AUSTRALIAN
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COUNCIL

Support local manufacturing

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Australian manufacturers are feeling pressure to reduce emissions. End use customers are seeking low carbon products and services and this need is percolating through supply chains.

Hydrogen can support decarbonisation of manufacturing in two ways:

- **As a fuel:** Hydrogen can produce heat though combustion or chemical processes. Manufacturing sectors that use industrial heat include steel, non-ferrous metals, chemicals, food processing, ceramics and cement. Around 23 per cent of Australia's energy is used for process heat, with an indicative value of A$8 billion per year.[122] Carbon emissions from combustion in manufacturing were 30 million tonnes in 2019.[123]
- **As a feedstock:** Hydrogen is already used as a feedstock[124] for several industrial processes, including the manufacture of ammonia, chemicals and synthetic fuels. Existing fossil fuel-derived hydrogen (generally steam methane reforming of natural gas) can be replaced with clean hydrogen to decarbonise these processes. Carbon emissions from chemical processes were five million tonnes in 2019, with the ammonia-making process releasing two million tonnes.[125]

Using clean hydrogen also creates new opportunities, such as growing Australia's domestic production of value-added commodities like steel. Further, with the hydrogen of the future not being exposed to fluctuating global prices for commodities such as oil and gas, it presents the possibility of offering more stable energy costs for industrial users.[126]

However, early adopters of hydrogen technology in manufacturing still face significant financial risk. There is public benefit in supporting Australia's manufacturing sector, and there could also be major avenues for job creation to add value to our hydrogen for export.

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116 ITP (2019), page xvii.
117 Wood, Reeve, and Ha (2021b), page 19.
118 This means it is not combusted for its energy value but used for its chemical value.
125 Wood et.al (2021b), page 19.
126 COAG Energy Council (2019), page 5.

5.1 Very high temperature processes are the first step

Process heat is said to be medium temperature when between 250°-800°C, and high temperature when over 800°C. Taken together, processes in these ranges represent around 10 per cent of total Australian energy consumption.[127]

Experts consider that electrification will be more cost effective than hydrogen and other alternatives for many heating applications. However, technological constraints make electrification challenging for processes requiring more than 800°C. Advisian[128] has rated high temperature heating as 8 out of 10 for dependence on hydrogen for decarbonisation.

Sector	PJ/year >800°C
Iron and steel	93.9
Alumina and other non-ferrous metals	85.5
Ammonia and other chemicals	38
Cement, lime products	28.5
Bricks and ceramics	14.9
Glass and glass products	6.6
Petroleum refining	6.5
Other mining	5.3
Other[129]	4.4

Table 7: Sectors using >800°C, extract from ITP (2019: 29).

Table 7 shows the sectors of the economy that use high temperature heat, with the energy per sector.

To calculate how much hydrogen demand this translates to, we multiply the energy by the heating value of hydrogen.

Taking the higher heating value of hydrogen at 142MJ/kg[130] then this gives a hydrogen demand of:

- Around 900 ktpa, as a lower estimate, which assumes use only for alumina and non-ferrous metals, and ammonia and chemicals.
- Around 2,400 ktpa as an upper estimate, which covers all high temperature heating.

As a point of reference, Deloitte[131] ran scenarios for the National Hydrogen Strategy that showed hydrogen production figures, where the most ambitious scenario had Australian total hydrogen production (for domestic use and export) at 1,777 kt per annum by 2030, and the second most ambitious scenario at 724 kt per annum. We can see that the lower estimate of demand for hydrogen to replace all high temperature process heating is more than the second Deloitte scenario's entire hydrogen production figure, and the upper estimate is 135 per cent higher than the first Deloitte scenario's entire hydrogen production figure.

The production of hydrogen to support high temperature processes can also support domestic manufacturing in new ways. As discussed by the Grattan Institute, new clean energy industries can "plausibly create new jobs at a scale comparable to existing carbon-intensive industries".[132] The scenarios addressed by Grattan suggest between 40,000 and 55,000 ongoing jobs across green steel, green ammonia, and biofuels for aviation, which is similar to today's 55,000 geographically-concentrated carbon workers. Further: "Manufacturing activities are typically more labour-intensive than renewable energy operation and are likely to have conditions and pay more like today's jobs in smelting and coal power stations".[133]

Many of these new and replacement jobs are likely to be located in carbon-intensive locations, because these locations have key infrastructure such as ports and electricity transmission, as well as access to natural gas networks. Such jobs are also likely to be created in other regional areas where renewable energy resources are most favourable.

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[127] ITP (2019).
[128] Advisian (2021) page 76.
[129] Includes 1.5PJ/yr for 'Other hydrocarbon products', 1.3PJ/yr for 'Other non-metallic mineral', 1.1PJ/yr for 'Solvents, lubricants, greases and bitumen', 0.4PJ/yr for fabricated metal products and 0.1PJ/yr for water and sewerage.
[130] Note the lower heating value of hydrogen is 120MJ/kg and using the lower value would increase this estimate by around 17 per cent.
[131] Deloitte (2019).
[132] Wood, Dundas and Ha (2020), page 26.
[133] Ibid., page 15.

5.2 Priority sectors

The processes that appear to hold the greatest benefits for more immediate 'no regrets' planning and investment include iron/steel, ammonia,methanol and aluminium/alumina.

This is because each of these sectors is more dependent on hydrogen for decarbonisation and can also drive large sources of demand. These are scalable markets and support both direct and indirect growth in jobs.

Achieving scale in hydrogen production for these sectors can then pave the way for other industries that use high temperature heating at relatively smaller scale, such as food and meat processing.[134]

5.2.1 Iron and steel

Steel is the world's second largest commodity value chain after crude oil.[135] Steel is used for building materials, including new clean energy infrastructure such as wind towers, hydropower, solar farms, electricity transmission infrastructure, and transport systems.[136] Producing more than 1.8 billion tonnes of steel per annum, the global steel industry is responsible for around 8 per cent of global direct emissions.

Table 8 shows the major iron and steel companies in Australia, and key facts about each. To provide an example of the scale of Australia's current largest steelworks at Port Kembla, the steelworks provides 11 per cent of Gross Regional Product (at A$1.6 billion) for NSW and 24 per cent of the region's total output (at A$6.5 billion).[137]

There are two common ways to make steel. Most steel starts as iron ore, which is reduced to iron in a blast furnace. The iron is then processed in a basic oxygen furnace to produce steel. The second common way to make steel is to melt scrap steel with other elements in an electric arc furnace.

A newer approach is to make steel from direct reduced iron (DRI) sent to an electric arc furnace. The direct reduced iron is produced from iron ore and reductant gases, where natural gas is primarily used now. Green hydrogen can be used instead of natural gas to produce the iron. When combined with renewable electricity for the electric arc furnace, the resulting steel will below to zero emissions, and ideally 'green'.

Advisian[138] rates steel as 8.5 out of 10 for reliance on hydrogen to decarbonise,[139] noting that while the economic gap will reduce over time, hydrogen use is not expected to reach parity with the incumbent process before 2050.

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[134] While there are many more food processing plants than refineries, the scale is much smaller. For example, a large alumina refinery uses around 30,000 to 40,000TJ/year, and a modest sized factory in the food sector might use 20TJ/year. See ITP (2019), page xiv.

[135] BHP (2020).

[136] BlueScope (2021), page 3.

[137] Ibid., page 3.

[138] Advisian (2021), page 75.

[139] Ibid., page 52.

Company	Suburb	State	Main activities	Production technology	Production capacity per year, in million tons	Energy use per year in PJ
Bluescope Steel (AIS) Pty Ltd, Port Kembla steel works	Port Kemba	NSW	Primary iron and steel manufacture	BF, BOS	2.6	52
Bluescope Steel Limited, - Springhill	Port Kemba	NSW	Integrated steel works, flat products	BF, BOS	-	-
Commonwealth Steel Company Ltd, MolyCop Waratah	Waratah	NSW	Secondary steel manufacture	EAF	1.7	-
OneSteel Manufacturing Pty Limited, Whyalla Steelworks (Arrium)	Whyalla	SA	Integrated steelworks, long products	BF, BOS	1.28	34
OneSteel	Rooty Hill	NSW	Secondary steel manufacture	EAF	0.625	-
OneSteel	Waratah	NSW	Secondary steel manufacture	EAF	0.33	-
OneSteel	Laverton	VIC	Secondary steel manufacture	EAF	0.74	-
Tasmanian Electro Metallurgical Co Pty Ltd, TEMCO	Bell Bay	TAS	Manganese ferroalloy smelter	EAF	-	-

Table 8: Major iron and steel companies in Australia (BF: Blast Furnace; BOS: Basic Oxygen Steelmaking; EAF: electric arc furnace). SOURCE: ITP, 2019: 121. Note: errors in table in original ITP report corrected in communication with author on 20 September 2021.

Green steel is a manufacturing opportunity that could potentially provide tens of thousands of new jobs. The Grattan Institute notes that today Australia produces 38 per cent of the world's iron ore and 18 per cent of the world's metallurgical coal, but only produces 0.3 per cent of the world's steel.[140]

Australia does not make significant amounts of steel because the economics currently favour sending the raw materials to major manufacturing and steel-consuming countries, such as China, Japan, Korea, and India. The cost of shipping is not high enough to offset the costs of producing steel onshore (mainly related to domestic wages). However, using hydrogen for direct reduced iron "turn the economics of steel-making on its head":

> *The cost of shipping hydrogen strongly favours making green steel – or at least the hydrogen-intensive direct reduction process – where the hydrogen is made. This is likely to be in renewable-rich Australia, rather than in countries that have lower-quality renewable energy resources and limited land, such as Japan, Korea, Indonesia, Vietnam, and Thailand.*[141]

Grattan states that it makes sense for Australia to export steel to countries with relatively high wages, such as Japan or Korea, and to export direct reduced iron to countries with lower wages, such as Indonesia.

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[140] Wood et al. (2020), page 22.
[141] Ibid.

The Energy Transition Hub[142] has modelled a scenario where the future Australian steel industry converts 18 per cent of iron ore output (where 18 per cent is 160Mt) into 100 million tonnes of crude steel per year, similar in size to Japan's current steel industry. This is produced by 40 plants. This scenario has the steel industry adding A$65 billion to its base revenue from the iron ore (A$19 billion), to make a total of A$84billion. This scenario as modelled provides 50,000 on-going jobs in the steel industry, plus the workforce for the new 160GW of solar and wind energy that willneed to be constructed.

The Grattan Institute has also modelled a future green steel industry based in central Queensland and the Hunter Valley (see Table 9).[143] This industry scenario has 40 million tonnes of steel exported per year to our regional trading partners, to a total value of A$65 billion, and capital investment of A$195 billion. Conservatively, this would mean 25,000 ongoing plant jobs in the region (just for steel manufacturing), to supply 6.5 per cent per cent of the world's steel.

	Central Queensland	Hunter Valley	Combined
Ongoing plant jobs in region	15,000	10,000	25,000
Direct reduced iron (DRI) output (Mt per year) DRI exported (Mt per year)	60 30	35 17.5	95 47.5
Steel exported (Mt per year)	25	15	40
Output as share of 2020 global steel market (including steel produced from exported DRI) Output as share of today's integrated steel production by prospecting trade partners Annual value ($b)	4% 30% 40	2.5% 20% 25	6.5% 50% 65
Capital investment ($b)	115	80	195
Renewable generation capacity required (GW) Renewable outgoing jobs (mostly outside region) Water input (GL per year)	75 2,000 200	60 1,500 150	135 3,500 350
Land required (share of state area)	0.45%	0.65%	0.5%
Notes: Assumes half of Australia's DRI production is exported, and half is used to produce steel in Australia. All jobs are ongoing full-time equivalent jobs, and exclude construction jobs. Plant jobs include operation and maintenance of both steel plant and electrolysers for hydrogen supply. Prospective trading partners are Japan, Korea, Indonesia, Malaysia, Taiwan and Vietnam.			

Table 9: Grattan Institute future steel industry scenario: Central Queensland and Hunter Valley. SOURCE: Wood et al. (2020), page 30.

It is difficult to do a direct comparison of these studies given the different coverage and assumptions, but there is a key message nonetheless, in that each study shows a potential green steel industry that is worth over A$65 billion, with at least 25,000 new jobs. This is for a level of global market penetration for Australian green steel that does not appear infeasible in principle.

These potential benefits need to be better understood, particularly against the cost of shipping for iron and steel (shipping steel will be much more expensive than iron), exposure to international markets in each, and how local and overseas delivery needs can be met (industry experts advise that steel users tend to require delivery of steel products quickly).

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[142] Lord, Burdon, Marshman, Pye, Talberg, Venkatamaran (2019), page 22.
[143] Wood et al. (2020), page 30.

5.2.2 Ammonia

Ammonia is the second most commonly produced chemical in the world, with most ammonia used as the basis for the fertilisers that support food production. Ammonia is also used to manufacture a range of other products, such as explosives and plastics.

Australia currently uses hydrogen from steam methane reforming as a feedstock to make ammonia, which means there is an opportunity to decarbonise this industry. Production of ammonia is by far the largest user of gas in the whole chemicals sector.

There are currently seven major ammonia plants in Australia. Table 10 shows the major ammonia plants and their production capacity as of 2019.

Company	Suburb	State	Main activities	Production capacity ton per year
Yara	Burrup	WA	Ammonia	85,000
Orica	Kooragang	NSW	Ammonia + AN + nitric acid	360,000
Incitec	Gibson island	QLD	Fertilisers	Ammonia: 360,000, Urea: 280,000, AS: 200,000
Incitec	Phosphate Hill	QLD	Ammonia for DAP production at Mt Isa	>950,000
Incitec	Moranbah	QLD	AN	330,000
CSBP, Incitec	Moura	QLD	AN	210,000
CSBP	Kwinana	WA		260,000

Table 10: Major ammonia-based fertiliser and explosives plants in Australia (AN: Ammonium nitrate, DAP: diammonium phosphate, AS: ammonium sulphate). SOURCE: ITP, 2019: 109.

The ammonia market is also likely to grow significantly, as ammonia also becomes an energy carrier or clean fuel. Japan anticipates using clean ammonia in power stations and is currently undertaking a large-scale demonstration of ammonia co-firing at the 4.1GW Hekinan Thermal Power Station.[144] Ammonia energy is also considered a logical replacement for the bunker fuel used for shipping.[145] Unlike hydrogen, ammonia has been traded globally for decades and has well developed technologies for large scale storage and transport.

Regarding the potential use of ammonia for shipping, Australia can engage with first movers across energy and maritime to collaborate on commercial-scale demonstration projects. The Energy Transitions Committee[146] sees this as vital, with a high priority for the shipping industry to:

> *choose pilot locations that offer privileged access to low-cost renewable electricity and hydrogen, opting for regions with large renewable energy potential, preferential prices and tax exemptions for major industrial electricity consumers, and industrial clusters where several transport and industry sectors will share energy infrastructure costs.*

Researchers from the Grattan Institute[147] state that if Australia was to produce 6.5 per cent of the world's ammonia with green hydrogen by 2050, there would be a further 5,000 ongoing jobs. This number rises by a further 15,000 jobs if global shipping moved exclusively to ammonia and Australia maintained 6.5 per cent market share.

Advisian rates ammonia as 8 out of 10 for reliance on hydrogen to decarbonise, noting that ammonia production using green hydrogen is unlikely to be competitive against natural gas until around 2050.[148] However, niche applications may become commercially attractive before then, and large-scale

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[144] JERA (2021).

[145] The American Bureau of Shipping (2019, page 46) notes a US company announcement for production of 275,000 tons of ammonia for a marine fuel by using methane pyrolysis powered by green renewable energy. Companies Ørsted and Yara have also announced plans to produce 75,000 tons of green ammonia per year using offshore renewable energy.

[146] Energy Transitions Committee (2020), page 19.

[147] Wood et al. (2020), page 36.

[148] Advisian (2021), page 78.

deployment of green ammonia production is expected to drive down costs rapidly.

While clean ammonia is not economically competitive in the short term, it "represents the easiest major strategic industrial transformation and is linked to the idea of future renewable energy exports".[149]

5.2.3 Methanol

Hydrogen is used for both fuel and feedstock to make methanol, and clean hydrogen is a good prospect to decarbonise the sector's high temperature processes.

There is an established global market, with extensive experience in handling. The global methanol market is growing, with China in particular said to be consuming over 50 per cent of the world's production:

> *Much of the recent growth can be attributed to China substituting methanol for petroleum derivatives as feedstock for the production of ethylene and propylene, the precursors for most types of synthetic polymers and plastics. However, a variety of fuel applications for methanol are also emerging. Methanol has been blended with petrol (similar to ethanol blending) in China and other countries for a number of years as a way of reducing air pollution. More recently, ships are being modified to run on methanol as well as diesel oil in order to comply with stricter air quality standards in many ports around the world.*[150]

Australia imports over 100,000 tonnes of methanol each year, mainly to produce formaldehyde for particle board and other manufacturing processes. Australia used to produce methanol at a site in Victoria, but the plant was "placed in care and maintenance mode" in March 2016 because of an inability to secure competitively priced natural gas.[151]

Like ammonia, methanol is considered a possible replacement for bunker fuels in shipping – it is already in operation for international shipping, albeit at a small scale.[152]

If the economics can be made to work, the production of methanol is another growth opportunity for Australia. Advisian[153] states that the methanol sector is considered to have high dependence on hydrogen for decarbonisation, with a rating of 8 out of 10.

5.2.4 Aluminium and alumina

As shown in Table 7, the aluminium industry is another strong prospect for using hydrogen to decarbonise the sector's high temperature processes, particularly in the production of alumina.

Primary aluminium is made from bauxite, which is refined to make alumina before being smelted to make aluminium. Refining bauxite to produce alumina has four stages: digestion, clarification, precipitation, and calcination. Digestion takes place at 150-270°C and calcination at temperatures above 1000°C.

Australia is the second largest producer of alumina in the world, and the largest exporter. In 2020, Australian total alumina production was 21.2 Mt, and export was worth A$6.8 billion.[154] Six Australian alumina refineries supply alumina to the four Australian aluminium smelters and the export market.

Advisian rates the alumina sector as 6 out of 10 for dependence on hydrogen, noting that it could be the key decarbonisation technology if the costs of production can reach parity with natural gas.[155] Further, there is a benefit for hydrogen if alumina calcination switched to hydrogen because the sector's significant energy consumption could "provide demand for demonstration and larger scale domestic hydrogen consumption".[156]

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[149] ITP (2019), page xvi.
[150] ADME Fuels (2019), page 2.
[151] Coogee (n.d.).
[152] Hand (2021), see also Maersk (2021).
[153] Advisian (2021), page 79.
[154] Australian Aluminium Council (n.d.).
[155] Advisian (2021), page 75.
[156] Ibid., page 74.

5.3 Barriers to hydrogen uptake

The barriers faced by parties seeking to integrate hydrogen into their heating and chemical processes are largely the same as for transport and any other use; that is, the significant cost required to convert assets, and the uncertainty about the total asset life costs of doing so given lack of current experience. For industrial processes there is also the complication of hydrogen being more expensive than the natural gas it is (often) replacing.

Starting with the costs of conversion, the investment needed to transform Australia's industrial asset base will be significant, with Grattan[157] noting that while there is no current estimate for Australia, an estimate for the European Union suggests required expenditure between 76 per cent and 107 per cent beyond that required for current technologies.[158]

If we look at steel for example, a modern blast furnace can have a lifecycle of 50 years or more, with major overhauls or 'relines' every 15-20 years to stay operational. The capital cost for a 4.0 Mt/year integrated steelmaking facility is around US$4 billion, compared with relining a blast furnace at between US$50 million and US$200 million, depending on the jurisdiction.[159]

In a submission to the 2021 NSW Parliamentary Inquiry into Hydrogen, BlueScope Steel[160] advises that its operational blast furnace at the Port Kembla Steelworks comes to the end of its current operating campaign around 2026 to 2030. It is still working but given the importance of the furnace working at full capacity (Port Kembla is a one blast furnace operation), BlueScope has commenced a pre-feasibility study on relining another blast furnace that was mothballed in 2011, to have this available from around 2026. BlueScope advises that a reline is the better option given the prospective hydrogen iron making technologies are promising but are in the early stage of technology development.[161]

Relining the mothballed blast furnace is said to cost around A$700-800 million, likely to be spent over FY2023 to FY2025.[162] To compare this with the alternative to use hydrogen, BlueScope advises:

- The capital cost of conversion[163] would be "prohibitive"; at more than A$2.8 billion it is more than four times more expensive than relining a blast furnace.[164]
- The high cost of natural gas and electricity in eastern Australia compared to other jurisdictions would result in output that was not globally competitive, with BlueScope's analysis indicating "even halving of…current gas prices would not allow such a plant to be competitive when compared to the existing BF-BOF plant".[165]
- Using green hydrogen would require an electrolyser of around 1.4GW, requiring 3GW of installed renewable electricity generation capability coupled with storage to ensure continuous supply.[166]

The BlueScope experience shows how long-lived industrial assets like blast furnaces need long term planning for major renewals. This planning needs to occur in the environment of changing social acceptance and uncertain technological choices, where the asset owner needs to maintain production while not locking in choices that in the future might be found to be poor. And the risk is particularly high with companies (and sectors) with few facilities, such as steel and ammonia.

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[157] Wood et al. (2021b), page 39.

[158] Material Economics (2019).

[159] BHP (2020).

[160] BlueScope Steel (2021).

[161] Ibid., page 7.

[162] Strategic Research Institute (2021).

[163] Converting from BF-BOF (Blast Furnace – Basic Oxygen Furnace) to DRI-EAF (Direct Reduced Iron – Electric Arc furnace) using hydrogen as the reductant.

[164] BlueScope Steel (2021), page 10.

[165] Ibid., page 12.

[166] BlueScope compares this to the total increase in Australia's installed capacity of large-scale renewable energy (mostly solar) in 2019 being 2.2GW across 34 projects.

While BlueScope chose to reline a mothballed blast furnace rather than take the chance on early technology, other companies or sectors may not have this flexibility and need to replace rather than refurbish 40-year-old assets if they are to stay operational.[167] This could mean closures (with associated job losses), or it could mean "a like-for-like replacement of an old facility, or shift to a proven but still relatively emissions-intensive process, locking in emissions for another 30 years or more".[168] This is all the more likely while producers cannot recover the additional costs of greener technology via green premium prices.

5.4 Recommendation

Recommendation 8: Support hydrogen for hard-to-abate industries

We recommend that the Australian Government funds a hydrogen readiness programme of at least A$1 billion for industrial processes that cannot readily be electrified, including (and not exclusively) for the production of iron/steel, ammonia, methanol, and alumina/aluminium.

Funding would be drawn from the Net Zero Fund and should be aligned with funding from state/territory governments.[169]

Funding should be prioritised for projects that protect or create local jobs and have a detailed plan for skilling and re-skilling. Applicants should be required to share information to support industry knowledge development – this could be assisted by engaging with industry associations to support delivery.

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[167] Regarding ammonia, Advisian (2021 page 77) advises: "A large portion of Australia's ammonia manufacturing capacity is beyond the initial design life of the facility and survives through judicious asset management and favourable domestic gas pricing".

[168] Wood et al. (2021b), page 37.

[169] Such as the NSW NZIIP fund for High Emitting Industries ($380 million), which "seeks to align with business investment cycles while achieving the lowest cost emissions reduction through a staged process, where potential funding is identified early and reserved (subject to future negotiation) to provide a level of certainty for long term investment decision making".
See Department of Planning, Industry and Environment (2021).

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