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# TOWARDS NET ZERO

## DECARBONISING PIVOTAL INDUSTRIES IN REGIONAL AUSTRALIA

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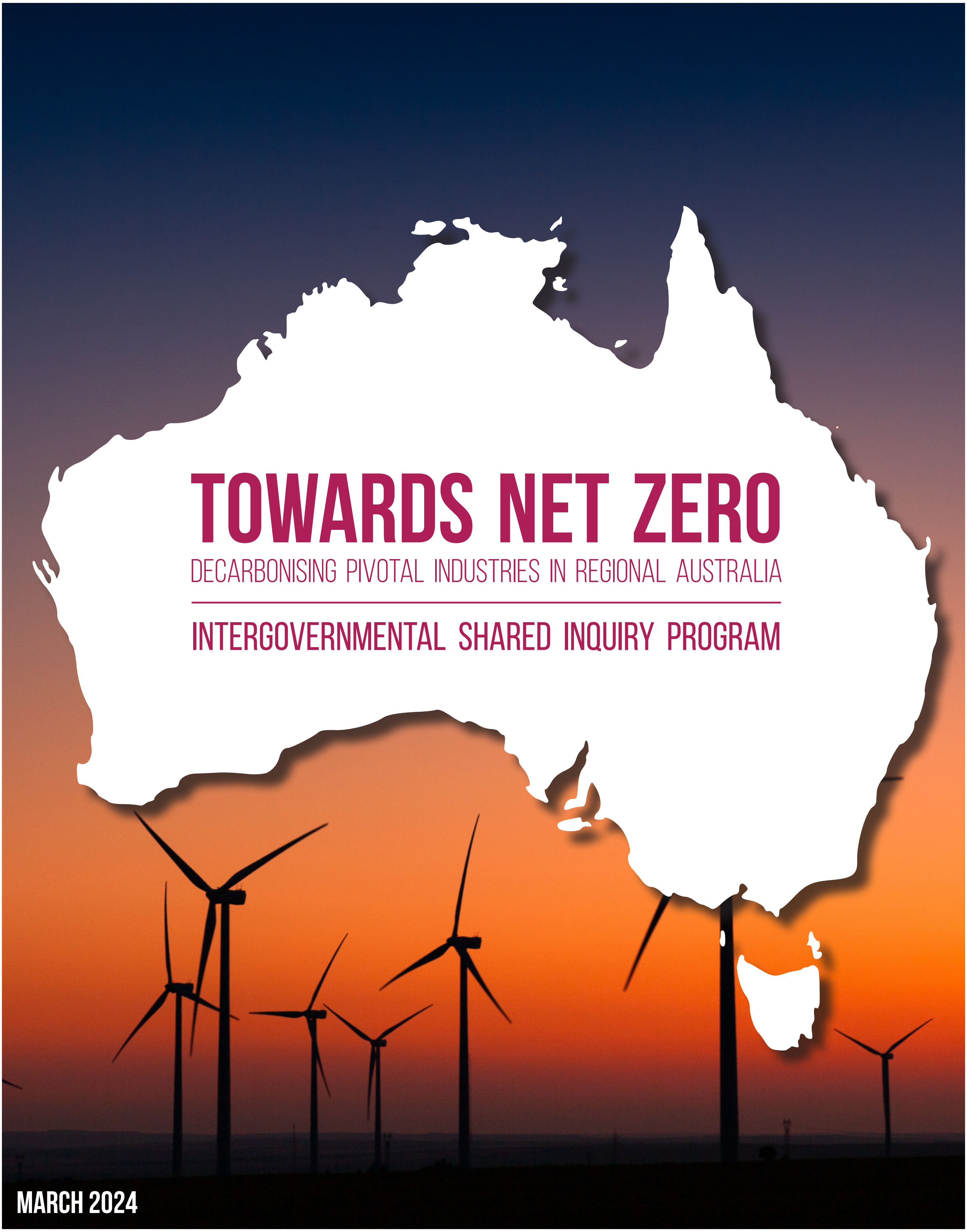
## INTERGOVERNMENTAL SHARED INQUIRY PROGRAM



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# ABOUT THE REGIONAL AUSTRALIA INSTITUTE

The Regional Australia Institute (RAI) is the nation's first and only independent think-tank dedicated to empowering Australia's regions. We are a not-for-profit organisation that undertakes research to stimulate and activate our rural and regional communities.

RAI celebrates 13 years in 2024. We are proud of the vast array of research, data, and detailed insights the RAI has provided into many of the significant issues and challenges facing regional Australia. The work of the Institute is made possible through research partnerships with Federal and State governments, the national Regions Rising event series, regional consultancy projects, membership, and philanthropic funding.

The RAI exists so that decision-makers at all levels of government, not-for-profits, industry, and community have the information they need to ensure the best outcomes for regional Australia. By replacing myths and stereotypes with facts and knowledge, the RAI builds bridges between city and country Australians.

**We care about the regions, because when our regions are strong, Australia is strong.**



## ABOUT THE INTERGOVERNMENTAL SHARED INQUIRY PROGRAM

This report is funded through the Regional Australia Institute's *Intergovernmental Shared Inquiry Program*. The program delivers an annual public interest research agenda focussing on topics of strategic importance to regional Australia through a partnership with federal, state and territory governments.

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The analysis in this report was prepared for the RAI by *Constructive Energy*, a regionally based energy consultancy firm specialising in developing renewable energy projects for regional Australia.

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# EXECUTIVE SUMMARY

This report is the second of four prepared by the Regional Australia Institute in 2023/24 looking into issues affecting regional communities in the transition to net zero emissions by 2050. The report investigates the challenges and opportunities of decarbonising the main fossil fuel consuming industries in regional Australia.

Some industries will face a more difficult pathway in the transition to net zero, particularly in regional Australia, which relies heavily on fossil fuels. The transport, mining, agriculture, and civil engineering industries are considered particularly difficult to decarbonise. How these industries reduce emissions will have a significant impact on the total transition experience of regional Australia.

This report provides an analysis of the potential pathways to decarbonisation in key regional industries.

A clear finding of the analysis is that there is unlikely to be a universal, singular alternative non-fossil fuel source – at least over the short-to-medium term. Within each sub-sector of each industry, there is likely to be a different ideal energy source. It is not simply a matter of hydrogen vs electrification vs low carbon liquid fuels, but rather what is best for each industry in each place.

There are a number of constraints on the pathway to decarbonisation. These include relevant skills and knowledge of users; vehicle life cycle and long-term contractual arrangements; level of remoteness of the community; cost – both upfront and ongoing; grid capacity for, and location of, charging stations in regional areas; and notably, the reliance upon foreign technological transformation. Regrettably, little of the research and production of these future technologies will occur within Australian borders. Global supply chains, and Australia's limited manufacturing capabilities result in much of the equipment being imported. For better or for worse, Australia is bound by the timeframes of our international partners. As a consequence, the decarbonisation pathway of many vulnerable communities in regional Australia will be subject to global trends. There are, however, some opportunities for Australian policy intervention.

Recent developments in Australia's political enabling environment have put Australia on good footing for achieving net zero emissions by 2050[1], however this will require an unprecedented global technological push. Opportunities for Australian policy intervention include supporting the rollout of charging stations; incentives for electric vehicles; a price for carbon; and an emissions trading system. Many of the renewable energy technologies require economies of scale and scope to be an economically viable alternative. In many of the small, vulnerable communities in regional Australia, this will require a collaborative regional approach rather than relying on action undertaken purely at an individual community level. Working with local communities, their surrounding regions, and supporting place-based initiatives will be critical for government and industry over the coming decades.

# REPORT INSIGHTS

Regional Australia faces unique challenges in reaching net zero including a high dependence on fossil fuel consumption, particularly in the key industries of transport, mining, agriculture and civil engineering. The report found that:

- All the industries examined are largely reliant upon imported technology and equipment. However, there are opportunities domestically to influence the rate of adoption.
- The two most prominent alternatives to fossil fuels are hydrogen-based and electrification.
- Regional communities, government and industry all have a role in the strategic planning and implementation of place-based, collaborative solutions that work for each community.

## TRANSPORT AND FREIGHT

- Regional Australia relies heavily on a functional and affordable freight sector.
- Almost 80% of non-bulk domestic freight in Australia is carried by trucks.
- The most prominent alternatives to fossil fuel in this sector are hydrogen-based fuels and electrification.
- It is likely these technologies will continue to develop in parallel. Bespoke technology solutions will be adopted to meet different needs.

## MINING AND EXTRACTIVE INDUSTRIES

- Australian mining and extractive industries are actively preparing for decarbonisation.
- Decarbonising mobile machinery will be the biggest challenge for the sector due to high energy needs and usage patterns that do not allow for significant downtime.
- The challenge could be addressed by conversion to hydrogen, or battery technology with appropriate battery swap systems.
- Incentive and penalty mechanisms may be required to bring forward change in this sector.

## AGRICULTURE

- The agriculture sector is simultaneously resistant to change and highly innovative.
- Primarily driven by financial and environmental sustainability, it is likely that many farmers will rapidly change practices if the risk is low enough and profitability high enough.
- The diversity of the agriculture sector means that a wide range of decarbonisation strategies will be required, tailored to individual streams within the sector.

## CIVIL ENGINEERING

- At this stage, there is limited uptake of decarbonisation in the civil works sector.
- However, the uptake of electric or hydrogen-fuelled machines could happen quickly if suppliers can reach a cost-competitive capital expense, or subsidies reduce the gap, particularly for smaller plant.

## HEAVY INDUSTRY

- Achieving net zero for heavy industry will be difficult and requires a significant capital expense spread across both private and public infrastructure.

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# 01. INTRODUCTION

This report is one of four produced by the Regional Australia Institute (RAI) in 2023/24 looking into issues affecting regional communities in the transition to net zero emissions by 2050.

This research was conducted under the Intergovernmental Shared Inquiry Program, which is jointly funded by the Commonwealth Government and the governments of South Australia, Victoria, Queensland, Western Australia and New South Wales. The thee companion reports from the research program are:

- *Towards Net Zero: Fossil Fuel Dependency in Regional Australia*
- *Towards Net Zero: Net Zero Transition Pathways in Regional Australia*
- *Towards Net Zero: Empowering Regional Communities*

This report examines the challenges and opportunities in decarbonising the main fossil fuel consuming industries in regional Australia. The companion analysis in the report *Toward Net Zero: Fossil Fuel Dependency in Regional* Australia showed that regional Australia's economic activity is underpinned by fossil fuel consumption in four main industries:

- Transport and freight
- Mining and extractive industries
- Agriculture
- Civil engineering

How these and other key industries transition to reduce carbon emissions will have a significant impact on the overall transition experience in regional Australia. But, while there is scope for some local and national innovation, these are global industries subject to global patterns of investment in research and development. As such, Australia is a small player in the technological innovations expected to drive decarbonisation in these industries.

This report presents an overview of current progress and trends in decarbonising these key industries, as well as heavy industry as a difficult to decarbonise sector. The analysis in the report was prepared by Constructive Energy, a regionally based renewable energy consultancy firm. It provides valuable information for regional leaders and policy makers about the trajectory that decarbonisation is likely to take, and issues needing particular attention.

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# 02. TRANSPORT AND FREIGHT

This chapter considers decarbonisation in the transport sector. The first section focuses on freight as a key regional industry facing specific challenges to decarbonise. The second section summarises decarbonisation options for other forms of transport as part of the broader net zero transition.

## 2.1 FREIGHT

Regional Australia relies heavily on a functional and affordable freight sector. Over the past 40 years, the percentage of freight delivered by rail and shipping has declined while the percentage of road freight has increased:

> **In 1976-77, trains transported 22.8% of domestic non-bulk freight in Australia, while trucks took 65.5%. By 2021-22, trains transported 16.7% of domestic non-bulk freight, with trucks taking 79.8%. Coastal shipping has also dropped significantly, from about 13% in the mid-1970s to less than 4% in recent figures[2].**

Accordingly, this report focuses on road freight or trucking in our exploration of potential decarbonisation pathways.

According to the *Australian Bureau of Statistics*, trucks consumed some 14,145 megalitres of petrochemical fuel in the 2020 financial year. Just under 90% of this was diesel and the average fuel consumption varied from 53.1 litres per 100km for articulated trucks, to 28.6 litres per 100km for rigid trucks, and 12.8 litres per 100km for light commercial vehicles.

These figures provide a sense of the big picture energy requirements of the trucking fleet and the scale of the transition required to decarbonise. In addition, there are practical considerations for accessing alternative fuel supplies including:

**Time taken to refuel/recharge** – while drivers must rest frequently, time not in motion costs money.

**Location of refuelling/charging stations** – stations must be strategically placed to integrate with delivery schedules and meet the needs of vehicles with different distance and battery capacities.

**Supply of refuelling/charging stations** – the existing distribution network may or may not have capacity to deliver large amounts of energy quickly to a truck station and the energy supplied must be cost effective.

Additional factors likely to influence the uptake of new technologies include:

Capital cost – while significant, fuel is a marginal cost in the context of capital, on-costs and running costs. The capital gap between internal combustion engines (ICE) and new alternatives needs to be around 10-15% to 'pay-back' fuel savings within 5 - 10 years.

Service and maintenance – will the new technology offer reduced operation and maintenance costs?

Skill/knowledge/experience base - at present this is highly limited leading to low confidence.

Insurance, finance, existing commercial arrangements, vehicle life-cycle – it makes no sense to retire a good vehicle and many trucking companies are 'tied up' in lengthy brand supply arrangements.

Another important consideration is that different vehicle types will require different solutions. Larger fleet, long-haul trucks typically complete longer, overnight journeys. These trucks need to carry more energy with them and would require high-capacity charging infrastructure in or around major route nodes. Smaller fixed-body trucks completing regular routes and/or return-to-base schedules could recharge overnight.

Current decarbonisation pathways for the freight sector consist of three main technological approaches analysed below:

- Low carbon fuels (biofuels and synthetic fuels made using renewable energy)
- Electrification
- Hydrogen



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### 2.1.1 LOW CARBON FUEL

It would be convenient to simply replace a non-renewable liquid fuel with a low or net zero carbon equivalent, such as biologically derived diesel. However, there are a range of barriers to this approach including financial viability, conflict with food security (particularly for first generation biofuels) and supply reliability. This is not to say that biofuels, renewable diesel or waste-derived fuels will not have a role, but that the role is likely to be a small, localised or niche. Studies have shown that the energy taken to grow first-generation biofuels heavily diminishes their carbon reduction value and that there is not enough arable land in Australia to meet the needs of our economy[3]. Incorporating a mix of first-generation and second-generation biofuels can help to meet this demand without unnecessarily increasing pressure on other uses of agricultural land.

The *Australian Bioenergy Roadmap* identifies 'hard-to-abate' sectors (renewable process heat, aviation fuels and gas grids) as market opportunities for bioenergy with a smaller subset in road transport biofuels. The lead driver of uptake is seen to be consumers' growing awareness of, and comfort with, biofuels. In this sense, biofuels are starting a long way behind battery electric vehicles (BEV) and even hybrid-electric vehicles. Anecdotally, resistance to biodiesel in large diesel engines remains high even though some manufacturers, such as *John Deere*, have approved the use of biodiesel in certain engines subject to fuels meeting national standards.

Synthetic fuels enjoy reduced resistance from consumers due to their chemical similarity to mineral oil-derived fuels and ability to control 'feedstocks'. The development process involves a source of green hydrogen being bonded with a source of carbon (atmospheric, industrial, biological) through synthesis and a trial plant is currently being developed in Tasmania backed by *HIF and Porsche*.

The inherent inefficiency of deriving synthetic fuels compared to simply powering a BEV may mean that in most cases the economics do not work in its favour. The process is very helpful, however, in deriving a wide range of necessary hydrocarbon liquids, from methanol to advanced lubricants, virtually all of which are currently imported and critical to industry. While fledgling at present, the growing ecosystem of enterprises pursuing both renewables, hydrogen and carbon reduction/sequestration could drive an important niche sector for which transport fuel is part of a value stack.

## 2.1.2 ELECTRIFICATION

Using approximations, one litre of diesel is equivalent to about 10 kWh of electrical energy. The conversion of energy from diesel into motion (e.g. a moving truck) is only about 30% efficient. Conversion of electrical energy into motion is closer to 90% efficient. However, there are 'round trip efficiency' losses that mean around 10% of the energy that goes into charging a battery is lost. These factors combined lead to a reasonable working figure of 80% efficiency.

Real life testing from *Volvo* with their FH Electric 40 tonne articulated truck resulted in energy consumption of 1.1 kWh per km and a 345 km range. If we assumed that the entire articulated truck fleet in Australia was equivalent (and ignored the impact of charging times) then the 8,181 million km travelled would require 8,999 GWh of electricity plus 10% for battery losses = 9,899 GWh of charging capacity.

To put this figure into perspective, Australia's total electrical generation in 2020 was 265,232 GWh[4], so electric articulated trucks would have consumed 3.7% of the national energy budget. Extending this logic to the entire truck fleet results in a required charging capacity of 37,863 GWh or the equivalent of 15.7% of national annual generation. Interestingly, using a figure of 30c per kWh as a charge rate leads to a combined 'fuel cost' of $12.5 billion compared to $21.4 billion with diesel at $1.50 per litre.

The prevailing argument against battery electric trucks has been limited range (partly due to the weight of batteries) and the time and inconvenience of recharging. This remains true if the battery is fixed within the truck, however there are examples emerging where expired batteries can be swapped for fully charged ones in a matter of minutes – equivalent to the time taken to refuel with diesel. *Reports* from China indicate very high growth rates in the uptake of heavy-duty electric trucks and associated charging stations where batteries are swapped automatically. Trials are also occurring in Australia.

A battery swap system could work well for trucking companies with regular routes. The separation of battery recharging time from waiting time is an important enabler. In addition, drivers report increased satisfaction, reduced fatigue, and 'game value' from trying to return to base having maximised the regenerative charging capacity of the truck to return the battery with higher residual charge. An Australian *example* of this was reported recently through a trial by Holcim, a supplier of aggregate from quarries, where there is potential for a fleet of trucks to deliver and return to base.

Apart from the fleet economics, there are limitations associated with the location of charge stations. Recharging facilities can only be located where there is capacity within the electricity distribution network to deliver large amounts of energy. Where a fast car charger might have 50 kW capacity, truck charging stations require around 200 kW capacity and there are fewer opportunities to introduce a new 200 kW load into the network than there are for 50 kW loads. Interestingly, a by-product of placing these battery banks around the electricity network would be the ability to offer network services (Frequency Control Ancillary Services) which would result in an additional revenue stream to the operator. In regional Australia, most towns and cities have trucking companies located in industrial estates where network capacity is more likely to exist for overnight or faster battery pack charging. Most of these operate return to base and/or repeat routes tied with major facilities.

Battery electric trucks are unlikely to work in all applications, however there are strong drivers for their uptake including:

- Measurable carbon reduction
- Price certainty for fuel
- Energy security
- Reduced maintenance

BEV trucks may present a viable solution for many regionally based trucks, particularly rigid body and smaller delivery trucks.

The Federal Government is developing a National Battery Strategy and National EV Strategy for which consultation has already occurred. Paired with the National Reconstruction Fund, this represents an opportunity for regions to support development of concepts outlined in this report.



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## 2.1.3 HYDROGEN

While the Federal Government has advised a *target price of $2 per kilogram for hydrogen*, there are existing smaller projects currently reaching approximately $5 – 6 per kilogram. Volvo and Scania both produce hydrogen powered trucks that are in advanced testing stages with a view to being commercially available in the second half of this decade. These companies already produce several battery electric trucks so the move to replace a battery with tanks and fuel cells is relatively straightforward.

Early reports stated that these trucks had a range of 200km and consumed around 1kg of hydrogen via fuel cell for every 80km travelled. At $5 per kg this equates to 6.25c per km. Diesel consumption for an equivalent truck is approximately 12.5L per 100km. At $1.50 per litre for diesel (after rebate) this equates to 18.75c per km.

Based on these simple economics, at $5 per kg for hydrogen fuel, a hydrogen truck is about one-third of the cost to run as the same diesel truck, however published figures vary widely. While there are potential advantages in running costs, remaining barriers to uptake include:

- Current capital expense premium of hydrogen trucks
- Fears around the explosive nature of hydrogen
- Challenges in distributing and storing hydrogen
- The absence of a refuelling network.

High capital expense compared to conventional ICE trucks can be mitigated by carbon abatement values to some extent and the current large premium could be expected to reduce with higher production volume if that occurs. In that regard, it is an advantage that the drive train is the same for both BEV and heavy electric vehicle (HEV) trucks. Safety fears can be addressed in the same way they have been with hydrocarbon fuels which are also explosive and toxic.

Distribution and storage challenges may be addressed through node and/or return-to-base applications which mitigate the need to transport and store hydrogen over long distances. This model ties well into regional renewable energy generation and distribution where, rather than having fuel trucks arrive from major capital ports/refineries, the fuel can be manufactured and consumed locally.

Hydrogen can also be injected into internal combustion engines and several truck manufacturers are proceeding down this path. The advantage of this approach is that existing fleets can be converted, and existing skills can be applied. However, detractors point to ICE consumption of hydrogen as being an inefficient use of a fuel that takes more energy to produce than it delivers. It takes about 50 kWh of electricity and 9L of water to make 1kg of hydrogen which can release about 33kWh of electricity via fuel cell. The efficiency of turning this energy into work via internal combustion would be significantly lower than via fuel cell.

Efficiency is, perhaps unintuitively, not necessarily a 'showstopper' in relation to hydrogen as a transport fuel. With increased renewable penetration in the national energy market, there are times when energy is very low- and even negative cost. Individual installations can be viable with vast periods of redundancy, such as solar installations on facilities that only operate on weekdays or irrigation pumps that operate seasonally. In this instance, hydrogen can be generated and stored sporadically as a value add to electricity generation that would otherwise be wasted. If these circumstances coincide with a regional hub-and-spoke or return-to-base delivery model, hydrogen may have a strong case.

There are several private enterprises actively pursuing hydrogen projects for transport fuels and ARENA has funded three commercial-scale renewable hydrogen projects and 16 research projects. The private enterprise projects are pursuing hydrogen for refuelling long-haul trucks between major industrial activity centres. In a *Media Release* from Tara Moriarty, Minister for Regional NSW, regarding Australia's first commercial hydrogen refuelling station at Port Kembla, the Minister makes the comment that, 'The H2 Station will be the first practical piece of enabling infrastructure towards de-carbonising the region's 7000 heavy vehicles as we move towards a cleaner, greener future.' As discussed later in this report, mining companies are also currently considering hydrogen.

Based on the CSIRO National Hydrogen Roadmap, the Australian Government developed a *National Hydrogen Strategy* in 2019 which is currently under review. The document highlighted several pilot projects underway in each state and territory and included the concept of Hydrogen Hubs. While strongly focussed on tech development, export and gas injection, the report includes objectives around increasing the uptake of hydrogen in the freight sector.

## 2.1.4 THE WAY FORWARD FOR FREIGHT

While hydrogen is receiving significant attention and investment as a potential transport fuel, the emergence of rapid-charge large truck batteries is a significant step to overcoming the recharge time barrier for freight activities. With a simpler set of technical and regulatory challenges, many decision-makers may step towards BEV freight rather than hydrogen. The rapid growth in BEV cars in the non-commercial market is also normalising this technology. Smaller delivery trucks and vans will most likely be the first to electrify, then back-to-base short haul, followed by larger fleet long-haul.

Hybrid ICE + BEV technology is likely to have a mid-term role, particularly in smaller commercial vehicles that can leverage the technological development that has occurred with hybrid SUVs for example. Despite their complexity and resource intensity in production, plug-in hybrid vehicles are seen as a viable pathway to reducing fossil fuel consumption while addressing the ‘range anxiety’ experienced particularly by regional Australians. Over time it is anticipated that the case for this approach will diminish as battery technology provides longer ranges (Toyota proposes 1,500 km range in the next five years with solid state batteries) and fossil fuels become increasingly undesirable.

Battery recharge stations can also be operated to recharge batteries at optimal times in terms of pricing and the batteries can also be applied to deliver grid stabilisation services when not being deployed on trucks. The stations do, however, depend on network capacity.

Advanced biofuels may have a transitional role to play in the heavy trucking industry, where heavy vehicles require a higher energy density fuel than electrification can provide.

Hydrogen fuelled trucks may be successful when tied to industries/enterprises that have other reasons to generate hydrogen, such as low-cost, excess electricity or other hydrogen-related processes such as the production of ammonia. Alternatively, a long-haul trucking firm controlling production and pricing of fuel on regular routes could make for a compelling case for change. Overall, the higher capital cost and lower volume of hydrogen powered cars will make it difficult for them to compete with BEVs in the open market.

## 2.2 OTHER TRANSPORT AND FREIGHT

In addition to freight, regional Australia relies on a diverse range of other transport services. Nearly all industries rely on transport to some extent and are serviced by a wide range of vehicles, including bikes, cars, vans, modified vehicles (ambulances, accessible taxis, emergency services), buses, trains, aeroplanes, and boats.

### 2.2.1 SMALLER VEHICLES

Decarbonisation of smaller vehicles is already starting to occur and factors such as reduced running costs, energy security, and cost control will likely increase the rate of uptake. While still some time away from ubiquity, driverless vehicles also have the potential to offer emission reduction by reducing the number of vehicles required for an enterprise. At present most cars spend most of the time sitting stationary in a garage or car space. Automation offers the capacity for these vehicles to be deployed as required, to provide mobility for people and products. Reducing the number of vehicles overall is the most effective carbon reduction strategy because it also avoids embodied emission from producing and disposing of the vehicle.

### 2.2.2 RAIL

Outside of major metropolitan railways, the railway network is dependent upon diesel powered locomotives. Tokyo is an example of a city that has already converted all commuter trains to renewably supplied electricity while looking toward hydrogen for rural, non-electric locomotives. The Australian Financial Review pointed to challenges facing the Australian rail sector, quoting executives from Pacific National and Aurizon, who foresee a long transition pathway interdependent with the mining sector’s transition from diesel to hydrogen powered drivetrains. As for freight, much of the barrier to change is around long-term service contracts, financing, and capital recovery models necessary to de-risk investment in rail.

It is worth noting that decreasing Australia’s reliance on road freight would have potential decongestion and safety benefits (safety risk to passenger transport), as well as carbon reduction benefits. Whilst a national net zero pathway for freight will likely need an increase in the share of freight transported by rail, which is a lower emissions mode of transport – this has less relevance to regional Australia as many areas are not adequately serviced by rail lines.

### 2.2.3 AIR

The fuel substitution argument for flight is similar to that for ground-based vehicles - hydrogen versus electric, versus sustainable air fuels. Similarly, the solution is probably not ‘either/or’ but a matter of ‘if/when’. It is likely that short-haul regional flights could be electrified within this decade (with commensurate augmentation of electricity supply infrastructure) but, unless there is a major breakthrough with battery energy density, liquid fuels will continue to be required for long-haul and international flights. Synthesized fuels and biofuels could have a role but given land use competition, are unlikely to be the only solution. A hydrogen economy developed for mining, shipping and heavy industry would naturally align to aerospace, particularly if the hydrogen plant is co-located with a suitable waste carbon source. In the short term, aviation fuel derived from plastic and other waste streams is also expected to have a role, however, in the long term, the dependency of this approach on an energy-intensive process and a carbon-intensive, potentially unreliable feedstock, may be problematic.

However, the need for aircraft at all is being alleviated by rapidly advancing drone technology, which is predominately battery electric powered at the smaller size but can be liquid or gas fuelled where higher payloads and longer range is required. Pipe and powerline control, survey and photography, and search and rescue are now being actively targeted by drone operators and it is likely that the pace of technical innovation and demographic/ economic factors will lead to more applications for drones. Attempts to substitute fossil-derived aviation fuels with ‘green’ fuels for large aeroplanes represent an approach aimed at keeping the status quo, not a systemic refresh of how humans move over large distances in short timeframes. This paradigm may be seriously challenged by the full suite of biophysical and geopolitical factors at play in the coming years. That said, the enormous legacy infrastructure and established systems create strong drivers for simple substitution of fuels.

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## 2.2.4 BOATS

Boating in regional areas is understandably biased toward coastal regions where commercial operators exist primarily for fisheries and tourism. A small fleet of agency boats exists on inland and estuarine waters, however the vast majority of vessels are used in private recreation and tourism. There is little evidence of any serious effort to decarbonise recreational boating in Australia, likely based on the very small percentage of emissions they are responsible for. That said, Mercury is one example of small vessel outboard manufacturers actively developing electric outboard motors as part of a strategic objective to lower emissions by 80% by 2025. At the larger commercial scale, Yamaha and Toyota are developing a hydrogen fuelled V8 engine for marine applications and there are several examples globally of hydrogen powered passenger ferries in development, including one in Gladstone.

While electric outboard motors may be applicable for some commercial fishers, such as oyster and estuarine prawn fishers, deep sea operators require high-horsepower, long range engines with a preference to weight minimisation. Hydrogen and low carbon fuels are more applicable for this scenario than battery electric power based on current battery energy density.

## 2.2.5 THE WAY FORWARD FOR TRANSPORT

Decarbonisation of the modes of mobility is as diverse as the various vehicles and applications themselves. Despite varied levels of readiness, it is true to say that effort is being placed into sustainable energy technology alternatives for all applications. A potential factor slowing decarbonisation in this instance, is the relatively small contribution to emissions of each subset. There is also a high level of capital investment into the vehicles included in this segment. This is likely to slow transition as operators seek to pay back the investment over longer timeframes unless simple fuel substitution or retrofitting technology becomes available and economically compelling.

While it would be convenient, it is unlikely that a silver bullet will emerge to provide low-carbon transport and power fuels. In the same way that grid electricity is changing from centralised to distributed energy, there are a wide range of bespoke motive power solutions emerging, many of which only make sense in their specific local context and geography.

The decarbonisation of transport may form part of broader circular economy approaches in regional Australia, where decarbonisation is considered in each part of the economy. For example, a regional council waste management centre incorporates a plant to convert dirty, mixed plastic into synthetic diesel which is used for tip-face heavy machinery. The garbage trucks run on hydrogen created from wastewater and excess solar, and the council fleet cars are all BEVs charged overnight.

# 03. MINING AND EXTRACTIVE INDUSTRIES

Mining is a key regional industry, contributing substantially to regional economies. This section considers decarbonisation of mining and extractive industries, including forestry, from the perspective of extraction and processing.

## 3.1 QUARRIES

For quarries of materials for civil construction, such as road base, highweight and low material values have resulted in multiple quarries located close to regional cities and towns. These are mostly modest in scale and involve a mix of drilling, blasting, digging, trucking, crushing/screening, and distribution. Where crushing is involved, the quarry will typically have a robust electrical supply, although it is common for diesel powered mobile crushing plants to operate in quarries. Permanent sites will also have on-site diesel storage for the heavy machinery that operates on-site, while fleets of trucks, usually local contractors with their own base, cart product direct to sites of civil works.

Mining operations tend to be larger in scale and the quarry/pit is typically closely located to a processing plant. Historically, Australian miners have limited the processing of mineral ores to producing concentrate, which is shipped overseas for refining, apart from some prominent examples including Mt Isa, Kambalda, and Gladstone. While there are remote diesel and gas powered mines, most mines are grid connected, using large volumes of electricity to operate crushing, milling and processing plant, pumps and fans (for underground mines), and buildings.

Open cut mining has been almost exclusively diesel powered for nearly a century, however electric underground mining equipment has existed for some time. This is in part because of the problem of exhaust pipe emissions in confined spaces and the fact that high-capacity electric cables are already run underground for ventilation, pumps, and lighting. Electric underground drilling rigs have been in operation for many years and increasingly manufacturers are offering battery electric haul trucks which are reported to have increased carrying capacity, with the advantage of no toxic emissions. Larger mines are leading early efforts to find alternative power sources for mobile plant and, as for the freight sector, there are advocates for both BEV and HEV powertrains.

There are two key factors for solution providers to deal with:

- Dump-trucks and haul trucks are usually required to operate continuously.
- Heavy plant is less mobile and it may be impractical to return to a refuelling station.

Advocates for hydrogen point to its capacity to address both these issues and examples of large haul hydrogen powered trucks already exist. Biofuels or renewable diesel would also be applicable for mobile plant. For less mobile plant, manufacturers are offering electric cable supplied machines. Volvo for example, is supplying all electric 50 and 100 tonne excavators which are 'plugged in' to an electrical supply. This approach already occurs in mining operations where a predictable pattern of excavation occurs, such as along a continuous bench of coal.



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## 3.2 FORESTRY

Forestry shares some common features with mining, in that a raw material is extracted and transported to a central processing plant. The primary difference is the area of extraction which commonly covers hundreds of square kilometres of forest. As part of a research and development project, Swedish forestry machinery supplier *Regal* expressed the challenges well:

> **'Electrification of machinery and vehicles within forestry and agriculture faces unique challenges compared to automotive applications. As forestry and agricultural machinery operate in rural or off-grid areas there is limited or no access to charging infrastructure. A wide range of duty cycles, operating hours and often seasonal use are also obstacles when electrifying forestry and agricultural machinery. Some machines are in operation non-stop during a full day or even several work shifts during high season. In these cases, the cost and weight of a large battery is high, and downtime due to charging during operation is not acceptable. In the other end of the range is specialised machinery only used for a specific task or during a limited time period during the season, as the utilisation rate is low, the cost of a battery electric system significant. In addition, the production volumes are small which makes it even more difficult to launch new innovative solutions, especially for small or medium size companies.'**

The Regal solution was to develop a 'modular battery swap system and electrify a combi forestry machine (forwarder and harvester combo) and an autonomous tractor'. It is not apparent how widely this approach has been adopted in Sweden or globally. However, the case study indicates serious attention being paid to the issue.

Timber mills and forest product processing plants are currently powered by electricity (saws, milling, etc) and gas or timber waste combustion (kiln drying). Substitution of electricity for renewable sources can be readily achieved, however, decarbonising the kiln-drying process is likely to be more difficult. Electric heating options do exist but may be constrained by existing network capacity given that the operating mills were constructed at a time when gas / biomass was seen as the lowest-cost, most effective heat source.

## 3.3 THE WAY FORWARD FOR MINING AND EXTRACTIVE INDUSTRIES

Australian mining and extractive industries are actively considering and preparing for decarbonisation. The process is straightforward and compelling in relation to those operational elements that are already electric, such as milling and processing. The largest challenge for these sectors is mobile machinery which has high energy demand and usage patterns that do not allow for significant downtime periods. This challenge could be addressed by conversion to hydrogen, or battery technology if battery swap or cable-drag systems can be implemented easily.

While preparation for decarbonisation is visible across the industry through discussion at forums and advertising in trade magazines, observationally it appears that some operators have no immediate plans to change. Many smaller businesses appear to be waiting for the larger operators to develop solutions that they can later adopt. This is exacerbated by the reality that machines are high capital cost items and often tied up in long term supply and service contracts.

Effective motivators will need to be applied as both incentive and penalty mechanisms to bring forward change in this sector.

# 04. AGRICULTURE

This chapter considers a diverse range of decarbonisation options across the agricultural sector. Actions are already underway in Australia to reduce emissions in the agriculture industry. The National Farmers' Federation has adopted a *Climate Change Policy* that supports the aspiration of net zero emissions by 2050 provided that:

- 'There are identifiable and economically viable pathways to net neutrality, including impacts from inputs such as energy; and
- Commonwealth and State legislation is effective, equitable and helps deliver on-ground programs that benefit agricultural interests and do not create unnecessary regulatory impediments.'

States are getting active too. For example, the Queensland Government recently released its *Queensland Agriculture Low Emissions Roadmap 2022-32* which was based on research by CSIRO into possible *Low Emissions Pathways for Queensland Agrifood*.

These policy statements go beyond reducing reliance on fossil fuels in the agriculture industry to address wider transition issues.

When considering fossil fuel reduction in the agriculture industry, this report uses the labels 'traditional' and 'industrial' to distinguish between different types of farming operations.

Traditional farms are held primarily by family units and typical operations include grazing, horticulture and broadacre cropping. Energy demands for these operations typically include homes, sheds, vehicles, some tractors, bikes, small plant and equipment, pumps (both liquid fuel and electric) and generators.

Industrial farms tend to be corporate owned and include feedlots, glasshouses, dairies, and large-scale horticulture such as fruit, tree nuts and vineyards. The operations tend to be more intensive in every sense, often drawing a significant energy demand but also producing large volumes of energy-rich 'waste'.

There are multiple machines that can be readily decarbonised on farms including bikes, mowers, small tractors, chainsaws, and other personal tools. The market for these exists and is growing with the realisation that the convenience of battery electric solutions outweighs the momentum for ICE versions. As an indication, Makita has stopped all research and development into ICE power tools and most garden and commercial landscaping companies are offering electric alternatives.

However, large tractors and harvesters remain problematic due to the challenge of usage patterns including the requirement for sporadic, remote, and intensive use. The natural inclination is to seek an applicable replacement source of energy and, again, most major brands are promoting the development of battery and/or hydrogen machines. There could be a stronger case for hydrogen in this scenario due to the ability to work within existing limited distribution network capacity to gradually build up reserves of on-farm or nearby hydrogen, ready for periods of intensive consumption.

Battery swapping would also be applicable except for the fact that, at a district level, cropping activities such as harvesting all tend to happen at the same time. Even if network capacity existed, a large number of batteries would be required to sequence recharging and use. This seems expensive, resource intensive and an inefficient use of resources.

Regional energy distribution networks were not designed to deliver large amounts of energy in short time periods to farms. Figure 1. shows a portion of the distribution network near Narromine, NSW, a region of broadacre cropping and bore watering. Connection points close to town have around 200kVA transformers in place, suitable to support TESLA fast chargers, for example. However, capacity quickly diminishes and the furthermost connection at the bottom left of the image is supplied with a 25kVA transformer, enough to run the home plus sheds and a modest EV car charger only. This is typical of the network surrounding townships throughout regional Australia, within a few kilometres of an urban centre there is most often very limited capacity.

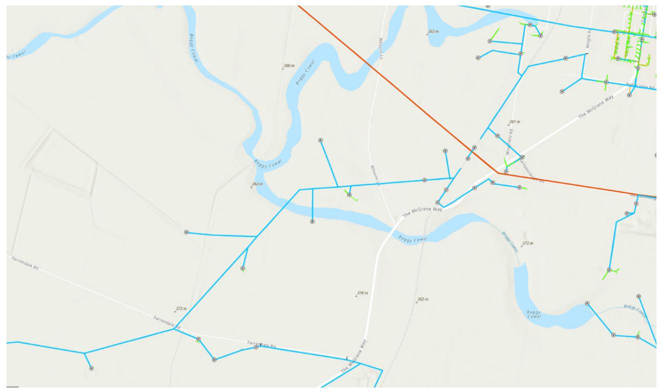

*Figure 1. Extract from Essential Energy Network*



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Reflection on network limitations leads to questions about the role of distributed point source generation and non-network energy distribution systems. For example, a 200kVA diesel bore pump could be replaced by a solar-electric plant. However, for most of the year the solar sits idle. Could this capacity be harnessed to produce hydrogen/ammonia, slowly building up reserves in the 'off-season'? The emergence of metal hydride storage technology could be an important enabler for this, and the energy density of such batteries mean that a shipping container could hold as much as 15MWh of energy – enough to power a 500hp/372kW tractor for about 35 hours.

The era of super-large tractors may be limited. In the face of technical innovation, robotics, regenerative agriculture and changing societal expectations, there is a move towards alternative proteins, zero-till farming and automated, swarm, robotic agriculture, for example. Such a view is radical, however not unforeseeable.

The farmers and agricultural enterprises engaged with by the authors generally share the same short list of motivators in the move towards decarbonisation:

**Cost control** - Escalating and uncontrolled energy costs are a source of stress which farmers would like to remove.

**Energy security/independence** - The thought of being self-sufficient is attractive to many agricultural enterprises, as long as it does not become 'another thing to worry about.' Affordability of diesel and the primary producer rebate persisting are more front-of-mind risks for farmers than availability per se.

**Sustainability** - Both as a part of being custodians of enduring enterprise and for market access and increasingly conscious consumers.

Aside from the emissions associated with the machines of modern agriculture, agricultural practice itself can be a source of emission or sequestration. Methane emissions from animal digestion can be limited through dietary supplements, but only limited. It is highly likely that farming communities will need to adapt to a complex and dynamic mix of decision drivers and unlikely that the status quo will continue unchanged.

A *2015 report from CSIRO* into land sector potential for sequestration found that 'carbon and environmental plantings were projected to be the most profitable land use across large areas of Australia's intensive agricultural zone by 2050 under the very strong (L1) and strong (M3) levels of abatement incentives.'

Fertilisers are also a significant source of climate damaging emissions both in production and use. The advent of technology to generate anhydrous ammonia on-farm as a source of nitrogen fertiliser has gained the attention of broadacre farmers. Pesticides and insecticides also currently bear an embodied carbon load which is not popularly considered.

Regenerative agriculture techniques aim to reduce and even remove the need for external chemical inputs while sequestering carbon and improving biodiversity. These are strong drivers with commercial value that, combined with growing consumer demand for sustainable practices, could see a significant shift occurring in the way agriculture is practiced in Australia, not just decarbonisation of agricultural machinery.

Increased climate variability and market drivers for low-cost foods are likely to result in an increase in controlled-environment horticulture. These facilities require energy for heating, cooling, irrigation, and create carbon emissions, sometimes even pumping CO2 into the growing spaces to enhance plant growth. In our experience, these operators are generally aware of their climate impact and actively working to reduce it, the most famous example being Sundrop Farms near Port Augusta, SA. While Sundrop provides good leadership, other existing operators may struggle to replace gas as a heat source due to network limitations and/or lack of capital to change approach.

Climate change, and specifically climate variability, is a major disruptor for the agriculture sector along with demographic change and geopolitical risk factors. The emergence of plant / bacterial derived protein products may combine with these forces to radically change the way landscapes are used in Australia to provide food and carbon-sequestration services.

Finally, of significance in relation to agricultural decarbonisation are the industrial facilities that aggregate and process farm produce. These include feedlots, abattoirs, tanneries, and food manufacturers. In our consultations, these operators are generally highly aware of the need to decarbonise, driven by factors including energy cost, shareholder pressure, market signals (e.g. EU border adjustments) and Environmental Protection Authority constraints. The processing and manufacturing plants suffer the same challenges as many industrial players, especially in relation to replacing gas for process heat. However, where large amounts of high calorific value biomass are involved, such as feedlots and abattoirs, the ability to use bio-digestion to create methane which is then used to power electrical generators is becoming ubiquitous. Examples include the 180,000-animal Rivalea piggery near Corowa that powers over 80% of its operation, including an abattoir, through methane collection and generation.

## 4.1 THE WAY FORWARD FOR AGRICULTURE

The agriculture sector is simultaneously resistant to change and highly innovative. Primarily driven by financial and environmental sustainability, it is likely that many farmers will rapidly change practices if the risk is low enough and profitability high enough.

Virtually every Australian farming group and cooperative research centre (CRC) has a net zero objective and is undertaking research to support farmers in the transition. The National Farmers' Federation Climate Change Policy is a case in point, supporting Australia's net zero by 2050 policy.

There is concern in the sector that agriculture does not become unfairly burdened because of wider decarbonisation efforts. As former National Farmers Federation president Fiona Simson said, 'A carbon neutral future must not be at the detriment of valuable food and fibre producing land.' However, this statement does not fully recognise the wide range of opportunities and benefits that decarbonisation will provide to the industry.

The agriculture sector is highly diverse and one size does not fit all when it comes to decarbonisation. It is likely that a wide range of strategies will be required, tailored to individual streams within the agricultural sector. Without this, it is likely that the percentage of farming operations actively engaged in decarbonisation will remain around the usual progressive third.



# 05. CIVIL ENGINEERING

This chapter continues the exploration of decarbonisation strategies, covering civil engineering and heavy industry.

## 5.1 CIVIL ENGINEERING

Many aspects of the challenge in decarbonising civil works have been addressed above, however, there are specific factors that require consideration, starting with the delineation between the *three tiers of contractors* operating in regional Australia. Tier 1 firms tend to be city based, highly capitalised and the primary suppliers of services to major infrastructure projects. Tier 2 firms are competitive in local government for modest developments including solar farms and regional subdivisions. Tier 3 are sole operators who tend to survive on farming, housing, and subcontracting to Tier 1 and 2 contractors.

Tier 1 providers are increasingly aware of their environmental footprint, and many provide aspirational statements and some reporting on their websites relating to reducing carbon emissions. Tier 2 suppliers may be involved in works designed to reduce emissions, such as renewable energy projects, but are rarely even aware of, or required to report on, their contribution to a carbon load for any projects. The authors' consultations have found that Tier 3 suppliers display limited interest in the decarbonisation of their activities, primarily based on the absence of demand for such in their client base.

There are tangible and immediate ways that emissions associated with civil works can be reduced, including the use of 'green' concrete, reduced land disturbance, material efficiency, and supply chain preferencing. The machines themselves, however, are almost all powered by fossil fuels. Machine usage is often unpredictable, sporadic, intensive, remote from utilities and interspersed with periods of inaction. Ideally, machines rarely return to a base other than for repairs and maintenance, and refuelling occurs via a mobile delivery truck.

A range of civil plant is already fully electric, ranging from boom lifts to temporary traffic lights. As battery technology improves, and if the economics/logistics of either rapid recharge or easy battery swapping develops, we are likely to see greater application of battery-electric technology in the civil sector. It may be that smaller plant becomes electrified such as skid-steer loaders and excavators developed by Bobcat. This size plant is easy to transport, capable of lasting an eight hour workday and could be recharged overnight. The equipment firm JCB has chosen to focus on hydrogen as a fuel and developed an internal combustion engine suitable for a wide range of machines. JCB maintain that ICE technology is more robust than fuel cells in the dusty, bumpy working environment of their machines.

Both battery and hydrogen solutions are still required to grapple with the practicalities of fuel/energy distribution and plant operation. It is impractical for large plant to return to base or face long periods of downtime. Hydrogen is currently transported in reusable cylinders or trucks and legislators are aware of and developing Australian Standards for the manufacture, storage and delivery of hydrogen.

At present there are several companies actively promoting existing technologies for transport and a small number of demonstration projects exist in Australia, with more proposed. Hydrogen is potentially viable as a fuel for civil contractors due to the portable nature of the fuel, provided it can be paired with affordable, renewable energy and reasonably short supply/delivery distances.

## 5.2 THE WAY FORWARD FOR CIVIL ENGINEERING

Aside from small case studies and aspirational rhetoric, there is limited uptake of decarbonisation in the civil works sector. There are plenty of examples where the works themselves are being completed in ways to reduce emissions, however the existence of non-fossil fuel alternative machines is at this stage, niche. That said, the uptake of electric or hydrogen fuelled machines in certain contexts could happen very quickly, as has occurred with battery electric tools. If suppliers can reach a cost-competitive capital expense, or subsidies reduce the gap, the superior performance and reduced operation and maintenance costs associated with electric plant may see rapid uptake, particularly for smaller plant.

# 06. HEAVY INDUSTRY

Regional centres are often the location of heavy industry due to more affordable land and distance from major population centres. As a legacy of the coal fired industrial revolution, these areas have traditionally been co-located with fossil fuel resources such as in the Hunter and Latrobe valleys. The emergence of renewable energy challenges the notion of proximity to coal, and opens opportunity where there is land with proximity to renewable resources and/or high-capacity electricity networks.

There appears to be a concerted move to decentralisation in response to population expansion pressures in existing major urban centres and specific efforts by governments to stimulate manufacturing and attract heavy industry into regional areas – such as the Special Activation Precincts in NSW. The following two studies are exemplary:

**Facility A. Food and beverage processor in Tamworth:**

**Current electrical demand** – 7 GWh pa
**Post-gas demand** – 16-23 GWh pa (8 MW Max thermal load)
**Current on-site infrastructure** – 3 x 1,500 kVA transformers
**Supply network** - 11 kVA + Low Voltage

**Facility B. Proposed bio-container manufacturing plant in Bathurst:**

**Projected electrical demand** – 1.3 MVA
**Projected gas demand** – 85 TJ pa. (Converts to 23.6GWh pa)
**Current on-site infrastructure** – 1 x 1,000 kVA transformer
**Supply network** - 22 kVA limited to about 3 MVA

In both scenarios above, significant network and on-site augmentation is required to convert heat creation from gas to electricity. The business case for doing so will be driven by avoided expenditure plus carbon values versus acceptable capital and on-going costs. The business case around constructing a large solar array to power heat pumps behind the meter is strong, however neither of these sites have proximity to sufficient land. There is potential for these companies to explore private high voltage direct supply, however this runs against current regulations.

These examples, and the many thousands like them, demonstrate the difficulties in 'getting off gas' via electrification of process heat. It is common that the distribution network is not capable of supplying the additional energy without significant capital costs for network augmentation – reaching into the millions of dollars for every example we have consulted on to date. This capital hurdle, combined with decision uncertainty and the daily pressures manufacturers are under, make it easier to continue to stick with the status quo with respect to increased gas prices. It is likely that a range of significant push and pull incentives will be required to make an impact on gas usage by heavy industry.

There are emerging alternatives to electrification for process heat in the form of hydrogen and bioenergy. Star Scientific is an example of a startup pioneering efficient conversion of hydrogen to heat which, if commercialised, moves the challenge of network capacity to one of logistics around moving hydrogen gas and/or water.

Likewise with bioenergy, while capable of creating affordable process heat, there comes logistical challenges which may limit its application. Bioenergy from wood products and agricultural by-products (e.g. straw) is well established in northern Europe but uncommon in Australia. Bioenergy Australia has been created to promote the role of bioenergy and facilitate expansion of the sector which the group sees as having a legitimate role as part of decarbonising regional industry. Bioenergy is a valid approach to process heat specifically in the context of industry type and geography. For example, using forest and saw-mill waste to create heat for kiln-drying or using baled straw in cropping regions to power food manufacturing plants.

As well as larger individual industrial facilities, we need to consider the decarbonisation challenge for the multitude of industrial product and service providers in the industrial estates that border every major regional city across Australia. From kitchen cabinetry firms to engineering workshops and specialist manufacturers, cities like Toowoomba service vast areas of mining and agricultural enterprises. The uptake of rooftop solar in these estates has been strong, however gas remains a problem as described above.

Attention is now being paid to the potential for hydrogenation of carbon dioxide that would see carbon-rich exhaust streams treated as a resource. Combined with hydrogen, CO2 can be fixed into methane and other longer-chain hydrocarbons, displacing fossil sources. While in its infancy at present, this approach has merit and may be stimulated by high carbon prices in coming decades once the limits of abatement and sequestration capacity become more obvious.

## 6.1 THE WAY FORWARD FOR HEAVY INDUSTRY

Achieving net zero for heavy industry will be difficult and requires a significant capital expense spread across both private and public infrastructure. Without compelling financial and/or regulatory drivers, the challenge of 'getting off gas' will remain unmet for the medium term. That said, there will be scenarios where bespoke solutions are compelling, particularly in association with biomass or where network capacity is readily available.





# 07. CONCLUSION

Although limited progress has been made to date, decarbonisation solutions are available or in development for every industry described in this report.

In its Net Zero by 2050 Roadmap for the Global Energy Sector, the International Energy Agency (IEA) states that 'net zero by 2050 hinges on an unprecedented clean technology push.' This push is reflected in the 30+ member countries that are now active in research and development, as well as the commercialisation of clean-tech.

Decarbonisation of existing electrical loads is regarded by many as simply a matter of time. The economics of renewable energy technologies are so compelling that many large industrial users with land are considering how to reduce carbon intensity, even if in some instances only, because of economic drivers. This is especially true for stationary diesel electric generation which is now significantly more expensive than battery powered renewable energy supply at all scales.

Replacing diesel fuel remains the greatest widespread challenge for decarbonisation of the regions. While it is tempting to regard the adoption of hydrogen versus battery electric solutions as a race, the diverse contexts for current diesel usage mean that a combination of solutions is likely to be required. It is likely that individual enterprises will find solutions that work specifically for them and likely include a range of technologies including batteries, hydrogen, and low carbon fuels – particularly biofuels and synthetic. This is potentially problematic if there are viability thresholds based on scale, an issue that points to the need for regionally based strategic planning and coordination.

For industrial applications of process heat, replacing gas is a significant undertaking. Gas is a convenient energy source and without substantial drivers it is unlikely that enterprises reliant on it will change. Multinational corporations facing shareholder pressure to reduce emissions are already investigating alternatives, but consultations show that the economics and practical constraints of 'getting off gas' for these companies is challenging. In the short term, most will seek to reduce consumption and lower their carbon exposure rather than seek to fully replace gas.

The bulk of decarbonisation in regional Australia could readily be achieved through electrification and renewables, behaviour change and clean-tech innovation. However, there are difficult components as described in this report and the IEA appears to consider hydrogen and alternative fuels as the most likely approach to meet this challenge. According to the IEA, hydrogen electrolyser manufacturing capacity has now reached 8GW/y and is likely to reach a total capacity of at least 134GW by 2030 – roughly four times the demand of Australia's electricity networks. This supply side push along with the joint efforts of international miners Anglo American, BHP, Fortescue, and Hatch, attest to the potential for the sectors like agriculture to be 'swept up' in the development of hydrogen as a power fuel.

The challenge of decarbonising the regions is not to be underestimated and success is subject to cultural and geographic factors, as well as the financial and technological factors which receive much of the focus. Further training of the workforce will be critical for the transition, as will continual communication between government and regional Australia to ensure the best chance of success. Despite the well-intentioned efforts of industry and government, the current status of decarbonisation in the regions remains immature. While pathways exist for many applications, serious efforts to decarbonise remain underdeveloped. The existing, largely unplanned, market-led approach to achieving net zero is unlikely to be effective in these difficult to decarbonise sectors, certainly over the short to medium term. Without substantial incentives and regional, place and sector-based coordination, decarbonisation will likely be challenging for many parts of regional Australia.

Recent developments in Australia's political enabling environment have put Australia on good footing for achieving net zero emissions by 2050. Opportunities for Australian policy intervention include supporting the rollout of charging stations; incentives for electric vehicles; a price for carbon; and an emissions trading system. In many of the small, vulnerable communities in regional Australia this will require a collaborative regional approach rather than relying on action undertaken purely at an individual community level. Working with local communities, their surrounding regions, and supporting place-based initiatives will be critical for government and industry over the coming decades.

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