations for battery exchange), allowing vehicles to operate 24 hours a day.

Sector coupling

Since hydrogen can also be used in the electricity, gas, and industrial sectors, investments in one sector enable shared benefits. This minimises costs for the whole community. For example, transport refuelling infrastructure could be made available to industrial users, such as forklift warehouse operations, for higher asset utilisation. In another example, electrolysers could produce hydrogen for blending into natural gas networks and for co-located refuelling stations. A remote mine site could produce hydrogen fuel on-site to use in vehicles as well as back-up power supply, with reduced local air pollution by replacing fossil fuel sources.

Sector coupling is discussed in more detail in the *Hydrogen to support electricity systems* and *Hydrogen in the gas network* papers.

Barriers and risks

Vehicle supply

The Working Group understands from discussion with manufacturers that the main constraint for zero-emission vehicles is not demand, but supply, as new production lines are developed to produce these vehicles. Australian importers compete within their organisations for supply of new technology vehicles like FCEVs, and global manufacturers are prioritising supply to markets that have demonstrated their readiness and support. Experience with BEVs suggests that if Australia does not demonstrate it is a supportive market, manufacturers will not supply a full range of models at competitive prices.

The main markets securing supply of FCEVs are California, Japan, South Korea, Europe and China.[22, 23, 24] These markets have employed a complementary mix of regulation, targets, incentives and investment to indicate market readiness, encourage supply and reduce price barriers.

Case Study: California experience supporting FCEVs

California first started incentivising zero-emission vehicles in 1990 with a 2% sales target for large vehicle manufacturers. The program has evolved over time and complementary policies have been introduced to support refuelling infrastructure. California has set a target of 200 hydrogen refuelling stations by 2025 and five million zero-emission vehicles by 2030.

The program has promoted both BEVs and FCEVs, and in April 2018, there were 4411 FCEVs registered in California, up from 125 vehicles in 2014.[25] More FCEV choices are available in California than other US states.[26] There were also 36 open-retail refuelling stations, and 28 additional funded stations.

While light vehicles are imported to Australia, a significant share of Australia's record demand for new heavy vehicles is met by domestic manufacturers, especially for buses and heavy freight.[27] [28] Manufacturing polices can complement other measures which encourage technology supply. This may provide opportunities for Australian manufacturers to develop hydrogen fuel cell vehicles or other supporting industries that could be competitive in the global vehicle supply chain.

Price of vehicles

Achieving price parity with ICE vehicles is a challenge. California's experience shows concerted effort over a long period is required to drive significant change. Even now, new FCEV vehicles are offered in California for around 60 000 USD (87 000 AUD) before incentives.[33] More than half of Australia's new light vehicle sales are for vehicles under $30 000.[29] However, cost reductions are expected should FCEVs move into global mass production, and lifetime costs could converge with BEV and ICE vehicles by 2030.[30] [21]

In the heavy vehicle and freight sectors, high capital costs and uncertain rates of return combine to deter fuel-saving investments in fleet renewal, even without the higher costs of FCEV drivetrains. A new heavy vehicle can cost hundreds of thousands of dollars, and a passenger ferry or specialised mining truck can cost millions. In other forums, stakeholders have proposed tax rebates as one way to reduce capital costs associated with modernising Australia's heavy vehicle fleet.[31] There may be others. The Working Group seeks stakeholder views on other options.

Fuel supply and refuelling infrastructure

There is very little hydrogen refuelling infrastructure in Australia and the few current refuelling stations are not accessible to the public. Early consultations suggest service station owners and franchisees have no case for investing in FCEV refuelling owing to a lack of present demand and uncertain future returns. Rollout is also constrained by a lack of community awareness and delayed planning approvals. Overseas, market creation is being led by a combination of government targets and public private partnerships for investment.[32, 33, 7]

Although the infrastructure for delivery of hydrogen gas exists commercially, it may not be ready to support widespread consumer use of hydrogen as an energy source for transportation. In California, vehicle suppliers offer a capped period of free hydrogen fuel with the purchase of a car, which removes the initial consumer barrier of fuel cost. Much of California's supply comes from excess production from oil refineries and natural gas.

Some stakeholders note a 'back to base' refuelling option may be possible for some applications, and could be simpler for early adoption than establishing a large scale refuelling network. Base stations appear feasible starting points for the 'chicken-and-egg' problem of scaling up network infrastructure. The International Council on Clean Transportation suggests combining 'clusters' (grouping stations in a small area with predicted demand) with 'corridors' (distributed refuelling points between clusters) is one way to stagger the investment burden as demand develops.[34] [21]

Case Study: ACT hydrogen refuelling pilot project

Canberra will be the first Australian city to pilot a publicly accessible hydrogen vehicle refuelling station under a partnership between the ACT Government, ActewAGL, and renewable energy developer Neoen. The project will be supported with 20 fuel cell vehicles, which will be added to the ACT Government fleet. The station will also be available to refuel private hydrogen vehicles.

The station is expected to be completed by mid-December 2019, together with the arrival of 20 hydrogen vehicles for the ACT Government's fleet. The construction of the station and provision of vehicles are being funded by industry, at no cost to the ACT Budget as a project under the ACT's Next Generation Renewables Auction.

Recognising the lack of Australian hydrogen standards, the ACT Government is working with ActewAGL to ensure the project is subject to an appropriate regulatory regime. Lessons learned from this process will support the development of a national regulatory approach.

COAG Energy Council Ministers tasked the Hydrogen Working Group with a 2019 project to map where the initial deployment of hydrogen refuelling stations could occur. This will include assessing which locations and modes hydrogen is most likely to be used in and will supplement similar work for BEV charging infrastructure.

Fuel price

The hydrogen fuel price will need to be similar to petrol and diesel on a per-kilometre basis for FCEVs to be embraced by large numbers of consumers. The likely retail price for Australian hydrogen fuel is unknown; preliminary research indicates the fuel costs for FCEVs and ICEs per 100 km are similar, but data is scarce. However, hydrogen has much more scope to reduce costs with greater scale of supply, unlike petroleum which is priced at peak scale and efficiency. The challenges of achieving supply at scale are addressed in the *Hydrogen at scale* paper. Energy costs for BEVs are likely to remain significantly lower, but FCEVs could be more competitive based on other attributes (such as range, weight and refuelling time) as the cost gap with electricity narrows.

Width and dimension rule limits

The maximum width of vehicles is set by the Australian Design Rules and is inconsistent with the major markets of Europe and the US. This is not a concern for the majority of the light vehicle road fleet, but does pose some restrictions on model availability of heavy road vehicles for Australia. This restriction is broad and applies to all vehicles and is currently under review by the Australian Government.

The rail gauge and rail infrastructure determines the type of wheelsets used and the outline of the rolling stock, and varies between jurisdictions in Australia. This is generally not an issue, with train sets built for a specific service line or rail network. Hydrogen fuel cell trains being developed for use in Europe for standard gauge would not be directly deployable to some jurisdictions in Australia. However, as with most powertrains brought to Australia, they can be adapted to different rail gauge and rolling stock outline.

Technology and operational risk

Purchasers will also be wary of financial risk associated with a new technology. Vehicle purchasers need to consider future maintenance, operational, and depreciation costs. These are difficult to predict for new technologies like hydrogen vehicles.

There are opportunities for governments to help remove risk. For example, trials and demonstration projects can establish credible real-world information on performance and costs. Governments and vehicle suppliers can work together to mitigate risks for early adopters by disseminating data and communicating results.

Early prospective options

The Working Group has identified urban buses, passenger ferries, long haul freight, light vehicles, remote mine site vehicles and non-road vehicles as prospective early use cases for FCEVs.

Urban buses and passenger ferries

Replacing ICE urban buses, which are often diesel, with FCEVs provides immediate local benefits by reducing air pollution in our cities. Replacing conventional ferries with hydrogen alternatives would eliminate the risk of marine pollution from diesel spills.

Hydrogen fuelled buses and ferries are being deployed overseas. Ferries are in use in the United Kingdom, France and Norway.[35] [36] In May 2019, the United Kingdom awarded a contract for construction of hydrogen double decker buses after the successful operation of hydrogen buses in London for several years.[37]

Urban buses and ferries are generally managed by state and territory governments. They have high public visibility and offer a good opportunity to increase community awareness of hydrogen as a fuel.

Case Study: Western Australian Government bus trial

The Western Australian Department of Planning and Infrastructure ran a trial of fuel cell passenger buses from 2004 to 2007.[38] The trial included three fuel cell buses and was run in conjunction with similar trials in Europe and Iceland. The trial included aspects of hydrogen production (by BP), purification and transportation of the fuel itself (by BP and BOC) and application in the domestic transportation industry (by the State Government). The trial concluded:

- The performance, reliability and operations of the buses exceeded expectations
- Public perception was overall positive and awareness improved after the trial
- The key limitation was the fuel quality and refuelling infrastructure
- Hydrogen purity was inadequate for fuel cells and the hydrogen had to be further purified before use
- The refuelling infrastructure had a technical failure that caused nearly three months of lost operation

The trial concluded that hydrogen is a technically viable fuel, and that fuel cell technology is an option for the public transport fleet.

Long distance freight

Long distance freight has limited opportunities for decarbonisation, and hydrogen is commonly identified as one of the most promising technology pathways for large mass, high mileage vehicles.[39] [21] There are real-world examples of FCEV trucks, trains and ships, although none are yet in mass production.[11] [40] [41] Encouraging vehicle supply is a critical step.

The freight sector is highly cost-competitive and additional costs beyond business as usual cannot usually be recovered from freight customers. Adoption of FCEV freight vehicles is likely to require demand-side support.

Strategic location of hydrogen refuelling stations will make successful deployment of FCEV trucks, trains and ships more likely. Refuelling sites can be chosen to reduce fuel transport costs and avoid congestion.

Many of the standards and regulations necessary for successful deployment will come from harmonisation and adaptation of global developments in policy. There are existing international standards for hydrogen safety and performance from peak organisations such as ISO.[42] The International Maritime Organization has a long term policy to reduce emissions from ships, which could include new fuels like hydrogen. [43]

Light vehicles

Light vehicles are Australia's largest transport sub-sector by sales, energy consumption, and greenhouse emissions. Given the dominant position of light vehicles in Australia's transport system, and the fact that several light vehicle models are already available overseas, feedback from consultations identified it as a priority sub-sector for hydrogen. However, given the likely competition from BEVs in this sector, it will be important to consider how light vehicles can be used to leverage more prospective options such as public transport and long distance freight once these vehicles become more available. [21]

Remote mine site vehicles

The Australian mining sector consumes large amounts of diesel for its off-road haulage trucks and vehicle fleets. Early consultations suggest mining companies are interested in trialling FCEVs due to their potential to reduce carbon emissions and provide fuel security. However, there are challenges due to limited availability of suitable vehicles, particularly mining equipment and haul pack trucks. While hydrogen is currently excise free, it faces economic challenges in mine applications due to the low cost of bulk diesel purchases and the refund of diesel fuel excise through Fuel Tax Credits.

Forklifts and non-road vehicles

Forklifts and similar non-road vehicles are well suited to FCEVs due to the option for on-site refuelling and zero-emissions without compromised refuelling times.

Global experience shows the right signals from government can increase the uptake of non-road fuel cell vehicles. The United States provides tax credits for fuel cell projects, including FCEV support vehicles, and had more than 20,000 sales of FCEV forklifts as of November 2018.[44] [45] Japan includes forklifts in their national hydrogen strategy and identified effective utilisation of hydrogen refuelling infrastructure as a necessary enabler to achieve their targets of 500 FCEV forklifts by 2020 and 10,000 by 2030. [32]

Case Study: Amazon fuel cell forklifts

In 2017, the company Amazon purchased a fleet of hydrogen fuel cell forklifts to replace electric forklifts at 11 of its warehouses. The purchase was part of Amazon's long-term energy and environment strategy, and included US$70 million upfront and US$600 million over the course of the contract. The trial program is expected to provide long-term cost savings and learning benefits that could be transferred to a future line of Amazon FCEV delivery trucks.

Regulation, safety and skills

Safety will be a key focus of national and state-based standards and regulations to support the deployment of FCEVs and associated infrastructure. The transport-related risks of using hydrogen are well known and there are steps in place to ensure vehicles are only deployed once safety has been confirmed. Standards Australia is already planning for future standards for hydrogen safety and has released a discussion paper to facilitate this.[46] Safety issues are discussed in detail in the *Understanding community concerns for safety and the environment* paper.

The use of hydrogen as a fuel for on-road vehicles is already possible through existing transport regulation, as is the movement and refuelling of hydrogen powered vehicles. The Australian Design Rules currently accommodate FCEVs but may need to be reviewed as the market grows. Recently passed national reforms will require hydrogen and battery electric vehicles to display an identifying label on their number plates so that first responders can safely identify and take necessary precautions when responding to an emergency situation.

Maintaining and servicing FCEVs requires new skills. For example, the California FCEV servicing standard has procedures for removing hydrogen from vehicles and replacing it with helium before a service can begin.[47] Skilled specialists will be scarce before the hydrogen sector achieves economies of scale. During this period of limited skills there is an opportunity for strategic sharing of skills for mutual benefit. For example, hydrogen mechanics could be shared between government bus fleet operators and private vehicle owners. The sustainability of safety systems will depend on the availability of properly trained specialist engineers, mechanics, technicians and inspectors. The key areas of focus will be hydrogen production, transport, storage, refuelling infrastructure and vehicle maintenance.

Greater use of FCEVs will also play a role in building familiarity with handling, storing and using hydrogen in everyday circumstances. Experience elsewhere has shown this to be an important part of creating community acceptance and endorsement of a hydrogen industry. The use of hydrogen as a vehicle fuel would see a significant expansion of hydrogen production in Australia. Current domestic consumption is generally confined to industrial sites. The existing regulations will need to be monitored to ensure they are still relevant for this change in use.

Actions to 2030

A series of actions will be required to develop greater use of hydrogen in transport by 2030. The table below has been developed in consultation with stakeholders. The Working Group seeks feedback on these options.

2019	2020-2025	2025-2030	2030-2050
Agreement to national approach through COAG Energy Council	Demonstration projects	Commercialisation financing	Decarbonising Australian economy and exporting to the world
	Refueling consortium	Public refueling widely available	
	Trials (bus fleets, ferries, light vehicle fleets)	Larger fleet projects based on market progress and trials	
	← Regulatory reform →		
	← Skills development. →		
← Build social licence and community acceptance through good governance, fair distribution of benefits and costs, and giving communities a say →			

Questions

The National Hydrogen Taskforce is seeking responses to the questions below. You can submit your comments via the Department of Industry, Innovation and Science's consultation Hub https://consult.industry.gov.au/national-hydrogen-strategy-taskforce/national-hydrogen-strategy-issues-papers

1. *What groups or companies could lead a consortium approach to building refuelling infrastructure?*
2. *What groups or companies could coordinate procurement of hydrogen cars, buses and ferries?*
3. *Other than emissions limits and procurement policies, how could government actions (federal, state or local) support private investment in vehicles and infrastructure?*
4. *How can governments and industry reduce the financial, technology and operational risks of purchasing new technology vehicles?*
5. *What are some ways hydrogen vehicles could be showcased and demonstrated to the community at large?*
6. *What are the key enablers and realistic timelines for a transition to:*
    - *Hydrogen-fuelled buses?*
    - *Hydrogen-fuelled passenger ferries?*
    - *Hydrogen-fuelled long-distance freight (including heavy trucks, trains and long distance shipping)?*
    - *Hydrogen-fuelled forklifts and ancillary vehicles?*
    - *Hydrogen-fuelled light vehicles?*

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