Hydrogen opportunities for dairy industries in Australia and Uruguay

Feasibility study | October 2021

The Hydrogen Dairy Project is supported by the Commonwealth through the Council on Australia Latin America Relations, which is part of the Department of Foreign Affairs and Trade.

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GLOSSARY

ADME – Administración del Mercado Eléctrico del Uruguay

AEMO – Australian Energy Market Operator

ANCAP - Administratión Nacional de Combustibles Alcohol y Portland, Uruguay

BEV – battery electric vehicle

CEFC – Clean Energy Finance Corporation

CO_2 – carbon dioxide

COALAR – Council on Australian Latin American Relations

CSIRO – Commonwealth Scientific and Industrial Research Organisation

DMSC – Dairy Manufacturers Sustainability Council

EPA – Environmental Protection Agency

ESG – Environmental, social governance

EV – electric vehicle

FSANZ – Food Standards Australian New Nealand

FCEV – fuel cell electric vehicle

GDP – Gross Domestic Product

GHG – green house gas emissions

GOS - galacto-oligosaccharides

GSC – Great South Coast (Victoria, Australia)

ICE – internal combustion engine

IEA - International Energy Agency

IFCN – International Farm Comparison Network

INALE – Instituto Nacional de la Leche

INE - Instituto Nacional de Estadística

MA - Ministry of the Environment, Uruguay

MEF - The Ministry of Economy and Finance, Uruguay

MIEM - The Ministry of Industry, Energy and Mining, Uruguay

N20 – Nitrous oxide

REZ - Renewable Energy Zone

SDFA – State Dairy Food Authorities

SGC – Sustainability Development Goals

SMA process – Steam Methane Reforming process

TCO – total cost ownership

URSEA – Unidad Reguladora de Servicos de Energia y Agua

UTE - National Administration of Power Plants and Electrical Transmissions, Uruguay

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Executive Summary

Hycel's Hydrogen Dairy Opportunities in Australia and Uruguay project, funded through DFAT's Council on Australian and Latin American Relations (COALAR) and delivered in partnership with Food and Fibre Great South Coast, investigated how hydrogen could be applied to dairy industries in Australia and Uruguay.

This study found that both Australia and Uruguay are motivated to develop both the domestic and export hydrogen industry. The Australian dairy industry is motivated by sustainable practice, which is demonstrated by the Australian Dairy Industry Sustainability Framework and the support of global Pathways to Dairy Net Zero. Uruguay has not yet signalled support for the Pathways to Dairy Net Zero. The impetus for the dairy industry to reduce energy intensity and emissions may increase in the coming years due to market and supply agreements that are impacted by trade partner emissions goals, and/or consumer preferences for low carbon footprint supply chains, along with regulatory frameworks that impose carbon pricing. There is, therefore, an emerging need for dairy industries to transition to renewable energy sources.

As hydrogen is in the emerging stages, initial pieces such as this feasibility study, along with educational opportunities to increase hydrogen literacy is integral for dairy industries. This foundational knowledge and subsequent educational opportunities are necessary to equip decision makers with the knowledge to investigate and interrogate the details of a hydrogen transition. This is commensurable with the broader hydrogen industries focus on social licence and skills development in these early stages of the industry.

In terms of hydrogen application to dairy industries, on the farm the opportunity of producing hydrogen from effluent via a biodigester is theoretically sound. In practice, however, farming practices in south west Victoria and Uruguay are primarily pasture based rather than intensive (thus biomass accumulates in paddocks or effluent ponds) so the biodigester potential using effluent feedstock to produce biogas is unlikely to be realised in the near future. Currently, hydrogen does not present an attractive solution to reducing emissions on farm, as the greatest contributor to farm emissions are from enteric methane from ruminant (cow) digestion (56% of emissions). Furthermore, farmers are already proactively reducing emissions through efficiency gains and a shift to renewable energy (predominately reducing grid electricity through solar power). While the economic feasibility of hydrogen does not stack up in the south west and Uruguayan settings, there may be potential application to more remote farms where fuel prices are higher.

The dairy industry is very proactive in looking at opportunities to reduce its greenhouse gas emissions and increase efficiencies, but their focus has been on stationary elements of the supply chain, which is energy intensive. In the near term (2025), hydrogen applications such heavy haul and return to base transport and light commercial vehicles (forklifts) are expected to be competitive with fossil fuel alternatives. If used for heat and power in processing hydrogen is not expected to be a competitive energy source until the longer term (2050) due to the current high use of natural gas.

While transport has not to date been visibly prioritised in emissions reductions strategies, it is a critical player in supply chains. The most advanced application of hydrogen is in transport and indeed, the near-term tangible application of hydrogen in both Uruguayan and Australian dairy systems is in heavy vehicle transport. Hydrogen powered milk tanker demonstration is already occurring in the Netherlands. The path to total cost ownership for hydrogen powered vehicles is difficult to project due to the infancy of the hydrogen industry, however, hydrogen heavy and medium duty trucks and buses are projected to achieve cost competitiveness earlier than other applications, estimated at 2025.

Summary of key findings

Factors influencing a hydrogen transition

Appetite for hydrogen investment

- Australia is motivated to become a hydrogen leader, for in both domestic use and export. Australian Federal and State Governments are actively investing in hydrogen pilots, demonstrations, and commercialisation opportunities.
- Australia has a national renewable energy target of 20% by 2030, and this will also help drive growth in sustainable energy supply in manufacturing.
- Uruguay is motivated by energy security, with 97% of electricity being derived from renewable sources, and there is an opportunity to turn surplus electricity into hydrogen.

Increasing focus for dairy supply chain sustainability

- The Australian dairy industry is motivated by sustainable practice, demonstrated by the Australian Dairy Industry Sustainability Framework and the support of Pathways to Dairy Net Zero.
- Dairy companies may be driven to reducing energy intensity and emissions due to market and supply agreements driven by trade partner emissions goals and consumer preferences for low carbon footprint supply chains, regulatory frameworks that imposes carbon pricing and volatile fuel and power prices.

Regional advantage

- The south west Victorian region is well positioned to become a hydrogen hub, to align supply and demand due to renewable energy capacity, Deakin University's Hycel Technology Hub and road and rail connectivity.
- Uruguay is positioning to become a green hydrogen exporter in the near and mid-term, with investments in the Port of Rotterdam feasibility and the Hydrogen-2-Uruguay Strategy.

Integral factors for a successful hydrogen transition

- Hydrogen is in the emerging stages and initial strategic pieces, such as this feasibility study, will facilitate a shared conversation between key stakeholders and inform action in the near to medium term.
- Hydrogen will become a fuel of the future only if communities believe it is necessary and safe, therefore market and community education and social licence building is integral to ready communities for the transition
- While the trajectory for development and maturation of hydrogen infrastructure for residential and industrial application straddles the coming decades, there is a need in the immediate future to concentrate on skill building and education to ready Australia's future hydrogen workforce.
- There is a need and appetite to bring together key community stakeholders to educate and generate community conversations about the hydrogen opportunity for dairy and broader agriculture/ rural industries.
- To create step change, commercial parties require additional inputs and strategy to facilitate independent assessments of the feasibility of the hydrogen transition.

Hydrogen – on the farm

- The suitability of biodigester potential using effluent feedstock to produce biogas is unlikely to be realised in Australia presently due to the pasture-based nature of most dairy farm systems: animal excretion predominantly occurs in paddock and dairy effluent ponds lack the economies of scale for useful production volumes of hydrogen gas.
- Hydrogen does not present an attractive solution to reducing emissions on farm, as the greatest contributor to farm emissions are from enteric methane from ruminant (cow) digestion (56% of emissions).
- Farmers are already proactively reducing emissions through efficiency gains and a shift to renewable energy (predominately reducing grid electricity through solar power) and so far, farmers have not investigated hydrogen as a necessary near-term option.

- The economic feasibility of hydrogen as a fuel source is dependent on future price and availability of current energy sources (e.g., diesel, grid electricity, natural gas). There may be potential application to more remote farms where fuel prices are higher.

Hydrogen – in processing

- The increased cost of energy has been a major driver for some dairy processors to reduce energy use.
- For most dairy manufacturers, 80% of their energy needs is for thermal processes (i.e. heating and drying milk, hot water for cleaning) and the remaining 20% used for electrical requirements. Electricity and thermal energy are generated both externally and on-site, typically using fossil fuels including coal, oil, natural gas and LPG, whilst a small number of plants supplemented their energy supply using biogas.
- Although very common in Europe, Anaerobic Digesters are still scarce in Australia, and have been trialled unsuccessfully by a number of dairy manufacturers over a 20-year period.
- In the near term (2020-2025), hydrogen applications such as heavy haul and return to base transport and light commercial vehicles (forklifts) are expected to be competitive with fossil fuel alternatives. If used for heat and power in processing hydrogen is not expected to be a competitive energy source until the longer term (2050) due to the current high use of natural gas.
- The dairy industry is very proactive in looking at opportunities to reduce its greenhouse gas emissions and increase efficiencies, but their focus has been on stationary element of the supply chain, which is energy intensive, rather than in the transport.
- A potential of hydrogen needs to be considered within the mix of current purchasing power agreements and the energy mix.

Hydrogen in supply chain logistics

- Hydrogen offers potential to deliver step change reductions in Green House Gas (GHG) emissions toward carbon net-zero food & fibre supply chains. Transport is a critical player in supply chains and to date often not visibly prioritised in agricultural sector strategies and supply chain GHG reduction targets – arguably because commercial enterprises require a level of confidence in a tangible pathway to achieve goals and targets.
- The most advanced application of hydrogen is in transport and indeed, the near-term tangible application of hydrogen in both Uruguayan and Australian dairy systems is in heavy vehicle transport. A hydrogen powered milk tanker demonstration is already occurring in the Netherlands.
- The energy needs of the processing component of the supply chain are particularly complex, which make assessing the feasibility of hydrogen on a monetary level difficult at this early stage. A tailored assessment, based on an individual company's needs, ambitions and projections is required.
- The path to total cost ownership for hydrogen powered vehicles is difficult to project due to the infancy of the hydrogen industry, however, hydrogen heavy and medium duty trucks and buses are projected to achieve cost competitiveness earlier than other applications, estimated at 2025.

Introduction

This investigation into the application of hydrogen in Australian and Uruguayan dairy industries is intended to lay the foundations so that dairy industries in both countries can engage and plan for a hydrogen transition. This report is intended as an education piece to broadly discuss hydrogen application in dairy contexts and to draw connection between Australia and Uruguay. The hydrogen transition will be gradual, so it is important at this stage, where governments and industries are investing in hydrogen research, development, pilots and demonstrations, to explore the ways in which hydrogen can be integrated into high value industries, including those in agriculture.

Global impetus to collaborate

The demand for nutritious and sustainably produced food and fibre for the predicted world population of 9-10 billion people by 2050 brings both challenges and opportunities. This is a shared and global problem. The impetus to produce more from less, while responsibly managing our natural resources, animal welfare, social responsibilities as well as meeting changing dietary preferences and consumer demands, is imminent. Mitigating the impact of climate change and reducing Green House Gas (GHG) emissions is front and centre. A volatile climate, markets and geopolitical impacts also contribute to the complexities. We need to globally work as a team to embrace diversity, our brightest minds, and resources to develop/advance technologies and innovations that can be locally nuanced to provide solutions across the globe.

Hydrogen is one rapidly emerging fuel source that stands to potentially deliver step changes in our industrialised practices and behaviours toward net-zero emissions. The expertise and advances globally are emerging, and a collaborative approach will enable research, development, and adoption to accelerate.

Agriculture and rural communities are ubiquitous worldwide and since early days the need to exchange and trade goods has provided the foundation for development of mutually beneficial relationships. Often, what prospers and is reaped from these relationships in years to come is unforeseen at the outset.

Australia and Uruguay are both, by world standards, not densely populated and share many similarities across our agricultural systems and rural communities. In both countries, agriculture is a significant contributor to the national economy, and largely characterised by extensive farming systems – both cropping and livestock (i.e., extensive grazing and cropping have provided the backbone to the agricultural sectors). The similarities between these two countries, and indeed the southwest of Victoria (and Tasmania) and Uruguay was recognised earlier last century through the development of (mutually beneficial) relationships between Corriedale and Polwarth sheep breeders and their associations. These relationships, both personal and commercial, between the sheep breeding communities of southwest Victoria and Uruguay continue today.

The dairy industry is one of the major agriculture sectors across both Uruguay and Australia – and specifically the southwest of Victoria. In both countries/areas, production is characterised by extensive, pasture-based farming practices and the industry recognised as leading technology adopters across the agriculture sector. It is a high touch industry that relies on the work and expertise of human capital across the supply chain. While dairy is a highly nutritious food, its production (like most other agriculture sectors) is a significant contributor to GHG emissions. Globally, the dairy industry recognises the important role it has to play in sustainable dairy production, including reducing GHG emissions and efficient resource use right across the supply chain – at the level of the farm, the processing as well as the logistics, distribution and storage of the raw and manufactured product. This is evidenced through aligned sustainability goals and commitments at multiple levels – that of individual dairy companies, industry, national and international. In September 2021, the global initiative 'Pathways to Dairy Net Zero' was launched with support already committed by broad array of leading dairy organizations and companies across the world, including Australia.

Collaboration on the advancement and implementation of hydrogen technology to deliver clean, renewable energy for the dairy industry supply chains, that can also be applied across broader agricultural sectors, offers a prime opportunity for further developing mutually beneficial relationships between Australia and Uruguay. In addition, there is the added benefit of continuing the cultural exchange and diversity while addressing arguably one of the biggest global challenges of our time: reducing greenhouse gas emissions to help mitigate the impacts of climate change, while still allowing the world to eat, sleep, and lead the uncompromised lifestyles to which we've become accustomed.

The emerging hydrogen economy

Hydrogen is seeing unprecedented and intensifying global support. Countries around the world are looking to hydrogen as a zero emissions fuel that can help to meet global carbon reduction targets by decarbonising transport and industry. While Japan was the first country to adopt a hydrogen strategy in 2017, the subsequent four years have seen leading global powers, including China, US, European Commission, Russia and UK, adopt hydrogen strategies. Global financial investment in hydrogen is growing, and is estimated at over $500 billion, with 359 large-scale projects announced in the first half of 2021[i]. Up until recently the expense of manufacturing renewable hydrogen and the durability of equipment were significant barriers. The development and reducing cost of solar and wind electricity as well as science, technology and manufacturing experience have unlocked the potential of hydrogen[ii]. These global policy, financial, and environmental levers are driving the uptake of pilots and commercial applications that use hydrogen in new ways.

While hydrogen is emerging in the public consciousness as a 'new' and 'future' fuel, hydrogen has been used for many years in a variety of applications. Hydrogen fuelled the first internal combustion engines over 200 years ago[iii], NASA began using liquid hydrogen in the 1950s as a component in rocket fuel[iv] and hydrogen has been used as an industrial feedstock for many years. Further, hydrogen fuel cells were first invented in 1839 by William Robert Grove and were used commercially by NASA in 1962 to generate power for probes, satellites, and space capsules[v]. Hydrogen is seemingly an 'old' fuel that is now being used in new ways.

Hydrogen is a different energy source than the hydrocarbon fuels traditionally used, which necessitates the development of new technologies, skills and approaches to transport and maintain safe and effective use. It is for this reason that analysts predict a gradual transition to hydrogen; forecasting suggests that demand will grow at a moderate pace until 2030 and then accelerate from 2035[vi]. To propel the hydrogen transition, it is important for governments and industry to launch strategies, initiate hydrogen pilot projects, develop regulatory frameworks and invest in hydrogen technologies. The COALAR hydrogen dairy project is aimed at starting the conversation and laying the foundations so that dairy industries in Australia and Uruguay are engaged and ready to embrace hydrogen opportunities when they arise.

What is hydrogen?

Hydrogen is one of the most powerful, versatile, and abundant substances in our universe. It is 14 times lighter than air, odourless, colourless, tasteless, and so small that 3 million hydrogen molecules can fit across the width of a human hair. Unlike other hydrocarbon fuels (petrol, diesel, natural gas), hydrogen doesn't usually exist on its own; it's mostly bound up in substances like water, natural gas, coal, and biomass.

To use hydrogen as a fuel, it needs to be extracted through processes such as electrolysis (using electricity to split water into hydrogen and oxygen) or thermochemical processes (using heat and chemical reactions to extract hydrogen from hydrocarbon fuels) which include steam methane reforming and gasification. Hydrogen can also be extracted from biomass via gasification (on farm this process is via a biodigester). When used as a fuel, the only by-products are heat and water, meaning that at the point of use hydrogen does not produce any carbon emissions. Further, when produced from zero carbon sources (using renewable electricity during electrolysis), hydrogen is a zero emissions fuel. There *are* emissions produced when hydrogen is extracted from hydrocarbon fuels (via thermochemical processes). Each method of extracting hydrogen requires energy and water; carbon emissions are dependent on the method used. The table below provides an overview of hydrogen production according to water use and carbon emissions[vii].

*Table 1. Australian production methods of Hydrogen and emissions of CO_2**

Production method	Water* (litres/kg hydrogen)	Carbon Capture Storage	Hydrogen type	Emissions (kg CO_2-e/kg hydrogen)[viii]
Electrolysis - Renewable electricity	9	N/A	Green	0
Electrolysis – grid electricity	9	No	Brown	40.5 (can vary)
Steam Methane Reforming - Coal gasification	9	No	Brown	12.7-16.8
Steam Methane Reforming - natural gas	4.5	No	Grey	8.5
Gasification - coal	4.5	Yes	Blue	0.71
Steam Methane Reforming - natural gas with carbon capture	4.5	Yes	Blue	0.75

* Water inputs are theoretical. In practice, water requirements may vary. See Australia's National Hydrogen Strategy for more information.

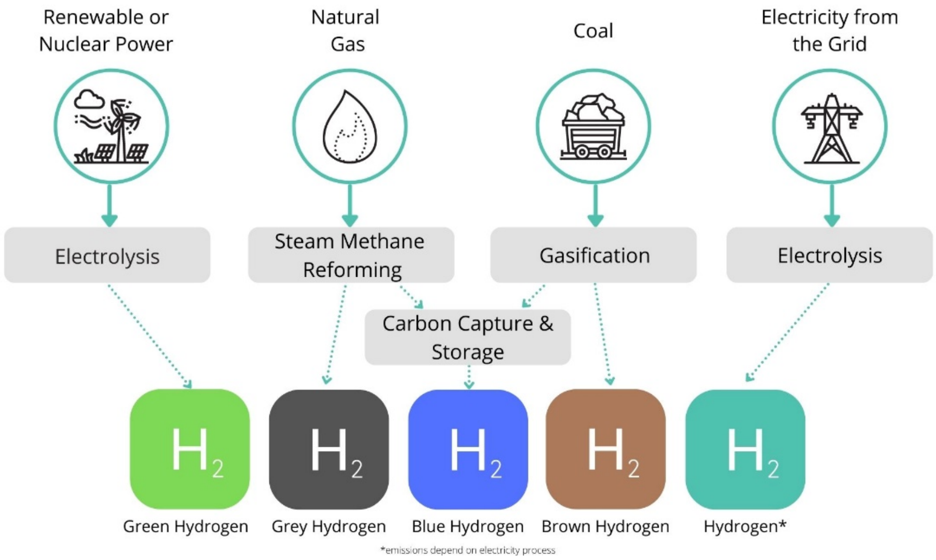


Figure 1. Hydrogen extraction methods and feedstocks[ix]

Currently only 0.7% of the world's hydrogen is produced renewably[x]. However, it is anticipated that as production costs decrease, due to falling renewable energy costs, technological advancements and economics of scale, renewable hydrogen will increase in production and demand[xi]. The current costs associated with hydrogen production and infrastructure prohibit widespread use.

How is hydrogen used?

Currently hydrogen is used mostly in oil refining and to create fertilizer. Hydrogen can be used in industrial, stationary, residential and transport applications.

Industrial

- Hydrogen is used to refine petroleum.

- Hydrogen is used to create ammonia fertilisers, by combining it with nitrogen.
- Hydrogen can be used to produce methanol.

Stationary applications

- Hydrogen can replace natural gas in steam turbines. In this application hydrogen produces heat through combustion or chemical processes as either pure hydrogen or ammonia.
- Hydrogen can generate electricity via a fuel cell. This application is mostly used for remote power systems, military equipment or back up generation. More information about fuel cells can be found below.

Residential

- Hydrogen can be used replace natural gas for combustion in natural gas pipelines, used for heating and cooking. Research is underway to ensure that natural gas infrastructure is compatible with 100% hydrogen. Currently hydrogen can be blended up to 20% safely.

Transport

- Hydrogen can be used in transport applications through combustion, though most applications will involve the use of a fuel cell.
- Fuel Cell Electric Vehicles (FCEV) comprise a hydrogen tank, battery, fuel cell and electric motor. Most transport applications can be transitioned to hydrogen.
- Currently forklifts, buses, passenger cars, light duty trucks are the most common application. Other applications include trains, ships and planes.

Due to the current reliance on combustion engines, which are powered by high carbon emitting and non-renewable fossil fuels, the transportation industry is at the forefront of advancement of hydrogen fuel cell technology with the use of hydrogen fuel cell electric vehicles (FCEVs). However, as hydrogen extraction, availability, costs, technology for its application and supply infrastructure advance, it is likely that further development of hydrogen fuel cells as a generator of energy in other sectors and industry will occur.

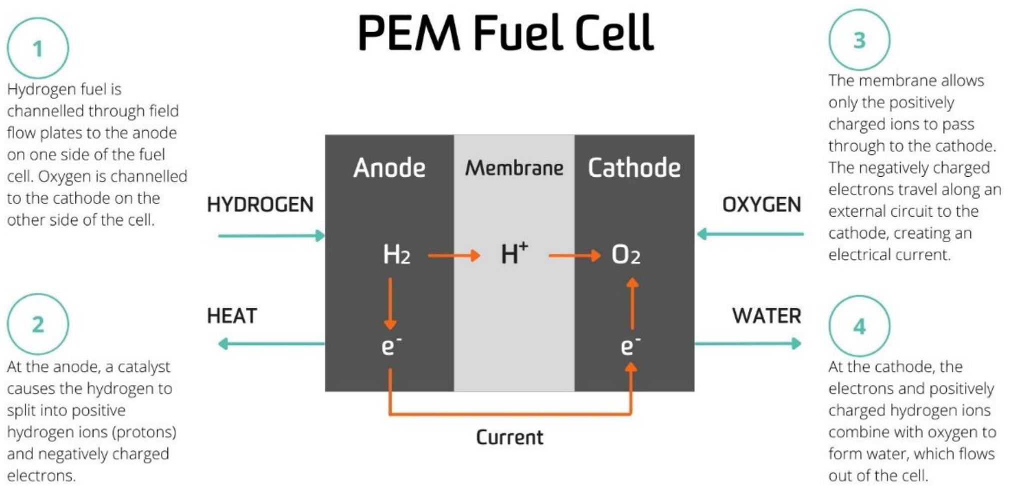


Figure 2. Diagram of Proton exchange membrane fuel cell[xii]

The hydrogen trajectory

At a global level, hydrogen technologies will need to be economically competitive with current fuel options in order to facilitate market adoption. The figure below provides an overview of the estimated cost competitiveness trajectories of various hydrogen applications.

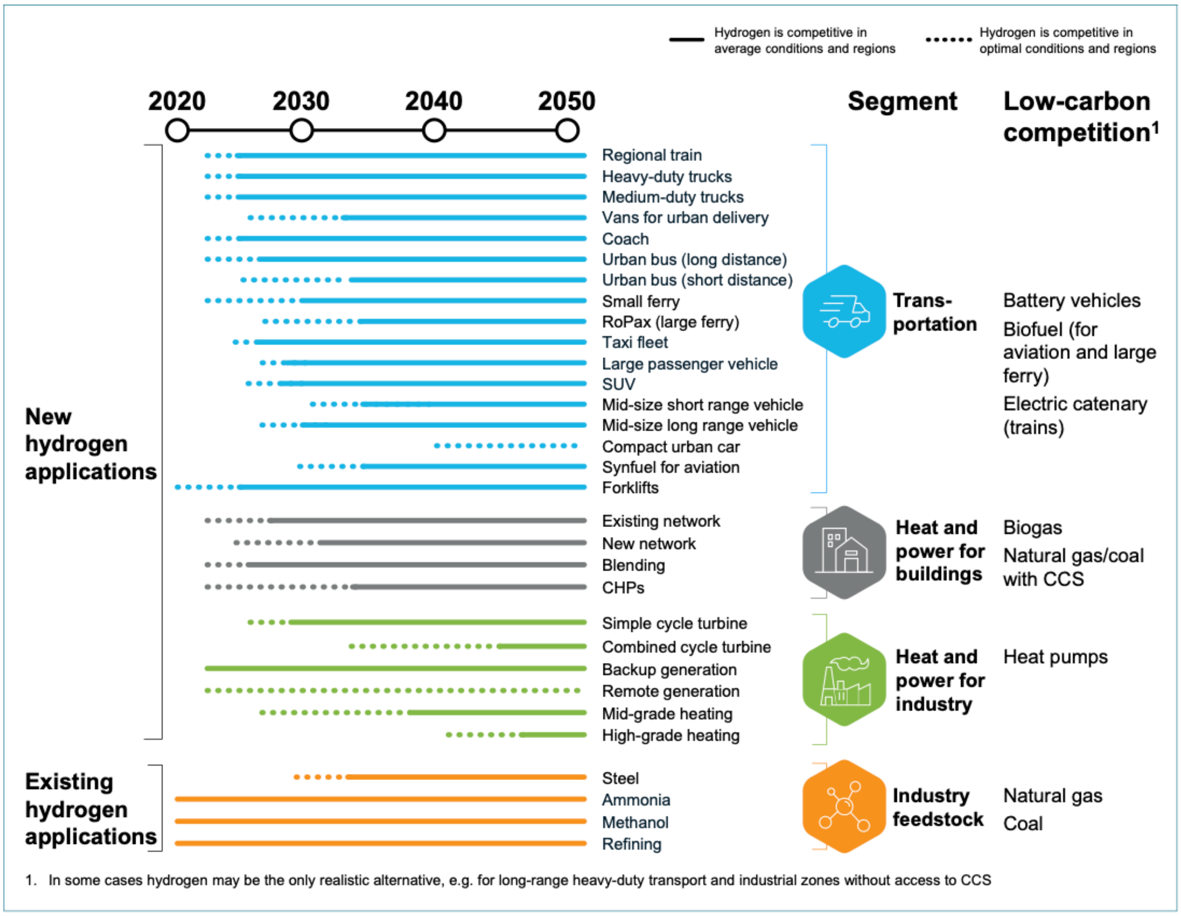


Figure: Cost competitive trajectories for hydrogen applications[xiii]

According to the global Hydrogen Council, it is expected that heavy and medium duty trucks and buses will emerge as achieving cost competitiveness earlier than other applications. Based on current projections, the Hydrogen Council expect that FCEV heavy duty trucks will have a total cost ownership (TCO) lower than diesel heavy duty trucks by 2030, and maybe even earlier in areas where the price of diesel is higher. The TCO will be influenced primarily by the cost of hydrogen fuel, but also on the cost of FCEV vehicles and their components.

The main factors influencing of the price of hydrogen, and therefore the economic feasibility of its use in various applications, include the following:

- Cost of green hydrogen production
- Collective demand for hydrogen as an alternative energy source
- Cost of hydrogen distribution and delivery
- Future price and availability of current energy sources (e.g., diesel, grid electricity, natural gas)
- Future price of Carbon
- Ability to adapt/replace current infrastructure and equipment to utilise hydrogen

There is much discussion regarding the purchase price of hydrogen for use in FCEVs to ensure it is competitive against other fuels (petrol, diesel, natural gas). The following table estimates the 'breakeven' price of hydrogen that needs to be achieved in Australia to ensure it is cost effective for use in a passenger vehicle. This does not consider the capital or maintenance costs of the vehicles.

Table 2. Hydrogen Break Even Price when compared to currently used fuels for a mid-sized passenger vehicle

Competitor fuel service	Hydrogen Breakeven price $/kg H2
Drive 100km using petrol (@ $1.43/L)	$13.31
Drive 100km using diesel (@1.50/L)	$11.21
Delivery 1GJ heat using natural gas (wholesale price of $10/GJ)	$1.20

Source: Australia's National Hydrogen Strategy[xiv]

Similarly determining the TCO for hydrogen powered heavy-duty trucks, is also difficult as there are many variables and considerations which will vary according to the type of truck, its use, where it is to be based and the fleet size. The figure below provides estimates for Australian based heavy-duty trucks and compares FCEV, Battery Electric Vehicle (BEV-1000) and Internal Combustion Engines (ICE) both in the current term and long term (2050).

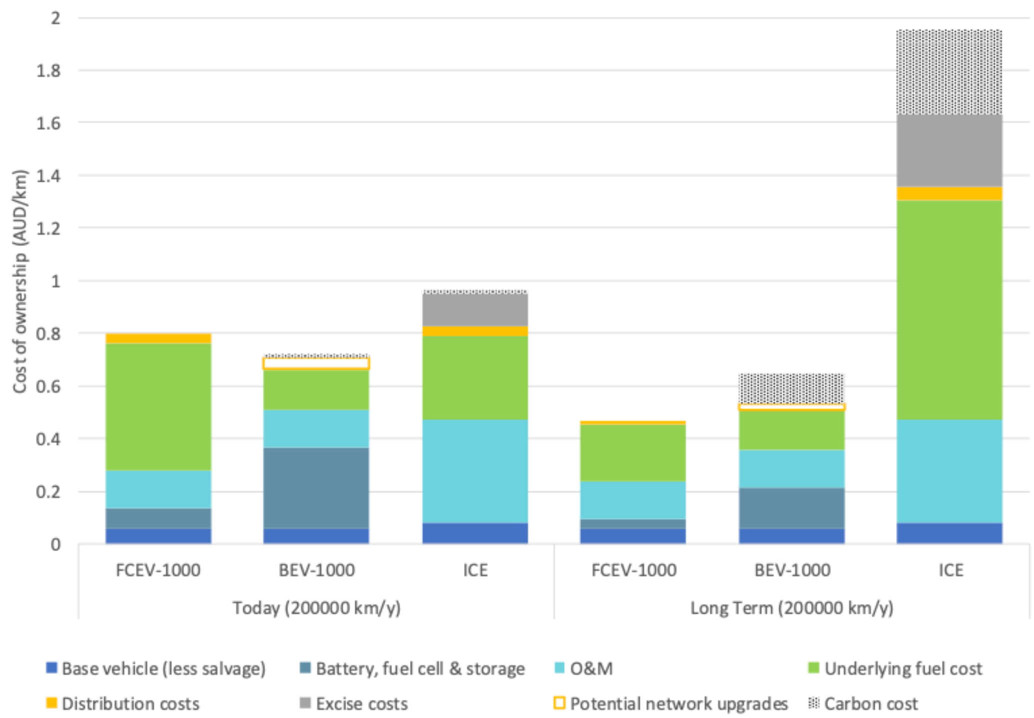


Figure 3. Estimated cost of ownership AUD/km for Heavy-duty/Line haul vehicles[xv]

Some of the key assumptions used in the above TCO estimates include price of hydrogen in 2050 @ $2.78 and price of diesel assumed to be $2.21. Fleet efficiency is assumed to be 36L/100km (it is noted that in some cases fleet efficiency will be higher).

In addition to the assumptions used in the TCO calculation in Figure 3, further elements to consider when determining the feasibility in vehicles include:

- Availability and location of hydrogen fuel stations
- Research and technological advances to optimise hydrogen fuel cells
- Scale of manufacturing of hydrogen fuel cells
- On-board hydrogen fuel storage
- Refuelling time
- Available payload
- Operation under different climate conditions
- Local regulations.

The Australian Market Hydrogen Study (2021), produced by Advision Pty Ltd, for Australia's Clean Energy Finance Corporation (CEFC) has noted that an important factor influencing the price of hydrogen, is the cost of delivery of hydrogen to suitably located fuelling stations. They state that the closer you are to a hydrogen production site (less than 100km), the cheaper the hydrogen price will be (approx. 30% lower). Although over time, as economies of scale are achieved and hydrogen take-up is increased, the distribution costs will also decrease and impact the end-user price of hydrogen.

Given the above-mentioned factors, it is difficult to estimate an accurate break-even price of hydrogen, particularly as it relates to its use in commercial truck fleets. However, across the globe, studies are showing that in relation to future applications, transportation is the 'low hanging fruit' of the hydrogen industry.

Evidence of up-take of hydrogen powered vehicles

Commercialisation of FCEV transport fleets across the globe is still in its infancy but expected to accelerate in the coming 2-3 years.

Early adopters taking up the opportunity to convert their transport fleets include the following:

- H2Bus Consortium are committed to deploying 1000 buses in several European countries with 600 buses expected to be in operation by 2023 in the UK, Demark and Latvia. The H2Bus Consortium involves collaboration with key supply chain players Everfuel, Wrightbus, Ballard Power Systems, Hexagon Composites, Nel Hydrogen and Ryse Hydrogen.
- FrieslandCampina (European based dairy company) have partnered with Hyzon Motors and carrier Transport Groep Noord to put a 50-tonne hydrogen powered milk tanker to use.
- Australian mining company Fortescue Metals Group Ltd (FMG) have plans to replace a fleet of 10 diesel coaches with hydrogen fuel cell coaches at their Christmas Creek mine in late 2021. They have partnered with Hyzon Motors Australia who are working with FMG to develop the custom-built vehicles.
- Coregas, an Australian owned industrial gases company (part of Wesfarmers), has placed an order for two of Hyzon Motor Australia's hydrogen fuel cell powered prime mover trucks, for delivery in 2022 to their Port Kembla site. Coregas is also working to develop Australia's first commercial hydrogen refuelling station to support the uptake of hydrogen fuelled heavy-duty vehicles.
- The Volvo Group is expanding as fuel cell manufacturers in the coming years, where the aim is for half of its European sales in 2030 to be from electric trucks, powered by either batteries or hydrogen fuel cells.

Optimising fuel cells and refuelling networks is a key focus of Deakin University's Hycel, which is building Australia's fuel cell assembly line at its Warrnambool campus in south west Victoria.

The challenges and opportunities to widespread use

The International Energy Agency (IEA) has identified several challenges to widespread hydrogen usage[xvi]:

- **High cost of hydrogen production**: currently hydrogen is costly, but projections suggest it could fall 30% by 2030 due to declining costs of renewable energy and scale up of hydrogen production.
- **Development of hydrogen infrastructure**: progress is slow and infrastructure (e.g., refuelling networks) is necessary to support the deployment of hydrogen applications and lower the price of hydrogen.
- **Current hydrogen supply is brown**: 98% of the world's hydrogen is produced by steam menthane reforming and gasification. The transition will require carbon capture of existing hydrogen production and scale up of green hydrogen.
- **Regulatory frameworks**: international regulations are in development but currently the lack of standardised regulations is limiting development.

Supporting the scale-up of hydrogen production and usage is at the heart of the IEA's identified opportunities, which include:

- **Hub model**: targeting industrial ports as the hub for scaling up clean hydrogen production.
- **Existing infrastructure**: Using existing infrastructure, like natural gas pipelines, with hydrogen; even a 5% hydrogen blend will increase demand and supply.

- **Transport**: support hydrogen transition through fleets, freight, and corridors to increase demand, supply and competitiveness.
- **Shipping**: launch hydrogen trade's first international shipping routes

Hydrogen in Australia and Uruguay

Hydrogen in Australia

Australia is well placed for the future as a producer of green hydrogen for both domestic purposes and export – potentially a global leader in the latter. Armed with the resources (significant renewable energy resources), and the experience, Australia is positioning to take advantage of increasing global momentum for renewable hydrogen and make it the country's next energy export. There is potential for thousands of new jobs, many in regional areas – and billions of dollars in economic growth between now and 2050[xvii].

The opportunity could integrate more low-cost renewable generation, reduce dependence on imported fuels, and help reduce carbon emissions in Australia and around the world. Australia acknowledges that while how much of this opportunity will evolve is uncertain, there are greater risks in not acting early.[xviii]

Australia's national hydrogen position

Prior to the launch of Australia's National Hydrogen Strategy in 2019, a range of research and development, feasibility, demonstration, and pilot projects totalling over $146 million had been invested in by the Australian Government between 2015-2019. In late 2018 the Council of Australian Governments Energy Council set a vision for 'a clean, innovative, safe and competitive hydrogen industry that benefits all Australians and is a major global player by 2030'.[xix] The Australian Hydrogen Strategy was developed to achieve this vision and is a result of considerable analysis, consultation with experts, industry and the public, plus an extensive body of original research.[xx] Designed to be a 'living document', the strategy takes an adaptive approach, which responds to industry advancements. The strategy is sectioned into two timeframes: now – 2025 focuses on foundations and demonstrations; 2025 and beyond focuses on large scale market activation. Detail is contained in the table below.

Australia's National Hydrogen Goals and Action Plan[xxi]
Goals: 1. Australia is one of the top three exporters of hydrogen to Asian markets 2. Hydrogen is providing economic benefits and jobs to Australians 3. Australia has an excellent hydrogen related safety track record 4. Australia has a robust, internationally accepted, provenance certification scheme in place. In order to meeting these goals, the following 'adaptive pathway' has been created: 2020 – 2025: Foundations & Demonstrations - Advance priority pilots, trials and demonstration projects - Assess supply chain infrastructure needs - Build demonstration scale hydrogen hubs* - Develop supply chains for prospective hydrogen hub **Hubs are defined as being 'regions where various users of hydrogen across industrial, transport and energy markets are co-located'.*

Some of the expected outcomes relevant to this report, are:

- Drive technology development
- Develop industry expertise
- Promote innovative collaboration
- Prove hydrogen supply chains at scale
- Incentivise growth of hydrogen hub demonstrations

Proposed actions 2025 & beyond: Large-Scale Market Activation

- Identify signals that large-scale hydrogen markets are emerging
- Scale up projects to support expert and domestic needs
- Build hydrogen supply chains and large-scale export industry infrastructure*
- Build and maintain robust and sustainable export and domestic markets and supply chains
- Enable competitive domestic markets with explicit public benefits

** Supply chain infrastructure includes powerlines, pipelines, storage tanks, refuelling stations, ports, roads and railway lines and any other facilities needed for hydrogen supply*

Supporting actions may also include:

- Financing of clean hydrogen supply chains or other policies that will attract private investment
- Policies to build widespread domestic hydrogen demand, including measures that enable:
  - using clean hydrogen for industrial feedstocks and heating
  - blending of hydrogen in gas networks
  - using hydrogen for long-distance heavy-duty transport and development of associated refuelling infrastructure
- Ensure community safety and confidence, deliver benefits for all Australians, and protect the environment.
- Provide long-term governance structures, and support market settings to foster industry growth and competition.

There is also a commitment to support the review and reform of underpinning regulatory legal frameworks, develop consistent approaches for efficient supply chains and markets and ensure a supportive investment environment, robust training requirements and safety standards.

What are hubs and why are they important?

As explained in the Australian Strategy *"A key element of Australia's approach is the creation hydrogen hubs – clusters of large-scale demand. These may be at ports, in cities, or in regional or remote areas, and will provide the industry with its springboard to scale. Hubs will make the development of infrastructure more cost-effective, promote efficiencies from economies of scale, foster innovation, and promote synergies from sector coupling. These will be complemented and enhanced by other early steps to use hydrogen in transport, industry and gas distribution networks, and integrate hydrogen technologies into our electricity systems in a way that enhances reliability[1]."*

Most States and Territories in Australia have dedicated hydrogen strategies, which target investment according to regional strengths and capabilities. The Federal government also released the Australian Government's first Low Emissions Technology Statement[xxii] in 2020, which lists the goal of clean hydrogen to cost under $2 per kilogram by 2030.

This is one of the priority 'stretch' goals that the Australian Government has made in relation to investment in energy technologies that will ensure lower emissions and lower costs.

There are currently 16 hydrogen industry projects either in operation or under construction in Australia, with a further 10 at an advanced stage of development planning.[xxiii] The projects range from large scale production, gas blending in natural gas infrastructure and hydrogen mobility.

Victorian hydrogen position

The Victorian Government's Victorian Renewable Hydrogen Industry Development Plan, launched in 2021, outlines the opportunities to transform its energy system with hydrogen.

The plan outlines three focus areas and outcomes:

Focus Area 1 Foundation for renewable hydrogen	Focus Area 2 Connecting the economy	Focus Area 3 Leading the way
- R&D accelerating innovation	- gas networks transition pathway	- pilots, projects and demonstrations
- safety standards and regulations development	- hydrogen export	- social licence for hydrogen
- workforce skills in hydrogen	- hydrogen transport sector	- Government purchasing power to strengthen sector
- higher education in hydrogen	- secure electricity system support	- Government coordination
- consistent state-wide planning	- industrial sector readiness	- Victoria as a hydrogen leader
- sustainable water use	- supply chain capabilities	- Victoria as an attractive trade destination

In February 2021, in collaboration with National Energy Resources Australia, the Victorian Government established four Victorian Hydrogen Technology Clusters based on Gippsland, Clayton, Geelong and the Mallee.

The Victorian Government has stated that Hydrogen technology clusters will:

- "*make Victoria more attractive to investors and hydrogen businesses by building strong, established networks to access project ideas, funding opportunities and expertise*
- *create awareness and understanding of the benefits of renewable hydrogen amongst their local communities*
- *support physical renewable hydrogen hubs in the future*"[xxiv].

The Victorian Government has set a target for renewable energy production of 50% by 2030[xxv] and therefore Victoria is well placed to benefit from investment in and development of the hydrogen industry. With an abundance of renewable energy sources, and increased expansion of renewable energy production, the cost of renewable energy production is reducing. This could see cost-effective production of hydrogen in identified Renewable Energy Zones, including south west Victoria.

South West Victoria hydrogen position

South west Victoria (also referred to as the Great South Coast of Australia) is known for two things.

The first is as one of Australia's leading producers of food and fibre by value. The region leads Victoria in producing $2.3 billion of agricultural produce per year, and accounts for over 21% of jobs in the region. Dairy is one of the region's top industries, producing almost 25% of the nation's milk. The climate, reliable rainfall and fertile soils are the key drivers behind the success of dairy in the region.

The second is its prime conditions for renewable energy production. The south west has been identified as one of six Victorian Renewable Energy Zones (REZ) through the Australian Energy Market Operator's (AEMO) Integrated System Plan (ISP). This is primarily due to the region's wind resource quality, demand matching, existing transmission infrastructure, terrain, population density and protected areas.

By way of example, the Barwon South West Renewable Energy Roadmap provides the following map detailing the locations of wind farms in the south west region in 2019. This represents over 480 operational wind turbines with a capacity of 1500 MW.

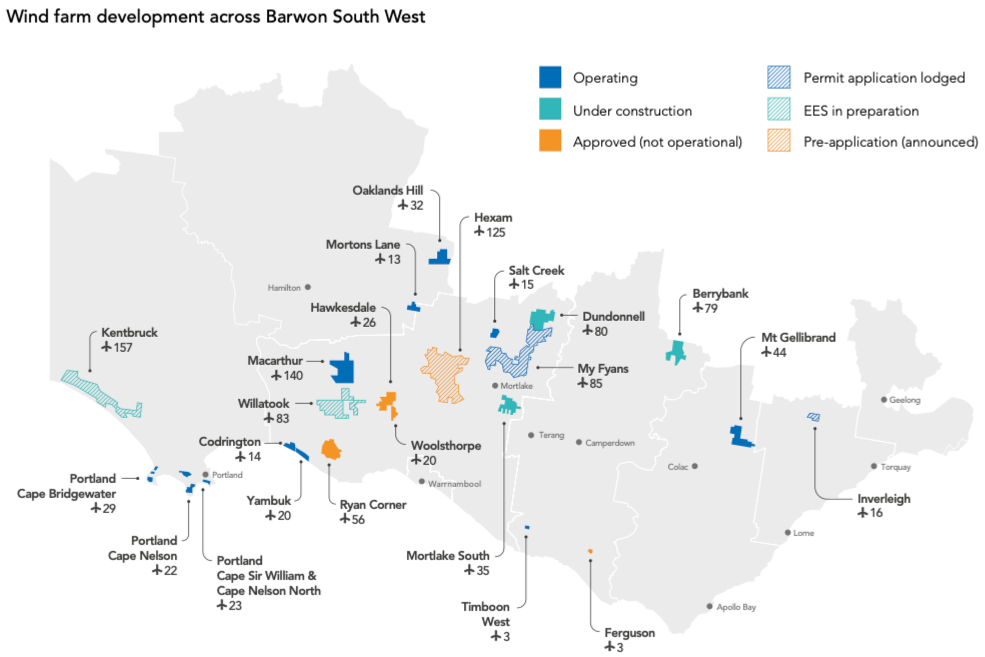


Figure 4. Wind farm development in the Barwon South West Region (REZ) in 2019. [xxvi]

This existing, and growing production of renewable energy further supports the region to be a key player in the hydrogen economy.

The Greater Geelong Hydrogen Technology Cluster takes in the whole of the Barwon South West Region, which includes south west Victoria and the major towns of Warrnambool and Portland.

Figure 5. Current Map of Greater Geelong Hydrogen Technology Cluster [xxvii]

Specifically, the Geelong Cluster will be working in the following areas within the region:

- **Projects**: identify project opportunities to support use cases of hydrogen and accelerate the commercialisation of hydrogen in the region
- **Educating and upskilling**: drive skill development through education, coaching, training and mentoring
- **International Linkages**: connect with international hydrogen centres, projects and start-ups
- **Safety**: Support the effort in developing regulations, standards and codes for the sector

- **Social licence:** work with key players to ensure a trusted and positive relationship with the community and customers.[xxviii]

The representative body for food and fibre in the region – Food and Fibre Great South Coast – has identified hydrogen and Deakin University's Hycel Technology Hub as a focus for regional value add in their Growing Our Regional Futures Strategy 2021-2023 [xxix].

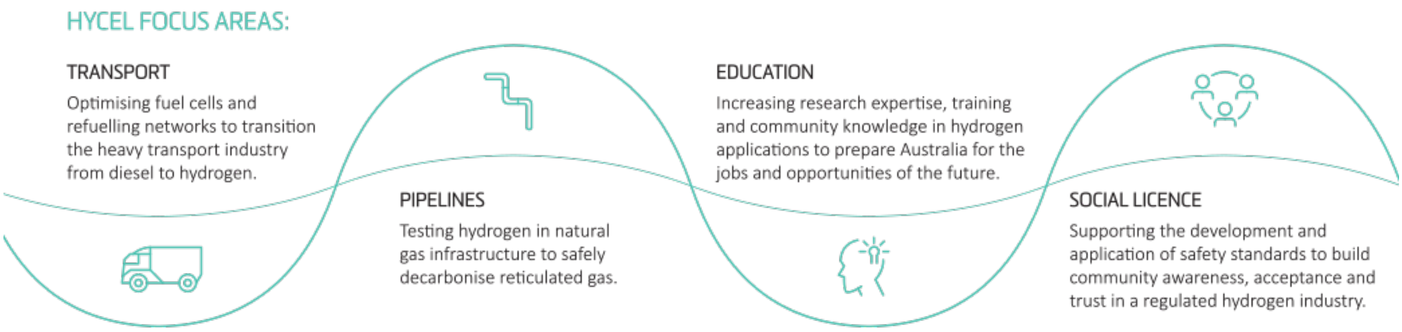
In addition to this, the Great South Coast Economic Futures report, published in 2020, identified hydrogen as a high value economic development pathway for the Great South Coast region[xxx]. The report identifies two major potential development centres. Portland, as the industrial centre and export port of the Great South Coast with the aluminium smelter and potentiality into the grid, was identified as site of comparative advantage for green hydrogen production. The other, Warrnambool, features Deakin University's Hycel, which has received $18 million in funding from both Federal and Victorian State governments to establish a hydrogen research, testing, training and community education facility at the Warrnambool campus. Further, Warrnambool City Council has secured an MOU with the City of Mariestad, Sweden, a global leader in hydrogen planning and application.

Given the potential for hydrogen production and use across Australia, south west Victoria is well placed to become a key player in the Australian hydrogen sector, including the potential for Warrnambool and Portland to be a 'hub' site. To become a 'hub', the following factors need to be considered:

- Ability to generate 'clean' hydrogen from renewable resources (particularly wind)
- Export potential –existing markets, new products, location to Asia, existing port locations
- Hydrogen fuel cell development– application in transport, industry, agriculture, dairy
- Victorian and Federal Government support to accelerate the development of the hydrogen sector
- Existing capacity – skills, people, knowledge, technology, including Deakin's Hycel

Hycel brings Deakin University's research expertise together with key industry partners to develop hydrogen technologies and pathways that ready Australia for the hydrogen economy. By working with researchers, industry, government, and community, Hycel aims to grow Australia's hydrogen economy and deliver clean and affordable energy solutions that meet Australian and Victorian emissions reduction targets.

Strategically located in Victoria's south-west, Warrnambool, Hycel is situated along key road and rail transport corridors that connect industries, communities, and resources. The Hycel Technology Hub will be one of Australia's first facilities for safely testing, assembling, optimising, and training in new hydrogen technologies. The facility will feature laboratories with specialist fuel cell equipment, offices, an innovation wing for SMEs and start-ups, training facilities and a science-on-display area for community.



Hydrogen in Uruguay

Uruguayan energy context

Since 2005 Uruguay has been developing renewable energy capability, with a focus on energy security. In 2010 the Energy Policy 2005-2030 outlined the path to reach 50% renewables by 2015; in particular, with a 15% share of non-conventional renewable energy sources (wind, biomass waste and micro hydro generation), and at least 30% of agro-industrial and urban waste. This plan also included the incorporation of 300 MW of wind power generation and 200 MW of biomass through private investment by 2015. This energy policy was heavily influenced by the 2008 - 2009 period where a severe hydrological deficit and oil price soar, from 61 USD/bbl on average for the first half of 2006 to 115 USD/bbl on average for the second half of 2008 (peaking at 145 USD/bbl in July 2008), caused significant fiscal cost for the country with expensive electricity imported from Brazil and Argentina.

In the following years, Uruguay tendered 150MW of wind farms in 2010, resulting in prices of $81 USD/MWh and another 150MW in 2011 resulting in prices of 68 USD/MWh. In 2013, tenders for solar PV awarded 196 MW at 87 USD/MWh, and biomass electricity further increased due to new investments in pulp production plants[xxxi], further diversifying the electricity mix. The table below, shows that Non-Conventional Renewable Energy (NCRE) installed capacity increased from 20 MW in 2007 to 1861 MW in 2020 (CAGR of 42% during the 13-year period).

Table 3. – Integration of non Renewable Energy Sources

	Biomass	Wind	Solar PV	Total NCRE
2007	20	0	0	20
2015	130	520	0.480	650
2020	155	1477	229	**1861**

Source: own elaboration base on ADME data

In 2018, 26% of electricity worldwide was generated with renewable sources, whereas in Latin America this percentage reached 60% and in Uruguay 97%[xxxii]. The main source of electricity generation in Latin America are large-scale hydroelectric plants. In Uruguay, hydroelectric plants could supply between 30% and 80% of electricity demand, depending on hydrological conditions. Notwithstanding, the case of Uruguay is particularly interesting given the already described mass penetration of non-conventional renewable energy sources. The share of electricity demand supplied by non-conventional renewable energy sources increased from 4% in 2010 to 62% in 2020. Today it is the second country in the world with the largest non-conventional renewable energy sources component in the electricity generation mix, after Denmark.

An important attribute of the electricity system of Uruguay, is that due to the intermittent nature of wind and solar resources, and given the rigidity of demand, there are structural electricity surpluses mainly during late night/early morning hours, for different exceedance probabilities for an average day of the 2020-2025 period. There could be hours of the day with over 850 MWh of surplus electricity (to put in context: average daily consumption in 2020 was 30137 MWh). This excess electricity generation points towards an opportunity to generate green hydrogen via electrolysis.

In terms of consumption, as of 2020, the industrial sector accounted for 44% of Uruguay's energy consumption, the transport sector 27%, the residential sector for 18%, commercial/services/public sector 7% and the primary sector for 4%. If we focus solely on fossil-fuel consumption, as the energy flow further below portrays, the transport sector accounts for 70% of the 1682 ktoe consumed in 2020, followed by the industrial sector 13%, primary sector 8%, residential sector 8% and commercial sector 1%.

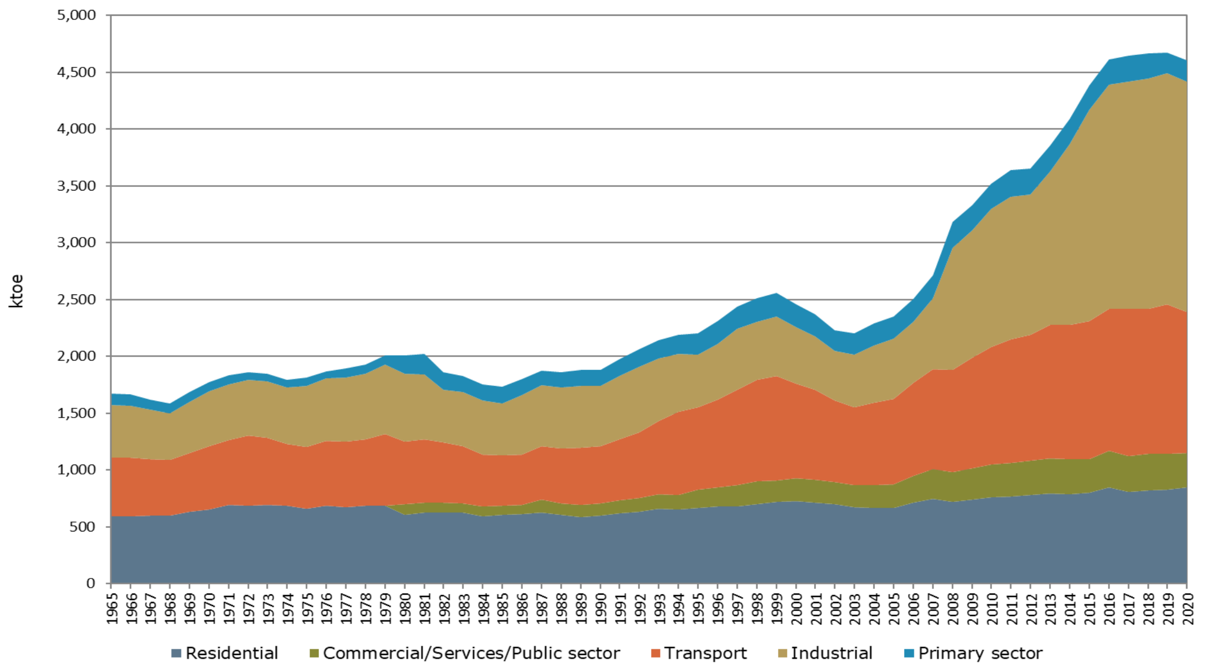


Figure 6. Energy consumption, by sector

Source: Balance Energético Nacional, MIEM, 2020

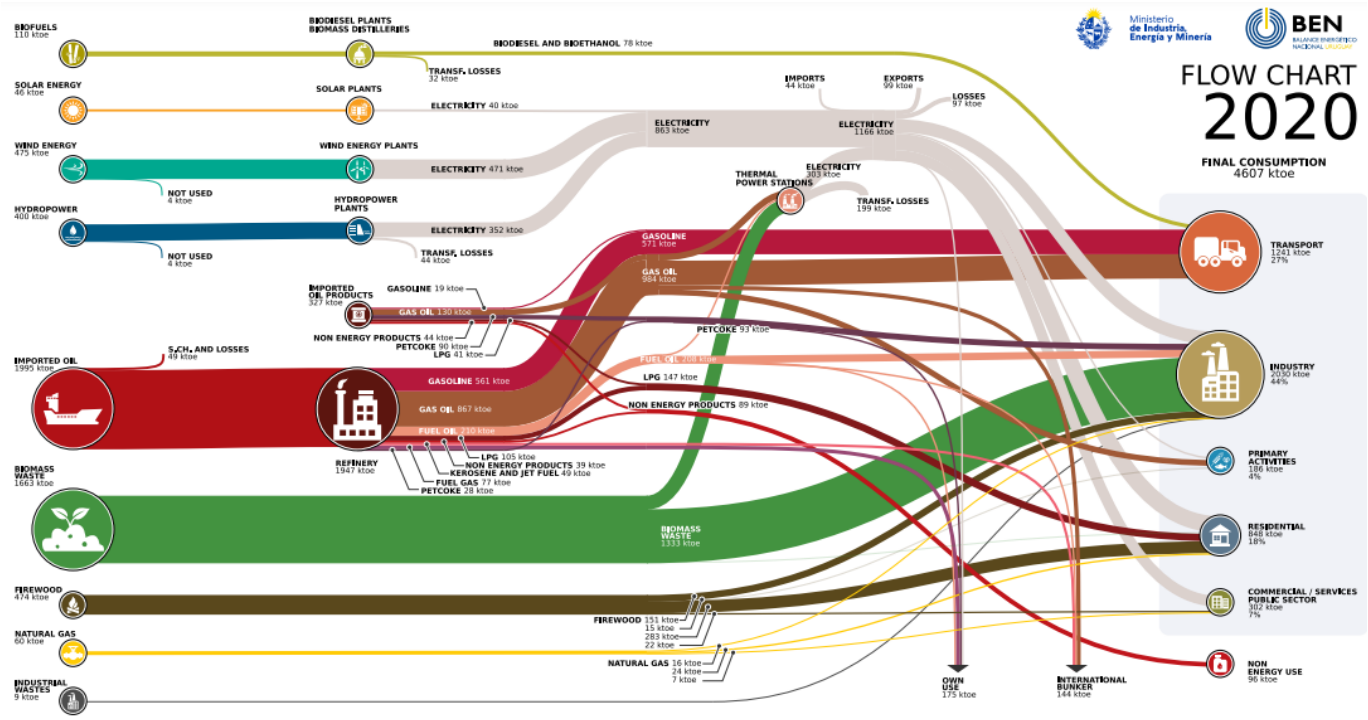


Figure 7. Energy source and consumption, by sector

Source: Balance Energético Nacional, MIEM, 2020

Uruguayan hydrogen position

Uruguay aims to become a green hydrogen exporter in the near and mid-term, currently exploring private and public investments with different countries such as Germany, The Netherlands and Japan. A successful renewable energy transition described above, and the synergies between wind and solar resources, port infrastructure, and macroeconomic and institutional stability put Uruguay in a privileged position to produce competitive green hydrogen, according to the local authorities.

In order to promote the Green Hydrogen strategy, the government of Uruguay has set up an interinstitutional group comprised of:

- The Ministry of Industry, Energy and Mining (MIEM): responsible for the policymaking concerning the industrial, energy, mining, telecommunications, micro, small and medium-sized enterprises sectors;
- The Ministry of Economy and Finance (MEF): responsible for the superior management of national economic, financial and commercial policy;
- The Ministry of the Environment (MA): in charge of the execution of national environmental policy, environmental regulation, sustainable development and conservation and use of natural resources;
- Administration Nacional de Combustibles Alcohol y Portland (ANCAP): the public utility responsible for the supply of fuels and lubricants, portland cement and biofuels;
- National Administration of Power Plants and Electrical Transmissions (UTE): the public utility responsible for the supply of electricity: generation transmission, distribution and commercialization activities.

The vision of the Government is to gradually generate capacities and experience, advance a National Green H2 Strategy and assist in the adaptation of safety and environment regulations. The government is also exploring the needs regarding port facilities ahead of future export opportunities.

Uruguay’s government structured its vision for the short, medium and long term. In their preliminary numbers, they estimate that the local yearly demand for green hydrogen could reach 150 kTon by 2025 if heavy transport diesel demand is substituted, plus additional 100 kTon in the mid-term if imported fertilizers produced with fossil fuels are substituted by, for example, green urea.

These would act as anchor for Uruguay to become an exporter in the long-term, coupled with further local demands such as a hydrogen fuelled train link, green steel, among other. A pre-feasibility study of a combined green hydrogen supply chain has been commissioned to analyse the different green hydrogen carriers, including an analysis on the flexibility of producing them with renewables directly

Port of Rotterdam feasibility study and the Hydrogen-2-Uruguay (H2U) Strategy

In 2020, MIEM and the port of Rotterdam carried a pre-feasibility study to provide an intended roadmap for the cooperation. The study provides an estimate of the accumulated investment required to build the Uruguayan Hydrogen Supply chain under several scenarios which go from producing green hydrogen to substitute fossil fuels in transport and industrial production to being a major exporter of green hydrogen for worldwide consumption.

Based on the Port of Rotterdam study, in 2021, MIEM has begun to develop a long-term national hydrogen strategy, has included funding in the 2022 budget for URSEA, the energy regulator, to develop the regulation required for the production, transport, commercialization, export, etc. of green hydrogen in Uruguay.

The H2U pilot project aims at testing a hydrogen ecosystem, identifying technical, legal and regulatory barriers and gaps, provide inputs for the construction of a green hydrogen roadmap and prepare Uruguay for the moment when hydrogen scales-up to mass adoption.

Finally, in early 2021, MIEM made a call for expressions of interest for a pilot project to build a small electrolyser and operate up to 10 heavy duty trucks or buses powered by hydrogen fuel cells produced by the electrolyser. The Ministry expects to launch the RFQ for the pilot project in the second semester of 2021.

The plan is to award a private company (or consortium of companies) a project to deploy a green-hydrogen fuel-cell vehicle fleet of buses and/or trucks, with certain government incentives to be defined. The fleet will comprise at least 10 nine-meter-long buses or 17-ton trucks. The minimum distance travelled by this fleet is estimated at 3,500 kilometres per day (in total).

The bidder must present an integral 10-year project of an estimated CAPEX of US$ 12 million, comprising:

- Production of green hydrogen: Design-Build-Finance-Own-Operate-Maintain.
- Compression.
- Storage.
- Charging infrastructure.
- Fuel-cell vehicles (trucks and/or buses).
- Transporters (off-taker that uses the vehicle fleet).

The electricity demand of the electrolyser is expected to range between 1.5 and 5 MW (production of approximately 500 kg of green hydrogen per day). The business model of the project is depicted in the figure below.

The government will provide a variety of fiscal incentives and subsidies including the site near the port of Montevideo where the electrolyser would be located.

The objective of the pilot is to kickstart the green hydrogen industry in Uruguay with limited public financial involvement while at the same time the required regulation is being developed. Also, during the 2nd half of 2021, ANCAP launched a call for expressions of interest to build an offshore windfarm to produce electricity to power the production of green hydrogen.

Dairy industries in Australia and Uruguay

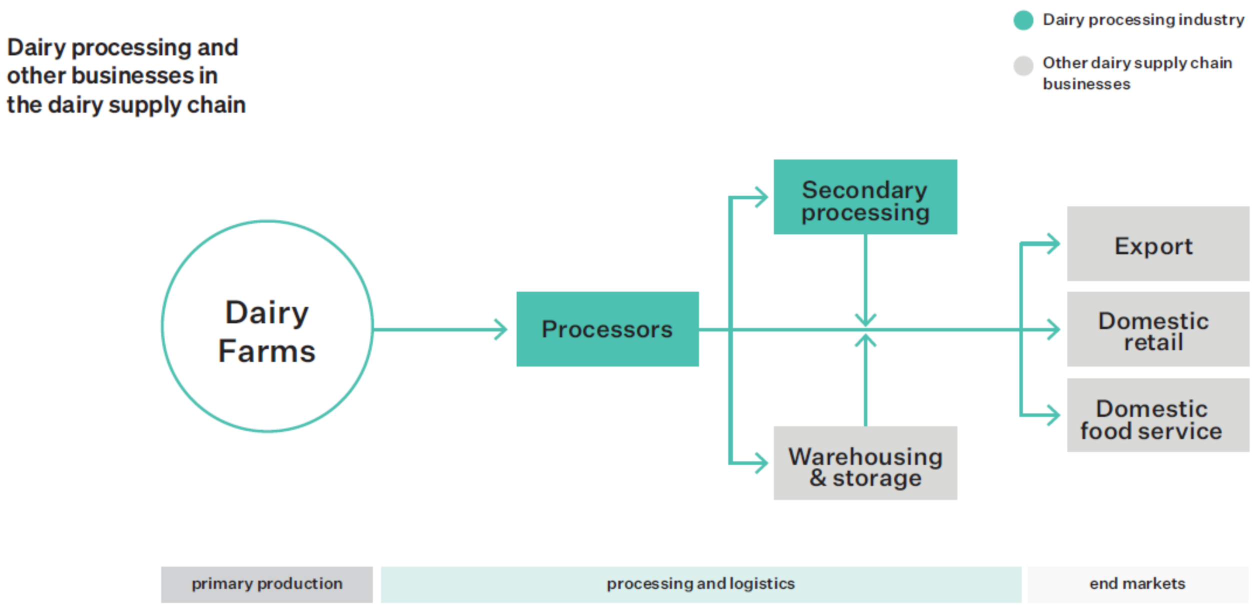
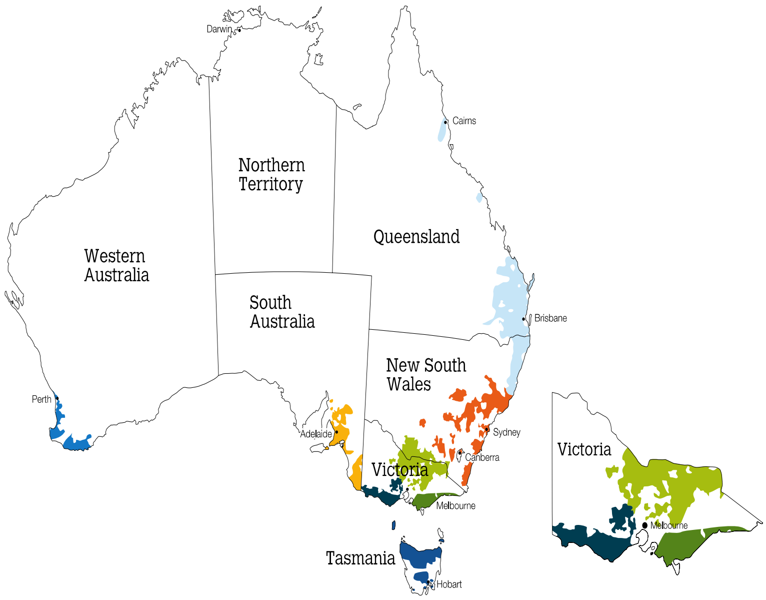


Figure 8. Dairy processing and other businesses in the dairy supply chain – Sourced from *Deloitte Access Economics (September 2021) Economic and broader contribution of the Australian Dairy Processing Industry.* Australian Dairy Products Federation. Adapted from *Productivity Commission (2014). Relative costs of doing business in Australia: Dairy Product Manufacturing.*

Australian dairy industry context



The Australian Dairy industry is a $13 billion farm, manufacturing and export industry which directly employs about 43,500 people and is the nation's fourth largest rural industry (over 100,000 people are indirectly employed in dairy related services nationally). Close to 9 billion litres of raw milk with a total farmgate value of $4.8 billion is processed by manufacturing companies into liquid milk and high value dairy products[xxxiii]. In 2019/20 71% of Australian dairy was sold on the domestic market for direct consumption or as ingredients in food and beverage. The remaining 29% of Australian dairy was exported, with a total value of around $3.48 billion per annum. Although the export proportion of Australian production is down ~6% on previous years, Australia remains the fourth largest dairy exporter (following New Zealand, the US, European Union - including UK) and contributes to 5% of global dairy trade.[xxxiv] Approximately 125 Australian companies export dairy products to over 100 countries. The largest markets by value are Greater China, Japan, Singapore, Malaysia and Indonesia.[xxxv] A key market access differentiator for Australian dairy is the industry's highly regarded quality assurance systems which underpin its globally recognised 'clean, green, safe and ethical' attributes.

While all Australian states produce milk and dairy products, milk production is concentrated in the country's south-eastern corner where a temperate climate with sufficient rainfall, or good access to irrigation water (schemes), provide the backbone to Australia's pasture-based dairy farming system. In these regions production is largely seasonal, peaking in October and flattening out in the winter months. Seasonality of production is less evident in NSW, Queensland and Western Australia where management of calving and feed systems ensure year-round milk production for the domestically focused market.

Close to two thirds (64%; 5.6 billion litres in 2019/20) of the national milk supply is produced in Victoria and this state contributes 62% by value of national dairy exports. The remaining milk production comprises 12% in New South Wales, 10% in Tasmania, 6% in South Australia, 4% in Western Australia and 4% in Queensland (2019/20).[xxxvi] Similar to Victoria, dairy production in Southern New South Wales, Victoria, Tasmania and South Australia are primarily orientated around exports and manufacture of high value products. A large proportion of exports are in the form of value-added products such as cheese, butter, ultra-heat treated (UHT) milk, and skim and whole milk powders.

Dairy companies in Australia operate in an open and internationally competitive market, and this influences the prices that Australian dairy farms are paid for their milk. Unlike many countries around the world, the Australian Government has no legislative control over the farmgate milk price. World dairy prices directly affect returns for the 29% of Australian milk produced which is exported as butter, cheese and milk powders. These products must then compete with other countries' exports. World dairy prices also influence the milk price for the additional 43% of Australian production that goes into locally consumed butter, cheese and milk powders, which must be competitively priced against imports. More than 70% of milk production in Australia is exposed to global dairy prices, while the remainder is consumed within Australia as liquid drinking milk.

Figure 9. Exporters share of world dairy trade in 2019 (milk equivalents) [xxxvii]

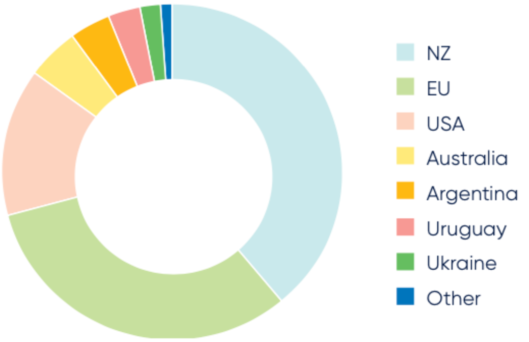


Figure 10. Australian exports by region in 2019/20 (A$ million) [xxxviii]

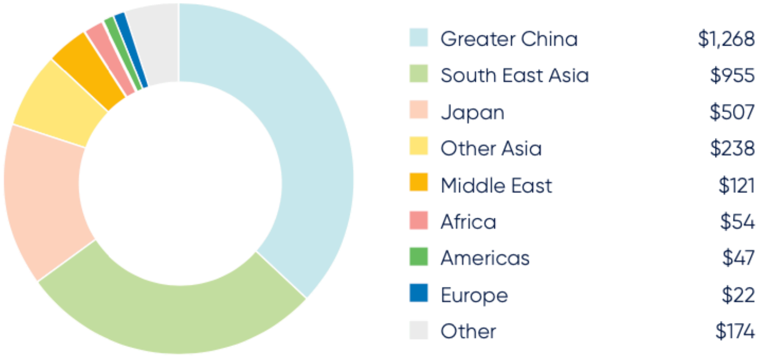


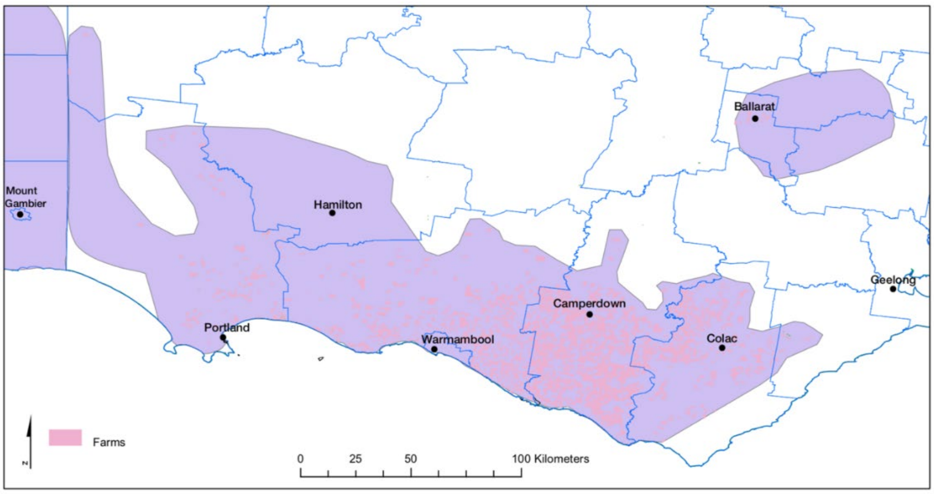
Table 4. Industry Statistics 2019/20 (Dairy Australia) [xxxix]

	National	Victoria	South west Victoria
Total dairy farms	5055	3889	1156
Dairy Industry workforce	Direct employment ~46,200	Direct employment 29,300	Direct employment 10,300
Milking herd	1.41 million cows	0.93 million cows	0.31 million cows
Avg herd size	262 cows/farm	261 cows/farm	261 cows/farm
Milk production /cow	5,819 L	5,761 L	5,761 L
Milk Production	8.8 billion L	5.6 billion L (64% national volume)	1.94 billion L (22% national volume)
Farmgate industry value	$4.8 billion	$3 billion	$1 billion
% Milk Vol exported	29%	29% (69% total national exports)	(22% total national exports)
Export Value	$3.4 billion	$2.1 billion	$0.7 billion
% National export value		62%	21%

South west Victorian dairy

The dairy sector is Victoria's largest agricultural industry, producing more than 64% of the national annual milk supply and exports valued at $2.1 billion (2019/20).[xl] Over 5.6 billion litres of milk is produced by 3,462 dairy farms spread across three dairy regions: Gippsland, northern Victoria, and south western Victoria.[xli]

South west Victoria is one of the largest milk producing regions in Victoria and Australia. It holds significant processing capacity which is utilised to process milk sourced from both within and outside the region. The region is commonly referred to as WestVic Dairy by industry which reflects the local regional development program coordinated by Dairy Australia. With a favourable climate and physical environment for a strong pasture based dairy sector, the region has a long dairy history. Developing from small family farms and numerous local producer co-operatives during settlement, the industry today is characterised by larger farms and herd numbers that supply a competitive processing environment comprised of both large, international players as well as smaller more specialised and artisan dairy enterprises across the region.



This map was developed by the University of Melbourne and edited by WestVic Dairy

Figure 11. Map of south west Victorian dairy production - WestVic

The region extends from the outskirts of Geelong and heads west to the South Australian border with a strong concentration around Warrnambool and into the Otways. From 1,156 farms, the region's annual milk production of nearly 2 billion litres (2019/20) represents 35% of Victoria's production, 22% of the national, and 22% of Australia's dairy exports (see table 5)[xlii]. The farmgate milk value is $1 billion and around 5,200 people employed on farm with a total of over 8,900 working directly in the industry.[xliii]

Table 5. WestVic Dairy Key Industry statistics average 19/20[xliv]

Number of farms	1156
Regional dairy herd (no. cows)	310,000
People directly working in dairy (full time and part-time)	8,900
People employed on farm (full time and part-time)	5,200
People employed in processing (full time and part-time)	3,700
Volume milk produced	1.94 billion L
Share of national milk production	22.1%
Value of milk leaving farms	$1.04 billion
Value of dairy products exported	$696 million tonnes
Share of national dairy exports ($value)	21%
Volume of dairy products exported	168,000
Share of national dairy exports (volume)	22%

Dairy farming in this area is dryland pastured based matched to seasonal growing conditions. Farm production systems range include one seasonal autumn calving (dominant system), to split calving across autumn and spring, and some farms managing year-round calving leveraging off peak milk payment incentives. Rainfall variability is usually low, with relatively consistent and longer growing seasons for pasture and fodder crops. Rainfall averages range from around 700-750mm in the Warrnambool region to a little over 1000mm in the Otways[xlv]. Toward Ballarat the average rainfall is closer to 700mm. Irrigation in the region is minimal (supplementary) and most farms will spread effluent onto pastures by various methods. Irrigation that does occur usually relies on groundwater and accessed through bores.

Fodder crops of brassicas (rapeseed), beets and chicory are often used to fill the summer – autumn pasture feed gap. Silage crops such as maize are sown by some farmers trying to reduce their reliance on (and exposure to volatility of) bought in feed rations. The region has seen a small increase in off-paddock feeding infrastructure such as feed pads, as a result of some farmers wishing to increase herd preserved fodder and/or mixed rations consumption and reduce this feed wastage.

(Large and medium sized) Milk supply and processing companies that operate in the region include:

- Saputo Dairy Australia
- Fonterra
- Bega Cheese
- Bulla Dairy
- Australian Consolidated Milk
- Australian Dairy Farmers Cooperation
- Union Dairy Company (Midfields Group)
- Camperdown Dairy Company

Smaller, micro dairy producers include

- Inglenook Dairy
- Schulz Organic Dairy
- Apostle Whey Cheeses
- Green Pastures

Dairy farm production systems

The number of dairy farms in Australia has been in steady decline with a shift towards more intensive operating systems providing economies of scale. The trend towards fewer farms is characterised by larger herds and increasing levels of milk production per farm: The number of large farms and their share of milk production continues to grow.[xlvi] Historically, Australia has been considered a low-cost producer of dairy products. A significant increase in production costs underpinned by variable season conditions, water access and pricing, supplementary feed (grain, silage) access and pricing, coupled with volatile global economic conditions and some skilled labour shortages has challenged the capacity of dairy farm businesses to remain profitable, and sustain profitable growth of their farms and industry.

In Australia, dairy farming systems have evolved in each regional area as farmers make best use of their resources and assets to respond to seasonal variations in climates and markets. The significant differences in location and resources available across regions highlight the reality that there is no one dairy system. These different farming systems are generally classified according to calving patter and differences in feeding practice. The later range from predominantly pasture based through to total mixed ration systems (in housed facilities) with varying feed compositions in between and are described below.

Table 6. Australian dairy farm feeding systems

	System	Description
1	Low bail	Pasture & forages grazed in the paddock with less than 1 tonne concentrates/cow/year fed in dairy bail
2	High bail	Pasture & forages grazed in the paddock, with more than 1 tonne concentrates/cow/year fed in dairy bail
3	PMR (Partial mixed ration)	Grazed pasture & forages most of the year, plus mixed rations in dairy & feedpad
4	Hybrid	Grazed pasture & forages < 9 months, and are fed mixed rations in dairy & feedlot
5	TMR (Total mixed ration)	No grazing, with cows fed forages and concentrates in fully housed environment

Concentrates: *high energy and protein source such as grains, cereals or commercial mixes (cereals, cereal by-products, molasses, oils and minerals) in the form of concentrates, pellets or meals.*

Partial Mixed Rations: *a nutritionally balanced mixture of supplements (fodder, silage and high-density concentrates) aimed at complementing the nutrients selected by the grazing animal.*

Total Mixed Rations: *a nutritionally balanced mixture of fodders, silage and high-density concentrates providing the animals complete nutrition requirement in the absence of grazed pasture.*

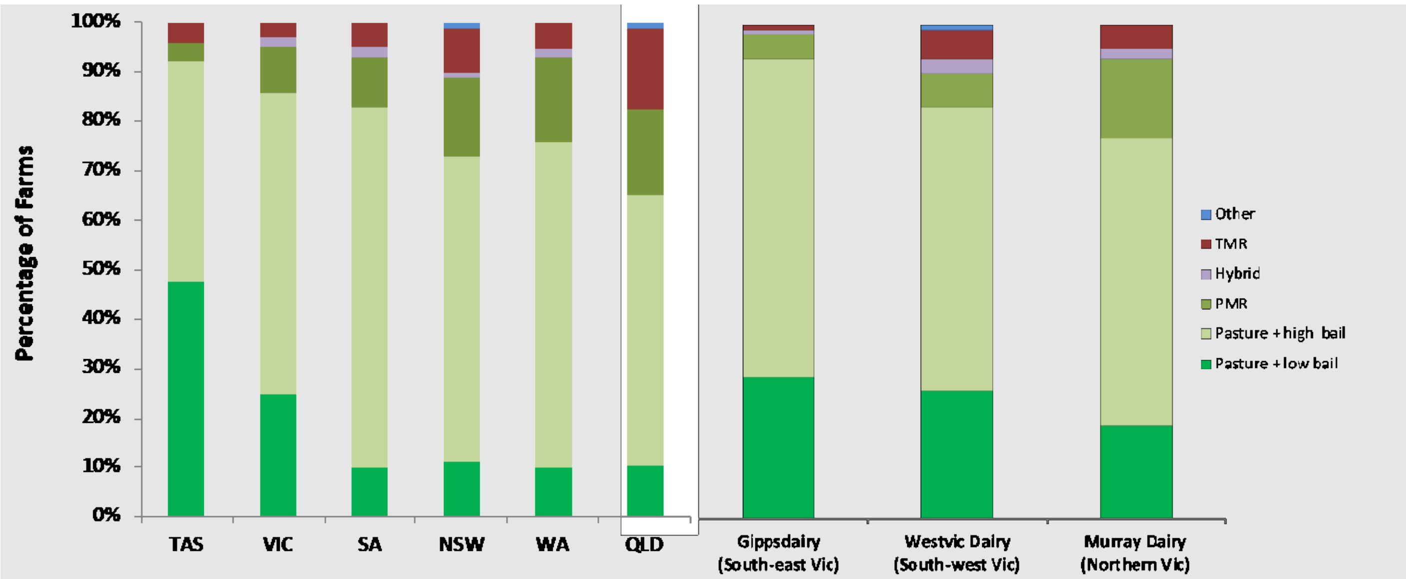


Figure 12. Relative distribution of Farm Feeding Systems across Australian dairy regions [xlvii]

As herd sizes and stocking rates have increased, effluent management has become a major environmental issue for dairy farms. Most farms have now adopted some form of effluent storage, treatment and recycling of nutrients back onto the farm. Ponding systems are the most popular with over 70% of farms using these systems. The industry has developed effluent management guidelines and online resources which provide advice for managing the environmental impact of dairy facilities. The potential use of effluent to produce on farm hydrogen gas is unlikely to be realised on pasture-based farming systems in the near future as the economies of scale are challenged with most animal excreta occurring in the paddock. The effluent that is collected from the dairy shed and yard into distilling ponds, also a provides a valuable source of non-labour-intensive fertiliser.

We acknowledge that on-farm anaerobic production of biogas from effluent is more suited to intensive dairy farming systems where various housed infrastructure are in place. In these scenarios on farm hydrogen gas production could be an area of investigation in the future.

On-farm energy & fuel use?

The three main contributors to energy use on dairy farms are water heating, milk cooling and milk harvesting, which together total about 80% of energy use.[xlviii] The remaining 20% of energy use arises from cleaning and effluent management, stock water, feed and sheds and lighting.[xlix] (This does not include irrigation which is typically the biggest part of the energy bill for irrigated farms, depending on the season). Fuel (diesel & petrol) are used to power farm vehicles such as tractors, small and medium utility vehicles (utes and motorbikes). Industry benchmarks indicate that fuel and diesel costs are about 2% each of total operating (farm) costs.[l]

The national average energy use on dairy farms is 48kWh/kL (kiloWatt-hour per kilolitre) of milk (this metric kWhr per kL of milk accounts for variations in milk volumes (L) and milk solids produced by a cow).[li] The amount of energy used by a farm is largely dependent on the volume of milk physically harvested and cooled. Further, energy use per kL milk is highly variable with a scale effect: dairies with larger herd sizes have lower energy use per kL milk. Nationally, energy use per kL milk declines by about 14% from herd size 100 to 200 and then by about 4% for every 100 cows up to 500 cows.[lii]

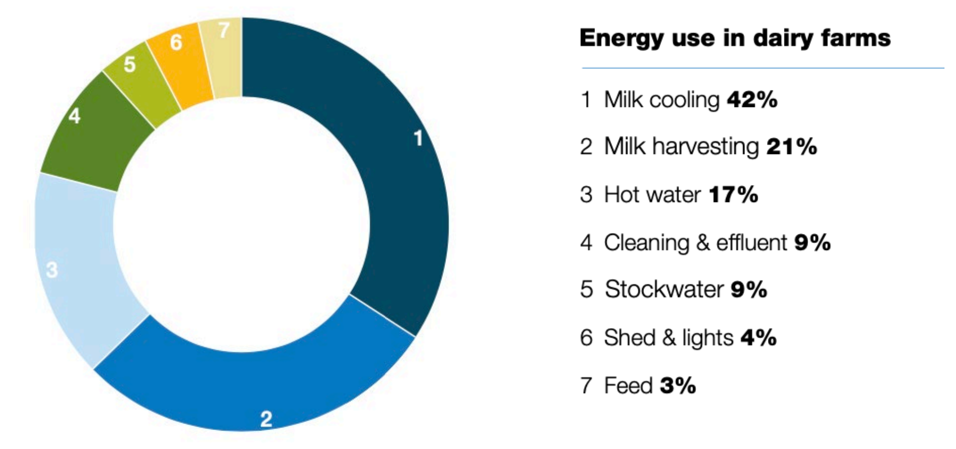


Figure 13. Typical energy use in Australian dairy farm [liii]

Table 1 Western Victoria benchmarks

	Western Victoria benchmarks		
	Low	Average	High
Total energy costs per 100 cows	$3,570	$5,500	$7,500
Hot water costs per 100 cows	$450	$1,450	$2,440
Milk cooling costs per 100 cows	$1,200	$1,940	$2,680
Milk harvesting costs per 100 cows	$600	$1,080	$1,560
Energy use per milk production kWhr per 1000L	32	47	63
Energy cost per milk production $ per 1000L	$5	$9	$13
Energy cost per kWhr (average for year of assessments from 2012 to 2015)	$0.16	$0.20	$0.23

These benchmark data relate only to dairy shed use and any other loads connected to the dairy metering point. The data excludes automatic, small rotary (herds <150) and large walk through (herds >300) dairies which all have higher energy use compared to others with a similar herd size. [liv]

Although energy inputs have traditionally formed a relatively small proportion of overall production and post-farm costs, the increasing cost (particularly of electricity) and intermittent reliability are becoming increasingly important issues for farmers (and processors) access to affordable and reliable energy is imperative for continued sustainability and enhanced growth in the agricultural sector.

Why is the cost of electricity increasing?[1]

The National Electricity Market (NEM) comprises five interconnected states that also act as price regions: New South Wales (including the Australian Capital Territory), Queensland, South Australia, Tasmania and Victoria. All electricity in the NEM is traded through a spot market, where supply and demand are matched in real time through a centrally coordinated dispatch process.

Higher wholesale prices were the overwhelming driver of the electricity bill increases experienced by businesses during 2016 and 2017. Over this period there were cumulative increases in wholesale electricity prices of between 77% and 176% across the four major NEM states.

Three key trends are in the process of NEM transformation – the generation mix is changing (from fossil fuels to renewables), the grid is decentralising (with multiple sources of generation, storage and demand management) and the demand profile is shifting (with businesses increasingly controlling not just where their energy comes from and how much they use, but when they use it). New renewable generation is entering the wholesale market, increasing supply, and therefore competition, and even more renewables are being built. Even so, few experts expect wholesale prices to return to the lows of 2015.

Cows are commonly milked twice a day via mechanical/automated milking machines in the dairy. Some farmers choose to run a farming system involving once-a-day milking, while dairy herds managed in more intensive housed systems and fed a higher energy Total Mixed Ration diet often milk three times a day. Milk is pumped directly into refrigerated vats located in the farm dairy and immediately chilled to 4 degrees Celsius. Depending on the holding size of the milk vat and the herd production level (which can vary seasonally), this milk is collected by the milk supply company (or third-party transport provider) in refrigerated tanker trucks once, twice or every second day and transported to a dairy manufacturing site for further processing. Milk processors traditionally pass on the transport costs to the farmer. This is usually done on a cents per litre basis.

The Australian dairy industry involves significant value adding through its downstream processing, much of which occurs close to farming areas (see Figure 13 below).

Processing

There are approximately 140 dairy processing plants across Australia, and these are typically located at an average distance of between 150 and 200 kilometres (km) from dairy farms.[lv] This is reflected through the distribution of dairy processing employment with 56.5% of industry direct employment located in regional Australia. Notably, this regional share of employment is considerably higher than the averages for other food processing (42%) and the broader manufacturing sector as a whole (31%).[lvi]

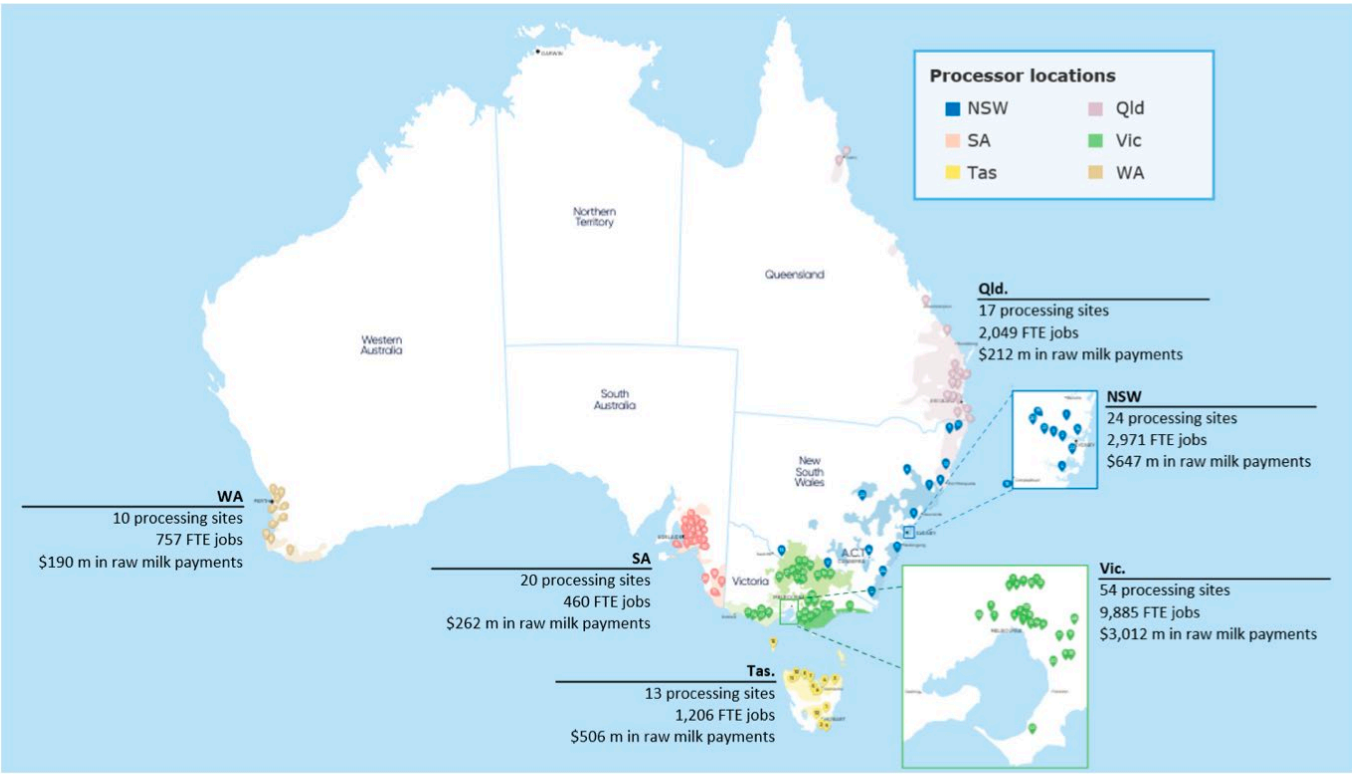


Figure 14. Australian Dairy processing locations and summary statistics[lvii]

Processing locations as at 2019; employment figures refer to 2020-21 average and raw milk payments refer to 2019-20. Australian Dairy Products Federation (2021) Economic and Broader Contribution of the Australian Dairy Processing Industry

A range of dairy companies operate in Australia including national and multinational companies, both privately owned and publicly listed. The large multinational companies currently include Fonterra (New Zealand), Lactalis (France) and Saputo (Canada). These large dairy companies tend to produce the full suite of dairy products from fresh and UHT liquid milk to milk powders, protein and whey powders, cheese, butter, cream and yoghurt. These companies leverage economies of scale and play into the global commodity market. Quality assurance and sustainability credentials are increasingly important to secure and retain international supply agreements.

Publicly listed Bega Cheese is the largest Australian owned dairy company, and like the large multinationals, produces a broad range of products. Other Australian dairy companies cover a diverse range of sizes, markets and products. Examples of Australian dairy processing companies operating in the southwest region of Victoria, in addition to Bega and the multinationals Saputo and Fonterra, include the likes of privately owned Bulla Dairy Foods and Midfield's Union Dairy Company, Australian Consolidated Milk, Camperdown Dairy Company as well as some smaller more boutique players. These companies process a diverse range of milk volumes into a variety of product portfolios. Notably, (due to the capital-intensive nature of processing facilities and the complexities of managing various product streams and by-products) some companies marketing their own dairy product lines, such as Coles and Woolworths, subcontract the production of their dairy brands to dairy companies rather than owning and managing their own processing infrastructure.

The overall product mix generated by the Australian dairy manufacturing industry has continued to change with a steady increase in the proportion of fresh dairy and cheese produced since 2005, and a corresponding reduction in dairy powders. This is largely due to the high cost of production for milk powder and its market value, relative to the lower cost of production and the market demand and opportunities for cheese. Cheese is consistently the major product stream, accounting for 39% of Australia's milk production. [lviii] Recent increases in cheese production capacity suggest this will become the case even more so in the future. Drinking milk and skim milk powder/butter production were the two next largest users of milk, accounting for 32% and 22% of Australian milk, respectively. [lix] A total of 4% of milk is used for whole milk powder while the remaining 3% of national milk production goes to a mix of other fresh and frozen dairy products. [lx]

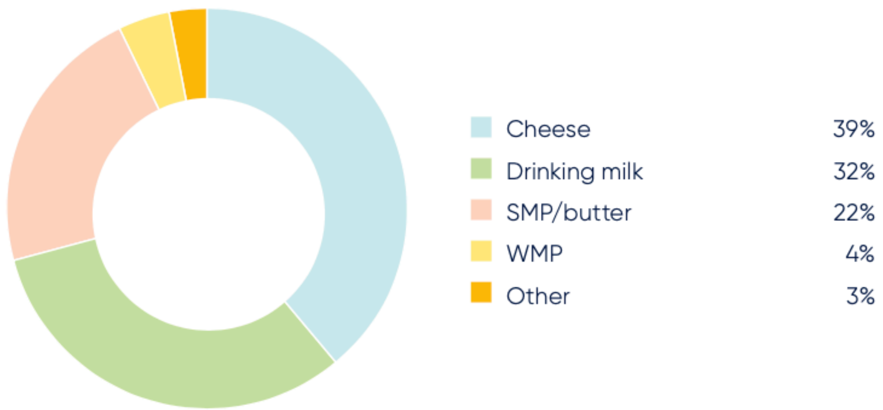


Figure 15. Australian milk utilisation in 2019/20[lxi]

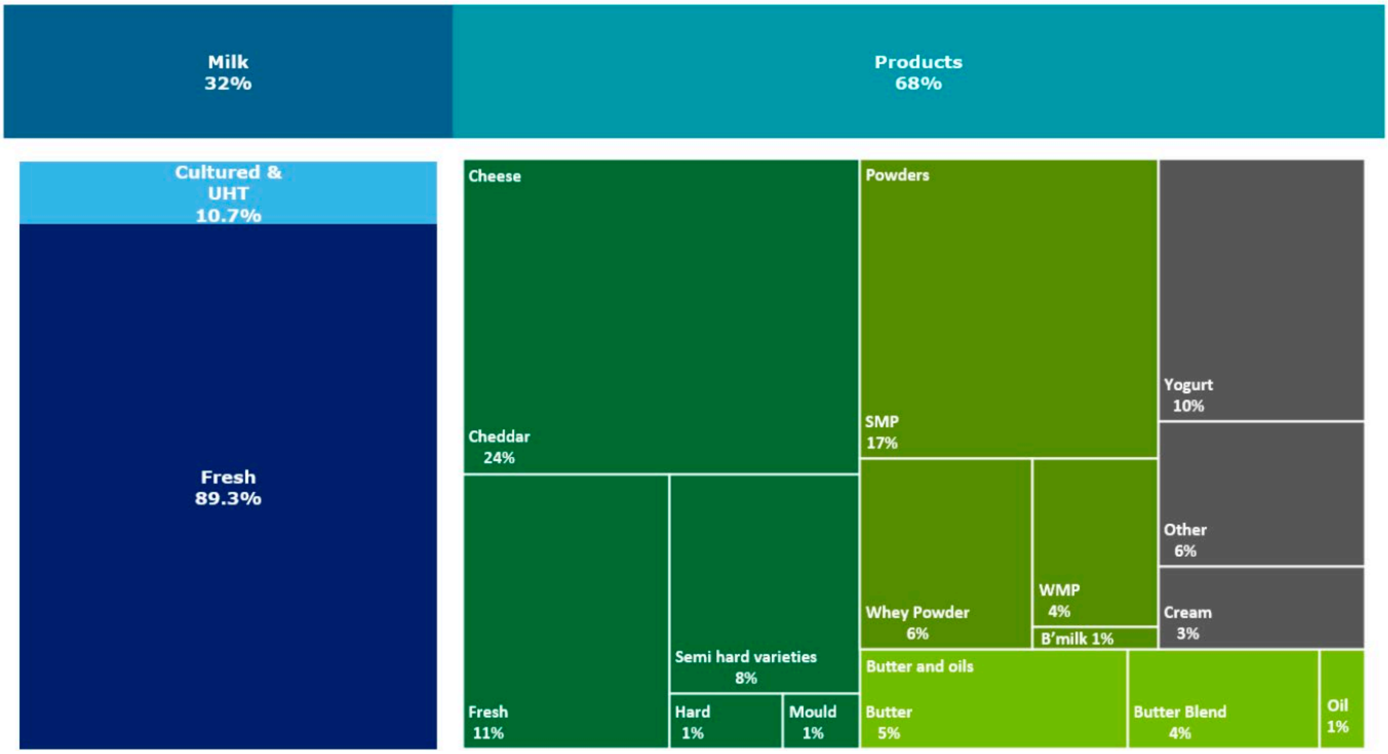


Figure 16. Dairy processing milk utilisation and share of milk and products production, 2019-20[lxii] [lxiii]

Note: UHT refers to Ultra High Temperature milk

About 41% of manufactured product was exported and the remaining 59% sold on the Australian market in 2019/20.[lxiv] This contrasts with drinking milk, where most was consumed in the domestic market – a total drinking milk sales volume of 2.5 billion litres across Australia.[lxv]

Throughout the 1990s the dairy industry experienced strong growth reaching a peak of 10.8 billion litres in 2000. This growth stalled following deregulation in 2000/01, the period which also coincided with the latter half of the severe and prolonged 'Millenium drought'. Increased levels of market and margin volatility have undermined confidence in the outlook many farmers, who are seeking reliable returns on which to build a longer-term future. As a result, the national milk volume has struggled to grow beyond 9 billion litres and industry has continued to undergo consolidation amongst processors and rationalisation has seen the closure of smaller processing facilities.

Energy use in processing

Across the dairy supply chain, dairy processing is roughly twice as energy intensive as on farm milk production.[lxvi] In 2019/20 Australia's dairy processing sector consumed a total 10.9 Petajoules (PJ) of energy.[lxvii] This was 4.6% lower than the previous year (11.4 PJs) with the industry accounting for a small share of the manufacturing (1.3%) and Australian totals (0.2%).[lxviii] [lxix] For most dairy manufacturers, 80% of their energy needs is for thermal processes (i.e. heating and drying milk, hot water for cleaning) and the remaining 20% used for electrical requirements.[lxx]

Energy use in dairy factories is dependent on the types of products manufactured. For example, milk powders require 1.7 times as much electricity as cheddar, and 6.0 times as much thermal energy due to evaporative processes.[lxxi] Plants producing mainly drinking milk and yoghurts use energy for heating and pasteurisation, cooling and refrigeration, lighting, air conditioning, pumping, and the operation of processing and auxiliary equipment. Factories producing concentrated dairy products such as butter, cheese or powders require additional energy, variously for churning, pressing, separating, concentrating, evaporating and/or drying. This additional energy use increases the relative energy-use intensity / ML raw milk processed.[lxxii]

Table 7 below shows typical percentages of energy supplied from electricity and other fuels used to produce thermal energy (i.e. steam) for Australian dairy plants (2015/16). Table 8 shows total use of energy (electrical and thermal) per kL of raw milk intake for Australian dairy processors (2015/16). Notably, energy consumption of Australian liquid milk and cheese plants is similar to the UK benchmarks.[lxxiii]

Table 7. Proportions of electricity and thermal energy use (2015/16) REF source

	Electricity (%)	Thermal (%)
White and flavoured milk#	49	51
Mostly cheese (and some powders)	21	79
Mostly powders (some cheese)	16	84
Mixed products	16	84
#excluding UHT milk		

Table 8. Total energy use – electrical and thermal (2015/16) REF Source

	Australian data (2015/16)			
Gj/kl raw milk intake	Min.	Max.	Average	No. plants providing data
White and flavoured milk only	0.38	0.87	0.53	10
Mostly cheese (and some powders)	0.52	1.99	1.46	3
Mainly powders	1.30	2.78	1.50	4
Mixed products	0.84	1.69	1.26	2
All dairy processors	0.38	2.78	1.02	22

Figure 17 and Figure 18 below show the typical breakdown of energy costs in two UK dairy processing plants, one producing mainly white milk and the other producing cheese and powders. For a short shelf-life milk plant, energy costs are relatively evenly distributed between refrigeration, general services, processing, clean-in-place, bottling and packaging (cartooning). For plants producing cheese, whey and powders, the main energy costs are in drying and evaporating, followed by general services, refrigeration and clean-in-place. These differences in energy requirements across dairy plants with different production lines highlight that the/any transition to hydrogen will need to be tailored to the user (specific plant) energy requirements locations.

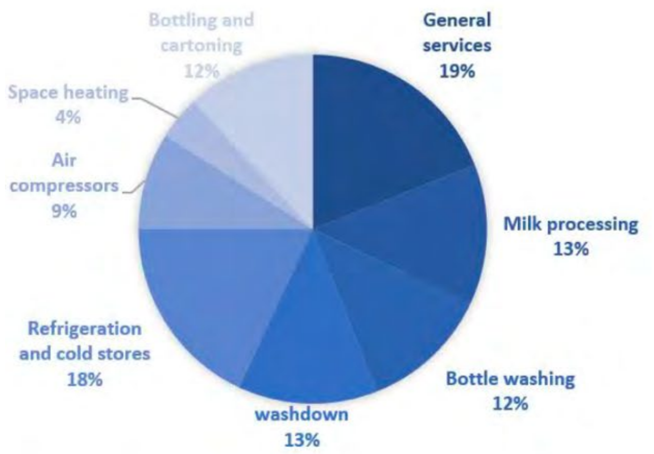


Figure 17. Energy cost breakdown by area: UK milk plant (ETSU, 1998) in Prasad et al (2019)

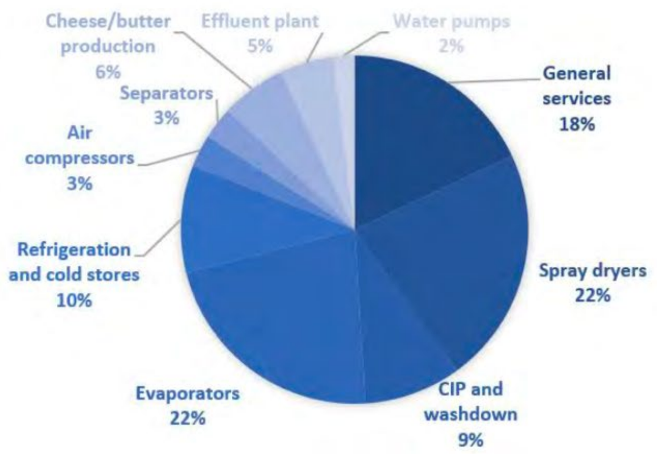
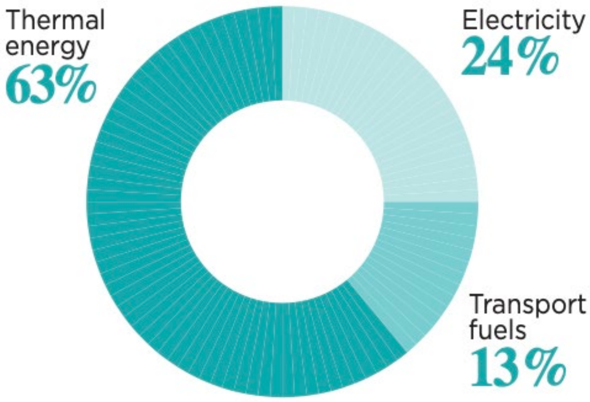


Figure 18. Energy cost breakdown by area: UK powder, cheese and whey plant

Australia's dairy processing energy intensity was 1.2 TJ per ML of milk received in 2019-20 is broadly comparable to overseas dairy processors, and 12.8% below the average of the 5 years prior (1.4 TJ per ML).[lxxiv] [lxxv] Much of this decline has occurred over the last three years, driving a 24.5% reduction in total energy use to 2019-20.

Reduced energy use has been driven in part by a shift in industry focus away from energy- intensive skim milk powders to higher value products (principally cheese). It also reflects improved energy efficiency within the dairy processing industry, integrating renewables and other energy saving innovations into manufacturing sites.

Electricity and thermal energy are generated both externally and on-site, typically using fossil fuels including coal, oil, natural gas and LPG, whilst a small number of plants supplemented their energy supply using biogas. The choice of energy source depends both on the required application and the geographical location with natural gas and grid electricity being the two main sources of energy reported by dairy manufacturers.[lxxvi] While natural gas produces fewer GHG emissions and represents a better value for money option, it is not available in all regional areas.

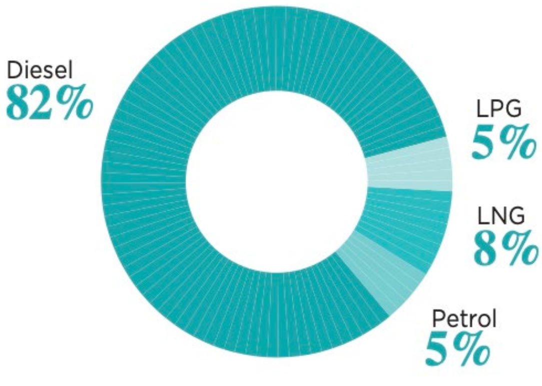


While this data is not particularly recent the volume of milk being processed remains similar. More notable, this likely does not include the transport of raw milk to processing plants by third parties, as well as transport logistics of dairy products to warehouses and markets (this option of outsourcing transport is becoming more common).

Figure 19. Distribution of energy use across thermal, electrical and transportation applications by the Australian dairy manufacturing industry in 2010/11[lxxvii]

Transport energy & fuels

Transport is an integral part of the dairy supply chain with processors typically involved in both collection from farm and distribution after processing. Dairy processors are increasingly outsourcing transport services however they do retain responsibility for getting freight to market, including raw milk from farm to processing point. Dairy transport fleets typically comprise prime movers (heavy freight vehicles) and various milk tankers combinations including conventional single as well as both 19m B-doubles and 26m A-doubles.



Energy used during transport can include that related to daily rinsing of individual milk tankers, but is more generally associated with fuel use, including refrigerated transport. Diesel fuel is the largest component of transport energy in the dairy industry contributing over 80%, while LNG, LPG and petrol each contribute 5%-8%.[lxxviii]

Figure 20. Break down of transport fuel type as used by Australian dairy manufacturing companies lxxix

The amount of fuel (energy expenditure) required for transportation varies depending on a range of factors. From the farm, collection occurs regularly (every 24 or 48 hours) due to the high perishability of raw milk. Distances travelled from farms and processing plants can range from just a few kilometres to as much as 600km and farm-milk collection schedule is optimised for various factors, including fuel use, and changes seasonally as milk supply volumes fluctuate. Transport costs also reflect the impact of weather, as an appropriate temperature must be maintained.

Once processed, dairy products are typically transported to other plants for packaging (if required), on-or off-site cold storage facilities, or distribution centres. After packaging, products for the domestic market are typically moved to centralised warehousing systems of retail outlets or directly to consumers. Increasingly, specialist milk distributors are contracted by processors to deliver dairy products to customers.[lxxx] Limited data exists on milk distribution and transport: The Productivity Commission reported in 2011 there were 745 milk distributors in Australia employing about 2,200 staff.[lxxxi]

As dairy processing is concentrated in regional areas in south-eastern Australia, dairy products must often be transported significant distances from processing plants to customers. This is again complicated by the perishable nature of dairy products (particularly drinking milk), which requires additional logistical and refrigeration costs. Dairy products destined for export markets are generally warehoused in storage facilities, prior to being trucked to port and shipped as containerised sea freight.

Based on 2017 CSIRO modelling (which focussed only on milk and cheese production), it is estimated that one megalitre of raw milk supports around 575 vehicle trips and 1.5 unique origin-destination paths in Australian dairy processing supply chains (based on 5.5 million vehicle trips between 2013 and 2016, and an average of 9.6 billion litres of milk processed during that period[lxxxii]).[lxxxiii] For 2020-21 (with around 8.8 billion litres of raw milk), this equates to an estimated 5.1 million vehicle trips and 12,888 unique origin-destination paths.[lxxxiv] Most of the associated transport costs (78.4%) are expected to result from trips occurring after the point of processing, and CSIRO also estimated freight transport associated with the dairy supply chain cost industry around 9 cents per litre between 2013 and 2016. For 2019-20, the cost of freight transport in Australia's dairy processing supply chain is estimated at around $890 million.[lxxxv]

As a share of total transport costs incurred by agricultural supply chains in Australia, dairy is estimated dairy to have accounted for approximately 15.1% of the total between 2013 and 2016.[lxxxvi] Notably, this share is expected to have varied considerably over the period, largely due to variation in seasonal conditions.[lxxxvii] For example, widespread and timely rainfall saw Australian crop production 34% higher in 2020-21 relative to that averaged between 2013 and 2016, when cropping accounted for a third of all freight costs.[lxxxviii] By contrast, meat production was 7.6% lower in 2020-21) than that averaged between 2013 to 2016 (when the industry accounted for around 20% of freight costs) as herd and flock rebuilding accelerated across Australia.[lxxxix]

Quality Assurance

The industry's comprehensive quality assurance programs span across multiple areas including food safety, animal welfare, chemical contamination and environmental responsibilities.[xc] Australia has developed stringent quality management systems that are underpinned by comprehensive regulatory requirements that meet both Australian and international requirements. Customer needs, food safety and product traceability are paramount for the quality assurance systems; The consideration and importance of animal welfare, biosecurity and environmental sustainability are increasingly under focus in the development of the quality management programs.

The national regulatory framework is an integrated system involving federal and state regulatory agencies, dairy farmers, dairy companies and Dairy Australia. Internationally recognised Codes and Standards provide a basis for Australian dairy food regulation. At the farm level, multiple standards and codes of practice, as well as guidelines are implemented by farmers and the farm service sector. For example, in accordance with Food Standards Australia New Zealand (FSANZ) all Australian dairy farms are required to have documented food safety programs. All dairy manufacturers and processors must also have a documented food safety program. State Dairy Food Authorities (SDFAs) approve the food safety program before a dairy farm licence is granted. Compliance with the food safety program is monitored and/or audited by an approved auditor on a regular basis.

Environmental legislation that regulates Australian dairy processing plants is implemented by authorities such as state environmental protection authorities (EPAs) and local councils. Dairy processors are generally required to have licences for emissions to air and surface waters and the disposal to land of some solid and liquid wastes such as sludge and treated wastewater. Disposal of wastewater to the sewerage system is regulated by local councils or water authorities.

The capacity to guarantee supply of a superior quality product while maintaining creditable resource stewardship across the dairy supply chain alongside dairy farm profitability is core to industry prosperity and resilience. The impetus for food enterprises to implement sustainable practices is emerging due to pressure from both the wider community and major food corporations and retailers. Dairy's "license to operate and sell" is rapidly being shaped by rising community expectations that include positive animal welfare, environmental and social outcomes. As highlighted in Dairy Australia's strategy, sustainability is an important risk management strategy for progressive industry players – incorporating improved profit as well as environmental and social outcomes is at the core of strategies for successful multinational food companies and dairy farmers, as is a focus on efficient resource use and positive and transparent practices.

Australian Dairy Industry Sustainability Framework

The Australian Dairy Industry Sustainability Framework[xci] outlines the industry's commitment to creating a vibrant industry that produces nutritious, safe, quality food while providing best care for our animals and being good stewards of the environment. Developed in 2012 to measure, report and improve the Australian dairy industry's sustainability credentials, it provides an evidence-based commentary on industry progress through tracking the performance of dairy farmers and manufacturers against economic, social and environmental targets.

The Australian Dairy Industry Sustainability Framework's four commitments are as follows. Each Commitment is underpinned by goals and targets.

Commitment 1:

Enhancing economic viability & livelihoods

Commitment 2:

Improving wellbeing of people

Commitment 3:

Providing best care for our animals

Commitment 4:

Reducing our environmental impact

'Resource use efficiency' has been, and will continue to be, a critical driver for the dairy industry's sustainable status. Environmental targets to reduce water, greenhouse gas (GHG) emissions and waste were established within the Framework's Commitment 4 to support dairy manufacturers reduce their environmental impact. These targets are reported on each year through aggregated data of the Dairy Manufacturers Sustainability Council (DMSC) whose membership-base[xcii] represent up to 86% of the national milk volume processed. With an industry- wide focus. DMSC assists member companies to work together pre-competitively to improve environmental performance and sustainability of their operations.

The Sustainability Framework sets out eleven sustainability goals for 2030 and table 9 outlines those directly relevant to this report - energy use and GHG emissions - as well the aligning United Nations Sustainable Development Goals (SDGs). The establishment of the Sustainability Framework goals is informed by various international standards including the Global Reporting Initiative[xciii] and the SDGs[xciv].

The SDGs guide a global effort to meet sustainability challenges, including climate change, population growth, water scarcity, responsible consumption and rewarding work. The Australian Dairy industry supports the SDGs and acknowledge the 2016 Dairy Declaration of Rotterdam, that recognises the SDGs as the dairy industry's overarching framework for sustainable development to 2030.[xcv] The SDGs have helped guide and refine the Australian Dairy Industry Sustainability Framework 2030 goals and targets. Many multi-national and Australian dairy companies are also using SDGs as part of their reporting.

Table 9. Australian Dairy Industry Sustainability Framework goals that are relevant to energy and GHG emissions[xcvi]

Australian Dairy Industry Sustainability Framework

GOAL 10	Reduce greenhouse gas emissions intensity
	Target 10.1 30% reduction in greenhouse gas (GHG) emissions intensity across the whole industry (from a baseline of 2015) by 2030
	For dairy companies, this (GHG emissions) is measured by tonnes of carbon dioxide equivalent (tCO_2~e) per ML of milk processed. Dairy processing contributes to scope 1 (direct) and scope 2 (indirect) GHG emissions through energy and fuel consumption, particularly from fossil fuels. In 2019/20 DMSC members consumed on average, an estimated 1.24 terajoules of energy per ML of raw milk processed. A number of manufacturers and global customers have committed to reduce their emissions and actively participate in global programs such as the Science- Based Targets Initiative. Most members of the DMSC are also subject to Australia's national legislation that requires public reporting of scope 1 and scope 2 emissions which form the basis of performance reporting for this target. For dairy farmers, this (GHG emissions) is measured by kilograms of carbon dioxide equivalent (tCO_2~e) per kg of Fat and Protein Corrected Milk (FPCM).

United Nations Sustainable Development Goals[xcvii]					
GOAL 7	Ensure access to affordable, reliable, sustainable and modern energy for all	GOAL 12	Ensure sustainable consumption and production patterns	GOAL 13	Take urgent action to combat climate change and its impacts

More recently (22 September 2021), the global initiative Pathways to Dairy Net Zero was launched, ahead of the UN Food Systems Summit held as part of the UN General Assembly in New York the following week. Led by Global Dairy Platform in collaboration with several key global organisations, *Pathways to Dairy Net Zero*[xcviii] will accelerate climate efforts already underway and drive further necessary action to reduce dairy's emissions over the next decades.

Forty leading organizations, including 11 of the 20 largest dairy companies in the world, already declared their support for the effort. Collectively, these supporters represent approximately 30% of total milk production worldwide. From Australia the initiative is supported by Fonterra, Saputo, FrieslandCampina, Ace Farming Company, Australian Dairy Products Federation, Dairy Connect and Dairy Australia.

Key global collaborators partnering with Global Dairy Platform on this initiative include the International Dairy Federation, Sustainable Agriculture Initiative Platform, International Livestock Research Institute, Dairy Sustainability Framework and IFCN Dairy Research Network. The Global Research Alliance on Agricultural Greenhouse Gases is a knowledge partner.

Pathways to Dairy Net Zero Outlines it will:

- Include commitments from every area of the global dairy community to tackle climate change, while nourishing a growing population and sustaining the billion livelihoods dairy supports.
- Create methodologies, tools and pathways to transform commitments into positive, practical actions.
- Highlight progress from around the world – share best practices and recognize that all farms, all dairy systems and all regions can be more sustainable.

The initiative is underpinned by six key principles:

- Mitigation. Continuing to improve production and process efficiency to further reduce the GHG emissions intensity of milk and dairy products.
- Greenhouse gas removals. Enhancing production practices that protect carbon sinks (soil, forests, grass, peatlands) and complement natural ecosystems.
- Avoidance and adaptation. Improving practices such as feed, manure, fertilizer and energy management.

- Insets and offsets. Identifying and implementing alternative, credible reduction options.
- Measurement and monitoring. Measuring GHG emissions to plan mitigation and monitoring progress.
- Overall support. Promoting the global initiative and emphasizing the dairy sector's climate ambition.

Notably, Uruguay has not signalled a commitment or involvement with *Pathways to Dairy Net Zero.* There is the opportunity to more deeply understand Uruguay's strategic approach to global dairy trade, market access and positioning to remaining a preferred supplier of dairy. Arguably, demonstrable progress to reduce GHG emissions will be important. Potentially this may offer an ongoing relationship opportunity between Australia and Uruguay, to share learnings on the increasing complexities of quality assurance and the current and emerging aspects to being a preferred, premium supplier of dairy products globally.

Carbon Emissions in Australian dairy

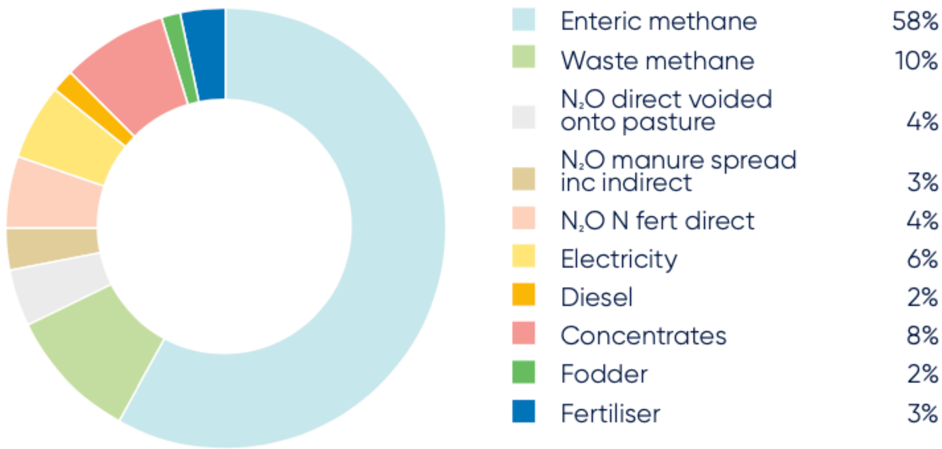
Australian agriculture contributes approximately 15% of Australia's greenhouse gas emissions (GHGs) with the dairy industry contributing to 12% of Australian agricultural emissions[xcix]. The dairy industry recognises it has an important role to play in saving energy and reducing GHG and, as outlined above, its approach is to focus on target setting and reporting on emissions arising from manufacturing, while continuing to fund projects and programs which have proven to reduce emissions arising from farming (ADIC, 2016).

The dairy industry contributes close to 12% of Australia's agricultural greenhouse gas (GHG) emissions[c]. This includes both pre- and post- farmgate activities with approximately 70% - 95% from farms and 5% - 30% from manufacturing - depending on the dairy product and the source of energy for processing (see figure 20 below)[ci].

Carbon Emissions - dairy farms

In 2019-20, the average estimated dairy farm GHG emission intensity was 13.6 tonnes, as measured by tonnes of carbon dioxide equivalents per tonne of milk solids sold (t CO_2-e/t MS), a reduction of 7% from the previous year reported at 14.5 t CO_2-e/t MS.[cii] Noting that these estimations of GHG emissions do not include any carbon sequestration activities that may be accumulated in farm trees or soils. The greatest contributors to total farm emissions were enteric methane from ruminant (cow) digestion at 58% and pre-farm emissions sources (such as carbon dioxide from purchased feed and fertiliser production, as well as direct use of fossil fuels and electricity and gas. (Figure 21 below).

Figure 21. Dairy farm Green House Gas emission



Source: Christie, K. 2020. Analysis of dairy farm greenhouse gas emissions data (DairyBase).

Methane from both ruminant digestion (enteric) and effluent ponds is the primary GHG emitted from dairy farms, accounting for 65% of all emissions at 8.8 t CO_2-e/t MS in 2019-20[ciii] Enteric methane is the major source (7.5 CO_2-e/t MS) contributing an average of 56% of total farm GHG emissions, and significant research toward cow and microbiome genetics, as well as feedstuffs and additives such as Asparagopsis seaweed, to reduce enteric methane emissions is being pursued both[civ], [cv]. Effluent ponds contributed the remaining 9% of total farm methane emissions, on average 1.2 CO_2-e/t MS across Victoria[cvi].

Carbon dioxide (CO_2) produced primarily from fossil fuel consumption (electricity and fuel) contributed 3.1 t CO_2-e/t MS, the second main GHG emitted (23%) on dairy farms.[cvii] GHGs emitted during the pre-farm gate production of fertilisers and purchased feed (fodder, grain and concentrates) are included in this amount: pre-farm gate sources accounted for 14% (1.9 CO_2-e/t MS) of the carbon dioxide emissions and 9% (1.2 CO_2[cviii]

The third main GHG source is nitrous oxide (N_2O) (12%) with an estimated emission of 1.7 t CO_2-e/t MS[cix] Nitrous oxide is produced from wastes (dung and urine), applied fertiliser and effluent ponds: fertiliser N_2O accounts for 2% of total emissions, effluent ponds N_2O contributes 1%, animal excreta 4%, while N_2O from indirect emissions accounts for 5% of total emissions[cx]

As previously outlined on page 29, while there is potential to produce hydrogen via anaerobic digestion of effluent, this is currently not well suited (economics nor practicalities) to pasture based dairy systems. And, although total farm GHG emissions increased slightly in Victoria from the previous year at 2,742 t CO_2-e/t MS per farm - mainly due to increased herd size - 2019-20 saw an overall increase in production efficiency compared to the previous year.[cxi] This was achieved by producing more milk solids from a similar set of resources which was coupled with a reduction in fertiliser use due to the poor seasonal conditions in the second half of 2019 across most of the state.[cxii] Additional reductions have occurred with declining electricity use from conventional sources (grid) with an increased uptake of solar generated power.[cxiii] Collectively, this indicates that farmers are already proactively making progressing reducing GHG emissions through efficiency gains and questions how much influence hydrogen technology may realistically have on reducing on farm GHG emissions in the near future.

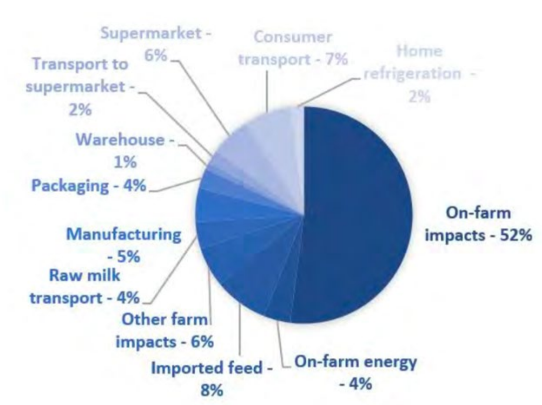


Figure 22. Australian Dairy Industry life cycle carbon emissions. Source: (Lunde, et al., 2003)[cxiv]

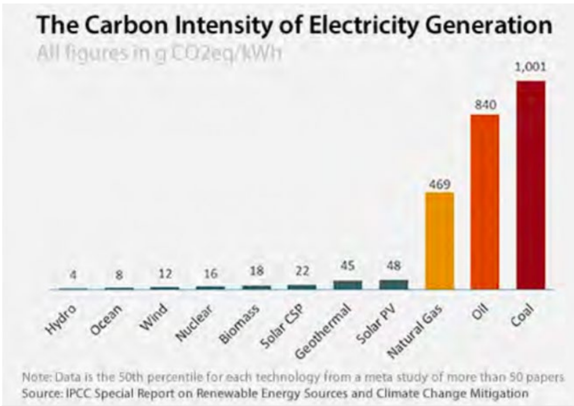


Figure 23. Carbon intensity of electricity generation by type. Reproduced from DA Eco-efficiency for the Dairy Processing Industry, 2019 (Data from Moomaw, et al., 2011)

Carbon Emissions – Processing

Within the entire lifecycle of a dairy product, processing (farmgate to supermarket/retail door) accounts for around 15%, the total carbon emissions (figure 22 above).[cxv] This variation reflects that GHG emissions from processing are related to the carbon intensity of the energy source used with fossil fuels being the most carbon intensive (fig 23 above), and the differing energy requirements for various products. Notably, the emissions intensity differs considerably across Australia's jurisdictions reflecting the sources used to generate electricity[cxvi]: Dairy processing facilities in Tasmania, for example, principally make use of renewable (hydro) electricity. This contrasts with New South Wales and Victoria where renewable sources accounted for just 15.6% and 21.9% of electricity respectively in 2018-19.

In 2019-20 dairy processing generated 1.2 million tonnes of carbon dioxide equivalent (CO_2e; includes scope 1, 2 and 3 emissions) accounting for 0.2% of Australia's total emissions.[cxvii] [cxviii] This equates to an estimated 137 tonnes of CO_2e per ML of milk processed.[cxix] In recent years, emissions intensity has declined, falling 14.4% from a peak of 160 tonnes of CO_2e per ML of milk in 2016-17. This fall in emissions intensity has driven a 23.5% reduction in total dairy processing industry emissions, a larger degree than which the Australian total fell (11.1%) during the same period.[cxx] [cxxi]

This trend likely reflects, in part, improvements in processing energy efficiencies and the growing use of alternative energy sources among Australian dairy processing, including biogas and solar supplementation sources.[cxxii] A steady decarbonisation of the Australian electrical grid has also supported these changes.[cxxiii] While Australia's dairy supply chain is considered to be relatively low emissions intensive in a global context, and despite the reductions noted above, when focusing on processing's emissions Australian lags much of the rest of the world, including New Zealand, owing to the high portion of non-renewable energy use.[cxxiv]

Table 10 below shows carbon emissions for production of various dairy products. Cheese and powdered dairy products use more thermal energy than for liquid milk processing which impacts on carbon emissions due to the variation in fuel sources. As mentioned above, there are growing examples of dairy processors utilising renewable energy sources to reduce carbon emissions as well as energy costs.[cxxv] One of the key challenges dairy processors have experience with onsite biogas digestors is achieving consistency in gas purity and supply.[cxxvi]

Table 10. Carbon emissions (Scope 1 and 2 carbon emissions) for production of various dairy products [cxxvii]

	Australian data (2015/16)			
Gj/kl raw milk intake	Min.	Max.	Average	No. plants providing data
White and flavoured milk only	48.2	111.8	74.5	10
Mostly cheese (and some powders)	62.4	205.0	109.9	3
Mainly powders	142.1	275	142.6	4
Mixed products	88.6	155.1	121.9	2
All dairy processors	48.2	205.0	109.4	22

Dairy Processor energy costs and the transition to renewable energies

The top ten manufacturers process roughly 85% of Australia's milk and, in general, operate in a low margin environment. With Australian gas and electricity prices rising sharply over recent years this has resulted in substantial cost pressures for these businesses. This limits both our international competitiveness and the price that processors can afford to pay farmers for milk.

Energy is typically the greatest of all utility costs in processing and Australian dairy processors as an aggregate spent in the order of $175 million[1] in 2016/17 on energy supply across the sector[cxxviii]. Australian manufacturers, including dairy, saw their electricity supply cost double in the seven years from 2007-08 to 2014-15, and continue to rise. For example, the (energy) combined electricity and gas bill for dairy processing company Burra Foods increased by almost $4 million per annum from 2016 to 2018.[cxxix]

The increased cost of energy has been a major driver for Burra Foods and other dairy processors to reduce energy use, with many initiatives being undertaken in recent times. Processors must also manage the increased risk of supply interruptions and the impact that has on product quality and processing costs.

In Australia, contributing factors to the rise in electricity prices are decreasing demand in grid electricity (which increases fixed and variable supply costs for a smaller pool of customers), increase in electricity sourced from renewables and closure of several coal-fired power generators which has impacted on the capacity to supply power to the national energy market (Wood, et al., 2017). Wholesale gas prices also tripled 2010 - 2017 due to LNG exports impacting on domestic supply.

The table 11 below shows typical costs for the energy sources commonly used in dairy factories, which vary between approximately $4.70 per GJ for black coal and around $19 per GJ for electricity.[cxxx] There is variation in the price paid for fuels and electricity within the industry, depending on the source, the supplier and the negotiating power of the

[1] Calculations for this energy cost were based upon conservative gas and electricity prices of $8 per gigajoule and $0.12 per kWh (delivered) were assumed, and a national milk production of approximately 9 billion litres in 2016/17[CXX]

business. Dairy processing plants choose their electricity supplier and purchase electricity on the contestable market where this is available.

Table 11. Typical cost for energy sources commonly used in dairy factories

Fuel costs	Calorific value[a]		Typical fuel cost ($/quantity of fuel)[b]		($/GJ)	CO_2 emissions kg CO_2 eq/GJ[a]
Black (bituminous) coal	27.0	GJ/t	$126	/t	$4.67	90
Heating oil	37.3	GJ/kL	$0.77	/l	$20.62	69.7
Natural gas (town)	39.0	MJ/m3	$8-15	/GJ	$8-15	60.2
Biomass (municipal and industrial)	12.2	GJ/t	-	-	-	1.8
Grid Electricity (Vic/NSW)	3.6	MJ/kWh	$0.07	/kWh	$19.40	219-300

a (Aus Gov, 2017)

b Coal price (KMPG, 2018, Heating Oil price (Indexmundi, 2018), Natural gas price (Oakley Greenwood, 2018), Momentum Energy, 2018)

For electricity, there are additional demand related charges that are not included in these costs, and which can contribute a further 30-50% of an electricity bill. Australian dairy processors have experienced steep increases in energy costs because of retiring and aging infrastructure, managing the rise of renewable energy sources and domestic markets (in the case of electricity supply) and managing supplies and volatility in the domestic and international gas market (in the case of gas) (Wood, et al., 2017) (CEFC, 2018).

Anerobic digesters in dairy processing

Several dairy processors have signalled an appetite for anaerobic digesters. The following case studies reproduced from Eco-efficiency for the Dairy Processing Industry (2019) by Prasad for Dairy Australia, provide information regarding the business case for anerobic digestion and the utilisation of biogas.

Business case for anerobic digestion: Dairy Manufacturer, Victoria (Dairy Australia)

Although very common in Europe, Anaerobic Digesters are still scarce in Australia. In 2018, an Australian dairy manufacturer undertook a detailed feasibility assessment to build a business case for Anaerobic Digestion in Victoria. The scope of the project included dairy input from operations (trade waste, whey and other by-products) as well as community impacts and environmental outcomes. The purpose of the business case was to prove the economic viability of an anaerobic digestion process in the dairy industry. In order to optimize the prospects of success, the Manufacturer looked into different scenarios to assess available options around operation, capital and space requirements. The outcomes of the business case were extremely positive. The volumes of whey and trade waste generated on site and their methanogenic potential would allow the production of enough biogas to power all operations, including biogas but also electricity through co-generation. Given the closed loop system, the costs associated with trade waste discharge could be reduced by up to 47% and whey disposal costs could be cut by 40% or eliminated altogether in the case of a built-owned-operated digester. In addition to securing a sustainable source of renewable energy, utility costs could potentially be reduced by 25% and about 30,000 tCO_2eq could be abated. Further points around long term planning capital and space availability are being assessed by the manufacturer.

Utilisation of biogas: Warrnambool Cheese and Butter, Allansford. 2004 Ed

Warrnambool Cheese and Butter in Allansford installed an anaerobic digester in 1993 to recover biogas for use as a fuel source in their boilers. The project was only moderately successful, due to problems encountered with maintaining a constant gas supply pressure to the boilers and the presence of moisture in the gas. The biogas was not refined in any way, and it caused excessive corrosion in the boiler combustion chamber. The use of the biogas was suspended in July 2003 pending further investigation and improvements to the operation. But it has the potential to provide 80–100% of the energy requirements for the production of hot water at the site and save $290,000/yr.

Anaerobic Digestion, Saputo Dairy Australia, Leongatha (RIRDC, n.d) and (DMSC, 2011)

Capital was invested in bioenergy and wastewater treatment upgrades at Saputo's Leongatha plant. In 2009, $20 million was spent on upgrading the existing wastewater treatment plant so all treated waste could be safely discharged to the ocean. The treatment reduced the organic and nitrogen load in the wastewater and generated approx. 9,000 m^3 of biogas.

In mid-2010, two biogas engines (760 kW combined energy) were installed with help of Sustainability Victoria ($140,000) and SP Austnet. The engines have capacity to generate 5000 MWh/yr and were projected to reduce grid electricity demand by 9%, saving $600,000 per year in energy costs as well as renewable energy certificates. Final commissioning post 2010/11 was expected to reduce carbon emissions by 11,000 tonnes CO_2e annually. Payback on the biogas engines was expected to be 3 years. The project suffered issues, however, due to poor process design for the scrubbing of impurities from the biogas. This led to damage to the generator sets and a re-think of the system design.

Transition to renewable energies.

Energy markets are transforming around the world with three key trends in the way businesses use, produce and contract their energy[cxxxi]. These trends include the global transition away from fossil fuels as renewable energy sources reach cost-parity, the decentralisation of the energy grid with multiple sources of generation, and more proactive involvement by business to control their electricity demands and sources. Australia has a national renewable energy target of 20% by 2030, and this will also help drive growth in sustainable energy supply in manufacturing[cxxxii].

Global demand for dairy in the coming decades is projected to grow at a greater rate than the current 2% per annum in global production (OECD-FAO, 2014). Underpinned by rising GDP, household incomes and urban migration, the developing world are a major component of this projected global growth in dairy demand. Expansion of Australian dairy exports (both volume and higher value products) into these potential markets provide an important opportunity for the value of Australia's industry to grow, as well as our current key markets such as Japan and China. Notably, Australia's largest dairy trading partners, China and Japan, as well as Korea, recently announced 2030 carbon neutral goals[cxxxiii]. These will influence terms of trade, market access and securing international supply agreements for Australian dairy and broader agricultural products/sectors. There is no doubt that more countries and markets will set similar goals in line with the United Nations recommendations.

As with most Australian industries, the dairy industry relies heavily on fossil fuels (particularly coal-generated electricity, thermal coal, oil and natural gas) for their energy supply across farm, transport and processing (and storage). In a carbon constrained future, dairy processors continue to reduce their greenhouse gas footprint by seeking out lower or no emission energy options. The industry needs to reduce energy costs and improve longer-term price security while also reducing the carbon footprint of Australian dairy products.

Although energy inputs have traditionally formed a relatively small proportion of overall production and post-farm costs, the increasing cost (particularly of electricity) and intermittent reliability are becoming increasingly important issues for farmers (and processors). Access to affordable and reliable energy is imperative for continued sustainability and enhanced growth in the agricultural sector.

Renewable energy is becoming increasingly attractive to dairy processors as the energy delivered by these technologies is reaching cost parity with traditional energy sources. In particular, biogas, biomass and solar PV are becoming more frequently used to supplement existing energy supplies. While renewable energy sources currently only provide a portion of total energy requirements, the industry is looking to the future with research undertaken by Walmsley describing a process for sustainable milk powder production using improved energy efficiency and 100% renewable energy sources (see box below). Other processors are utilising power purchase agreements to reach targets of 100% of supply from renewable sources.

Factory of the future with 100% renewable energy sources (Walmsley, et al., 2016)[1]

Walmsley undertook an analysis of requirements to integrate 100 % renewable energy into a 10 t/h ultra-low energy milk power factory of the future in New Zealand and California. Three case studies from three different locations are reported. In New Zealand the best option is to use renewable electricity from wind, hydro and geothermal for the factory electrical needs, and high temperature geothermal energy when available for process heating up to 210°C and low temperature geothermal energy with MVR technology upgrading for process heating up to 180°C. When no geothermal energy is available the best option is renewable electricity driven heat pumps for heating up to 85°C, and biomass (wood residue) for high temperature heating up to 210°C. Biomass production, however, will require 35% more land than the farms require for producing the milk. In California renewable energy is best met using biogas from anaerobic digestion of cow manure and solar thermal. Biogas converted into biomethane on farm fuels a combine cycle gas turbine with a heat recover steam generator (HRSG) to meet process heating needs above 8 °C and all factory and biogas compression electrical needs. Solar thermal with day-night storage provides hot water utility. A cow manure collection rate of 37% is required to meet both process heat and electricity needs.

Case Study: Hydrogen opportunities for Saputo Dairy Australia

Saputo Inc. is one is one of the top ten dairy processors in the world and its Australian division, Saputo Dairy Australia (Saputo), is one of our country's largest dairy processors. With a strong footprint across south-eastern Australia, Saputo produces, markets, and distributes a wide range of high-quality dairy products including cheese, fluid milk, extended shelf-life milk and cream products, cultured products, and dairy ingredients.

One of Saputo's largest processing plants is situated in Allansford, southwest Victoria, where it processes fresh and UHT milks, cheese, butter, cream, various milk and protein powders as well as specialised nutritional ingredients (powders) such as lactoferrin and galacto-oligosaccharides (GOS) (lactose derived prebiotics) through its joint venture with FrieslandCampina. Saputo operates its own milk tanker fleet servicing suppliers with farm collection and its processing plants within Australia.

Like most Australian and multinational dairy companies, Saputo recognises it has an important role to play in sustainable dairy production including reducing greenhouse gas emissions and efficient energy use. This is also critical to managing the company's bottom line, particularly as energy is typically the greatest utility costs for Australian dairy processors, as well as risk management for market share and access (supply agreements) in a world where customers are demanding (caring more about) a carbon neutral production footprint.

Saputo prides itself on seeking continuous improvement and being accountable in all that it does, including environmental impact. The company is committed and aligned to an array of international, national and industry sustainability and GHG goals and targets including:

- Australian Dairy Industry Sustainability Framework
- Dairy Manufacturers Sustainability Council (Australian)
- United Nations Sustainable Development Goals
- Pathways to dairy 'net zero' by 2050 (Global Dairy Platforms collaboration)
- Australian national legislation – Pollutant emissions reporting

Saputo Inc has developed its own accountability and (ESG)* strategic framework, the Saputo Promise, to guide and ensure aligned and demonstrable continuous improvement to social, environmental and economic performance. The Saputo Promise is underpinned by the following seven pillars:

Saputo's 7 pillars

- Food Quality & Safety
- Our People
- Business Ethics
- Responsible Sourcing
- Environment
- Nutrition & Healthy Living
- Community

"We recognize that climate change is a challenge for us all. Collectively, we must continue to address our use of fossil fuels and embrace sustainable manufacturing practices, as well as find ways to adapt our practices to ensure sustainable agriculture. This is critical to the long-term future of our business, our patron farmers and the communities where we operate." [1]

*Environmental, social, and governance (ESG) criteria are a set of standards for a company's operations that socially conscious investors use to screen potential investments. Environmental criteria consider how a company performs as a steward of nature. Social criteria examine how it manages relationships with employees, suppliers, customers, and the communities where it operates. Governance deals with a company's leadership, executive pay, audits, internal control, and shareholders rights. ESGs are an increasingly popular way for investors to evaluate companies in which they might want to invest.

Why is reducing energy intensity use and GHG emissions of its operations so important to Saputo? [2]
Risk management!

Market & supply agreements:

- <u>*Countries with ambitious emissions targets*</u> could seed to impose emissions standards on trading partners. For example, two of Saputo's (and Australia's) largest dairy trading partners, China and Japan as well as Korea, have announced 2030 carbon neutral goals
- <u>*Shifts in (market) consumer preferences*</u> to neutral/low carbon footprint supply chains potentially creating demand for food produced with reduced emissions throughout the supply chain.
- <u>*International supply agreements*:</u> External third-party auditing and benchmarking (eg UniLever) is increasingly used as part of preferred (international) supplier assessments and the ability to include certain ones/accreditation gives Saputo a level of confidence in securing and retaining company supply agreements.
- Until recently milk supply companies have been able to use Australian industry data to meet supply requirements, but increasingly companies are now being asked for company specific detail, as well as demonstrate *progress* in performance as well
- <u>*Milk supply (raw ingredient) security*</u>: dairy farmers will also be driven by alignment of their own values and own risk assessment of a milk supply company's market relevance and risks. This may include alignment with cost reduction strategies, effective and efficient use of resources (including energy) and emerging technologies.

Regulatory:

- <u>*Carbon pricing mechanisms (Direct costs):*</u> Fuel prices in certain jurisdictions where Saputo have operations are affected either by carbon taxes or by emissions trading schemes. Saputo purchases energy to process raw materials and manufacture finished goods. Fuel/energy taxes and regulations can increase costs.
    - In the UK and US (California) two processing facilities are currently subject to an emission trading scheme and are obliged to comply with the requirements. One facility in Canada is also participating on a voluntary basis. Carbon permit (or credit) price is not fixed and is subject to market forces of supply and demand, which have historically resulted in price increases year-over-year.
- <u>*Carbon pricing mechanisms (Indirect costs):*</u> Fuel prices in certain jurisdictions where Saputo operates are affected either by carbon taxes or by emissions trading schemes which can impact our transportation costs. *Noting that Saputo's mitigation strategy includes exploring opportunities for electric powered fleets to protect against future fuel cost fluctuations*.

Input costs:

- <u>*Volatile power and fuel prices:*</u> Most of Saputo Australian operations have and could continue to be exposed to volatile electricity prices, and potentially diesel.

Saputo's environmental pledge commits to:

- **Enhance** our ability to proactively manage environmental risks and opportunities
- **Reduce** our resource dependency, operating costs and environmental impact
- **Drive** business value by addressing relevant environmental opportunities

[2] *Information sourced from: Saputo Promise 2021 Report (Climate risk assessment); Saputo Inc. CDP Climate Change Questionnaire 2021; Dept. Agriculture, Water and the Environment (2020) Global responses to climate change: Opportunities for Australian agricultural producers Australian Bureau of Agricultural & Resource Economics and Science, Canberra.*

In 2020 Saputo pledged to accelerate their global climate performance and announced clear targets and a formal commitment to make significant and sustainable progress by 2025.[cxxxiv]

Specifically, by 2025

- **Reduce CO_2 intensity of our operation by 20%**
- **Reduce the energy intensity of our operations by 10%**

This target includes all manufacturing facilities and distribution centres operated by Saputo globally. Fleet and offices are excluded. Saputo expects to deliver on these goals through targeted initiatives focusing on renewable electricity.

Notably, Australia is the only country where Saputo operates a milk transport fleet and offers the opportunity to target reduced GHG emissions across the supply chain. With increasing scrutiny and accountability across whole of supply chains for carbon neutral production, this area demands attention. Demonstrable progress in reducing GHG emissions (Carbon intensity) across the whole supply chain will increasingly be a significant part of negotiating both local and international supply agreements: Dairy companies will need to respond.

Consideration of the potential for a hydrogen transport fleet potential could enable Saputo to commit to transport GHG reduction goals and move to whole of supply chain GHG reduction strategy.

The hydrogen opportunity for Saputo

- Reduced GHG emissions across the supply chain
- Reduced reliance on escalating utility and fuels costs
- Access to renewable energy source – especially in the southwest
- Leaders in net-zero food / agriculture supply chains

Applications of hydrogen

With many different types of hydrogen applications still in the early stages of development and commercialisation, it is an opportune time for Saputo to consider the future role that hydrogen can play in the organisation.

In the dairy industry there is potential to use of hydrogen as an energy source in the following sectors (based on estimates from the Hydrogen Council 2020[cxxxv]):

- Transport (heavy haul and return to base) – expected to be competitive in the short term (2020 – 2025)
- Light commercial vehicles including forklifts – also expected to be competitive in the short term (2020-2025)
- Heat and power for manufacturing – due to the current high use of natural gas (low cost, low carbon energy) hydrogen is not expected to be a competitive energy source until the longer term (2050)

Transport fleet

Introduction of hydrogen fuel cell vehicles into the Allansford transport fleet, would enable the organisation to reduce its reliance on fossil fuels (diesel), lower the carbon footprint of this manufacturing site and reduce the costs associated with milk and product distribution.

When looking at the 'feasibility' of the conversion of the current diesel fleet to a fleet of hydrogen fuel cell electric milk tankers (FCEV) there are many aspects to consider, including the economics, operations, social, regulations and safety concerns.

Due to issues related to the current price and availability of hydrogen, a FCEV milk tanker is not currently a feasible option for Saputo Australia. However, in the short to medium term, the opportunities outweigh the issues.

These opportunities and issues have been considered in relation to their application to Saputo Australia and are outlined below.

Opportunity – declining fuel costs

As we continue to see changes in emission regulations and consumer expectations, we can expect that the cost of fossil fuels and carbon will increase. As this occurs, it will add to the already increasing costs associated with transportation of milk from farm to the factory.

(Hydrogen) Fuel Cell Electric Vehicles offer the option to introduce a fleet that has a fuel type that is expected to decrease in cost as it becomes more widely used and does not have carbon emissions – therefore removing the need to budget for the future cost of carbon.

There are also opportunities to produce hydrogen at the site where it is used allowing for further reduction in the price of hydrogen fuel as well as the potential to use biowaste as a feedstock for hydrogen production.

Opportunity - emissions reduction

With a hydrogen milk taker fleet in place, the current level of CO_2 emissions produced by Saputo Australia's current diesel fleet would be reduced to zero.

This would help meet Saputo's key goal to safeguard the environment while continuing to grow as a world-class dairy processor, help support the 'Saputo Promise' to:

- "Reduce CO_2 intensity of operations by 20%
- Reduce the energy intensity of operations by 10%"
- Allow Saputo to confidently establish and commit to transport specific GHG targets

Opportunity – declining hydrogen fleet costs

In the next 2-5 years it is also expected that the economic costs associated with the purchase, maintenance and operations of a FCEV milk tanker fleet, would be lower than the current diesel fleet.

In the longer term, the economics become even more favourable as the expected price of diesel and carbon rise.

While the 'opportunities' are becoming more and more positive, particularly over the medium to long term, there are some issues to respond to and these are outlined in the Table below.

Issue / Opportunity	Context	Resolution
Price & availability of hydrogen fuel	Currently the cost of hydrogen is high and the availability is low. As the industry scales up, the price of hydrogen is expected to fall. However, the cost of hydrogen distribution will still be a major proportion of the cost of hydrogen to the end user.	This issue will be addressed as the hydrogen production and applications scale up. Production of hydrogen close to the end user will also drive down the price of hydrogen. Options for Saputo include: - **Step 1**: Convert grid supplied renewable energy to hydrogen* - **Step 2**: Involvement in development of a regional hydrogen hub - **Step 3**: Hydrogen production at manufacturing site.
Calculating total cost of ownership (TCO) of Fuel Cell Electric Vehicle (FCEV) fleet	To determine the TCO so economic comparisons can be made between a FCEV fleet with a diesel fleet, there are many influencing variables. These vary according to a fleet's current and future.	Using Saputo's current and future fleet data (including projected use, diesel price, and carbon cost) to determine a specific TCO. Then compare this with current fleet TCO.
Timelines to comparative advantage	Difficult to predict when FCEV will be a cost-effective alternative – again this will be dependent on many external factors, including price of vehicle, price of hydrogen, skills, etc.	Remain informed with hydrogen industry changes and updates. As the technology and regulations progress, timelines will become clearer.
FCEV availability in Australia	Given the new technology and availability of hydrogen, there are only a few FCEV trucks operating in Australia.	Several companies are looking to supply the Australian market with FCEV trucks. Hyzon Motors Inc. are working with Australian companies, Fortescue Metals Group and Coregas to supply FCEVs (buses and trucks). Hyzon has also produced a FCEV 55 tonne milk tanker for FrieslandCampina in the Netherlands.
Capital costs & life of vehicle	The current cost of a FCEV milk tanker may be in the order of 2 – 2.5 times the purchase price of a diesel combustion engine tanker. It is unlikely that parity with diesel trucks will be achieved. Consideration of the life of the vehicle is also required.	Over time it is expected that capital costs of FCEV will reduce as economies of scale occur. Other factors that influence TCO of a FCEV fleet are expected to bring it below that of a diesel fleet. The life of the vehicle is also expected to be comparative with that of a diesel truck.
Repairs and maintenance – new knowledge, skills, equipment, cycles	Transferring an entire fleet to FCEV would require changes to the current repairs and maintenance budget, infrastructure, and skills of the workshop team. To ensure continuity and safety levels are maintained, as well as the continuation of Saputo Australia using their own 'workshop' facilities at Allansford- these would need to be addressed prior to the introduction of FCEV to the Saputo business.	Repair and maintenance costs are expected to be approximately ½ that of a diesel vehicle (fewer moving parts, less lubricant, less dirt). The micro-credentials required to service and maintain FCEV include: - Auto electrician (600-volt DC skills) - Gas Fitter (with hydrogen ticket) - Battery technician Currently TAFE sector is working with Deakin University and industry to establish specific training requirements to meet the skill demands.

Suitability to use (loads, road type, distances)	Given the current requirements of the Saputo Australia milk tanker fleet, a FCEV fleet would need to achieve the same operational performance (or better) as the current diesel fleet – including consideration of load carrying, performance, manoeuvrability, road type (topography, access), distances, frequent stopping / idling, milk cooling and return to base.	FCEV heavy haulage vehicles are expected to offer similar or better performance than an equivalent diesel engine. Fuel usage is expected to be around 10kg hydrogen / 100km. While hydrogen fuel tanks do take up space, there is allowance for this in a truck such as a milk tanker. A FCEV milk tanker would be able to achieve all the other operational requirements as per their diesel counterparts. FCEV trucks have the advantage of being fuel efficient for short runs as the vehicle does not waste energy while stopped. Efficiencies are also realised with the refrigerated unit operating from its own fuel cell. Thus, FCEV trucks are an efficient type of vehicle to use as a milk tanker.
Regulations –plus road use, licences	A FCEV fleet would need to meet current vehicle and licence regulations. Consideration would also need to be given to emergency situations, given the different fuel type and motor components used.	FCEV trucks are built to suit Australian roads and conditions and it is expected they would meet the current vehicle registration requirements. Current heavy vehicle licences would be used for a FCEV as they relate to size, not fuel type.
Safety and social implications	The use of hydrogen as a fuel poses some safety concerns and emergency responses.	Emergency responder training is required for those expected to be working with FCEV (and hydrogen storage). This training is currently available for industrial purposes and would also transfer to FCEV related applications. Social aspects of driving a FCEV are favourable in relation to the reduction in sound, smell, reduced dirt/grease and vibrations.

Applications in manufacturing

The use of hydrogen as an energy source in manufacturing is not likely to be competitive until 2050[cxxxvi] there are interesting factors to take into consider.

As the hydrogen production and application technology advance, the associated costs will also reduce. The main factors impacting the future use of hydrogen in industrial applications will be:

- The cost of hydrogen (delivered to the site of use)
- The cost of natural gas – which currently is seen as a low cost, low carbon option and is widely used in Australian manufacturing.

The opportunity

- Early adopter / investigation into new technologies
- Circular economy approach – utilising waste to create energy to then feedback into system
- Potential to lower manufacturing carbon footprint – delivering on the Saputo Promise
- Consumer / market pressures

The challenges

- Longer term outlook - 2050
- High reliance on and cost of natural gas
- Cost of conversion of current power system

- Safety, regulations, permits, planning
- Social licence development and consumer confidence

Production of Hydrogen – onsite

To ensure an economic supply of hydrogen to a manufacturing system, such as Saputo plant at Allansford, on-site production of hydrogen could be included in a future model.

The opportunity

- Organic waste could be utilised as a feedstock to produce hydrogen, therefore reducing the costs and issues associated with existing waste removal systems e.g., biodigesters in a circular economy.
- Renewable energy produced onsite (wind / solar) for onsite energy uses, could also be used in the hydrogen production process. The Allansford site has good access to wind and solar resources, with potential for Saputo to invest further in renewables.
- Production of onsite hydrogen using grid sourced renewable energy
- Production of hydrogen at a local level would reduce the overall cost of hydrogen (reduced distribution costs) for various applications
- Hydrogen can be produced and stored onsite until it is ready to be utilised

How is organic waste used as a feedstock for hydrogen production?

Organic waste (effluent from cows, milk / cheese production) is fed into a biodigester. This biodigester produces biogas, which is then converted to biomethane. Biomethane can then be used in three ways:

- fuel for gas fired equipment
- exported into the natural gas system
- used to produce Hydrogen using steam methane reforming (SMR)

The challenges

- Capital costs of plant and equipment for onsite hydrogen production and storage
- Complex nature of producing hydrogen from organic waste and feasibility is dependent on organic wastes used and consistency of biogas produced
- Capture and storage of CO_2 is produced during the SMR process
- Capital costs of renewable energy capture systems (solar / wind)
- Suitable and safe transport and storage of hydrogen at the Allansford site
- Upskilling of staff to manage and operate hydrogen production systems and equipment
- Regulations, permits, applications to operate.

Uruguayan dairy

The Oriental Republic of Uruguay is located in the eastern region of the southern cone, bordering Brazil to the northeast and Argentina to the west. According to the last census of the Instituto Nacional de Estadística (INE), it has a population of approximately 3.2 million inhabitants, on an area of 176,000 km2 of which approximately 160,000 km2 have agricultural potential. Its capital is Montevideo and it is located in the south of the country, with a population of 1.3 million inhabitants according to the last national census[cxxxvii].

Figure 24. Location of Uruguay

Uruguay has a temperate and humid climate and four defined seasons. Rainfall is distributed evenly throughout the year and has an annual average of approximately 1,200 mm. It presents a hydrographic network of rivers and streams that extend throughout the country, nourishing the soil and making it suitable for planting crops and growing native pastures that are the basis for fattening animals[cxxxviii]. It has coasts to the Uruguay River to the west, Río de la Plata to the south, and the Atlantic Ocean to the southeast, where various important ports are located such as Nueva Palmira, Colonia del Sacramento, Montevideo, and La Paloma. Regarding the transport of agricultural products, it is done by trucks using a network of highways that cover all the country and the railroad to a lesser degree.

The natural characteristics of Uruguay make livestock production from natural pastures favourable, which has distribution in its production with peaks in spring-summer. The Uruguayan economy is dominated by the agricultural-livestock sector, oriented to exports, and by a developed agro-industrial sector[cxxxix]. Cattle are raised in open air, under natural conditions within a temperate climate, fertile soils, and a great abundance of water generated in its numerous rivers and streams, ensuring the well-being of animals. Investment in technology, added to the sanitary status and the quality of its products, converted Uruguayan meat and dairy products attractive to the most demanding markets[cxl].

Due to the importance of this sector in the Uruguayan economy and society, it is imperative to determine the possible impacts of climate change and its variability. In this sense, the National Adaptation Plan was created with the objective of the “development, design, coordination and prioritization of policies, programs, and projects which support the vulnerability to climate change of the different agriculture sectors, generating a change of paradigm towards sustainable development. The final aim is to enhance farmers' lives through sustainable farming systems”[cxli]. The plan integrates adaptation and mitigation to climate change policies with actions to increase food security. Some of the policies are Climate Smart Agriculture outputs, such as: increase productivity, increase net return, improve inputs use and efficiency, reduction of emissions, increase resilience, increase gender and social inclusion[cxlii].

Strategies 2050 of the national adaptation plan for agriculture

- Develop and adopt animal and plant production systems less vulnerable to the impacts of variability and climate change.
- Conserve agro ecosystems and their services.
- Improve the livelihoods of rural populations.
- Strengthen institutional capacities for the management of these sustainable and adapted production systems.

In this sense, on the most important sectors in in terms of economic, social and environmental aspects is the dairy sector. Yet, there is room for the application of more policies that contribute to the sustainable development of the Uruguayan dairy sector in the years towards 2050.

Uruguayan dairy industry context

Uruguay is the 7th largest exporter of dairy products in the world, and despite having a population of 3.5 million people, in only 5% of its territory produces enough milk for more than 18 million people[cxliii]. Moreover, agriculture represents 6% of the Gross Domestic Product (GDP) and over 80% of the country's exports which means more than U$S 7,000 million of income[cxliv].

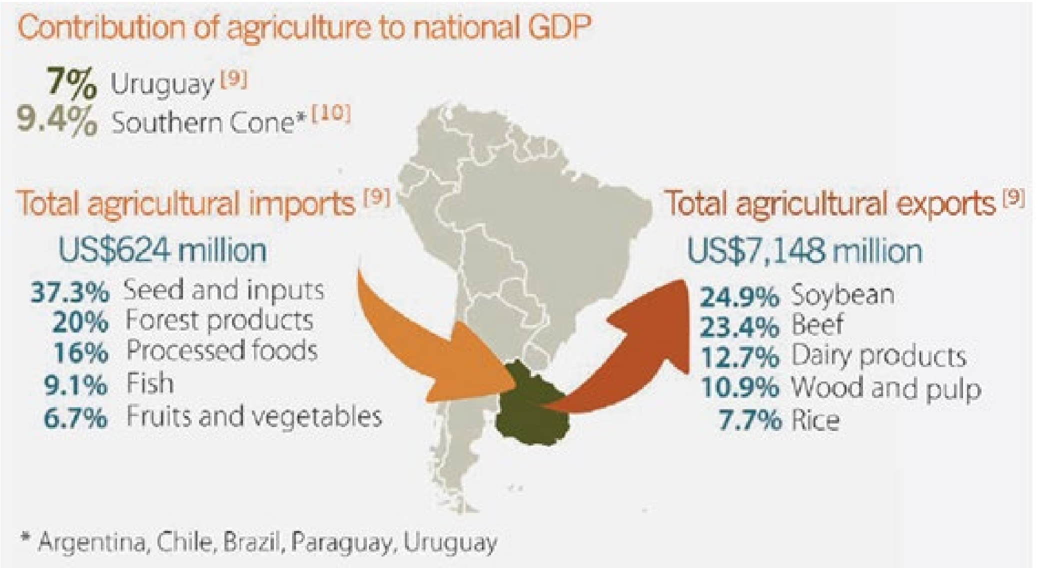


Figure 25. Economic Relevance of Agriculture

The dairy sector concentrates the highest technological development and seeks the greatest productive efficiency through the adoption of new feeding technologies. Dairy farming is practiced mainly in the south and southwest, on 890,000 hectares. This area represents only 5% of the total agricultural land but accounts for 12.7% of the total Uruguayan exports or U$S 900 million/year approximately[cxlv].

Figure 26. Distribution of Dairy Farms in Uruguay
Source: INALE (2020)

Currently, 10% of the Uruguayan farmers are dedicated to dairy production, representing 3,800 farmers. Moreover, 73% of these farmers are dedicated to milk remission (2,200 million litres/year) while 27% are cheese producers. Uruguay has a consumption of 230 litres of milk per capita per year, a fact that makes it the largest consumer of dairy products in Latin America. However, domestic consumption represents only 30% of the annual remission, while the remaining 70% is exported to various markets (with projections of an increase to 90% in the next 10 years). It destinies its production to more than 60 countries, where the Mercosur has main relevance but also other markets as Asia, Europe, and Africa [cxlvi].

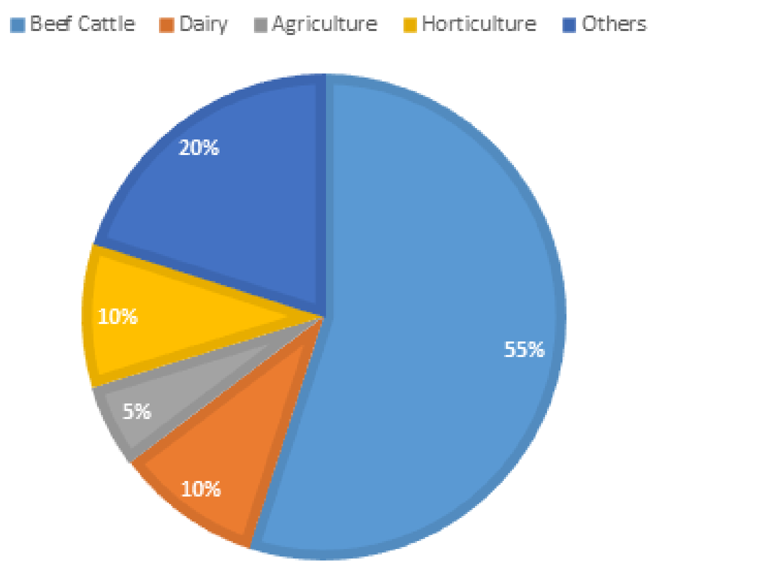


Figure 27. Farmers per sector

Farms between 50 and 199 hectares represent 50% of the total number of farms and 21% of the surface dedicated to milk production of the country; those of 200 to 499 hectares represent 22% of the total and 26% of the surface, and those of 2,500 hectares and more are the 0.8% of farms and 11% of the surface. One of the main phenomena that occurred in the sector is the reduction in the number of farmers and the concentration on bigger farms. However, agricultural production has had a constant increase due to a rise in productivity per hectare, maintaining a relatively constant stock of cows [cxlvii].

Table 12. Stock of cows

Year	Total	Milking cows	Dry cows	Others	Calves
2010	764	296	134	274	60
2011	793	320	130	282	61
2012	755	320	121	253	61
2013	782	331	114	275	62
2014	772	297	127	291	57
2015	783	329	123	273	58
2016	767	308	117	288	54
2017	780	320	118	288	54
2018	794	325	119	295	55

Source: INALE (2020)

Uruguayan dairy sector key facts:

- Uruguayan producers work with extensive, intensive, and semi-intensive systems. The extensive system is based on an almost purely pastoral diet; the intensive or enclosure system uses a grain-based diet and energy concentrates and finally, the semi-intensive system where grass and grains are used proportionally.
- 70% of Uruguayan dairy producers are associated with the National Cooperative of Dairy Producers, better known by its acronym in Spanish CONAPROLE. It was founded in 1936 and since then has operated under a cooperative regime.
- The dairy industrial sector comprises national and multinational companies that have continuously expanded their installed capacity.
- The demand for dairy products by the domestic market is widely covered, leaving an exportable balance of 70% of production. The main exported products, ordered by annual volume, are whole milk powder, cheese, skim milk powder, and butter.

In the primary sector, the main inputs of the system are CO_2 sequestered by pastures and woodland; water; energy produced by wind turbines; (hydro)electric pumps or anaerobic digesters; and fertilizers and seeds for crops. On the other hand, after processing these inputs to generate feed for the animals to sustain milk production, the outputs generated are CO_2, N2O, and methane from enteric fermentation; manure and Gasoil used by machinery with the consequent CO_2 emissions. According to the World Bank (2015), the GHG emissions of the agriculture sector represent 75% of the total emissions of the country, from which 56% comes from enteric fermentation (see figure 28). The key process that balances the inputs and outputs of the system is the photosynthesis of pastures which transform CO_2 into energy that is consumed by cows to produce milk generating a sink of GHGs. Thus, more productive pastures could increase the sequestration of greenhouse gases.

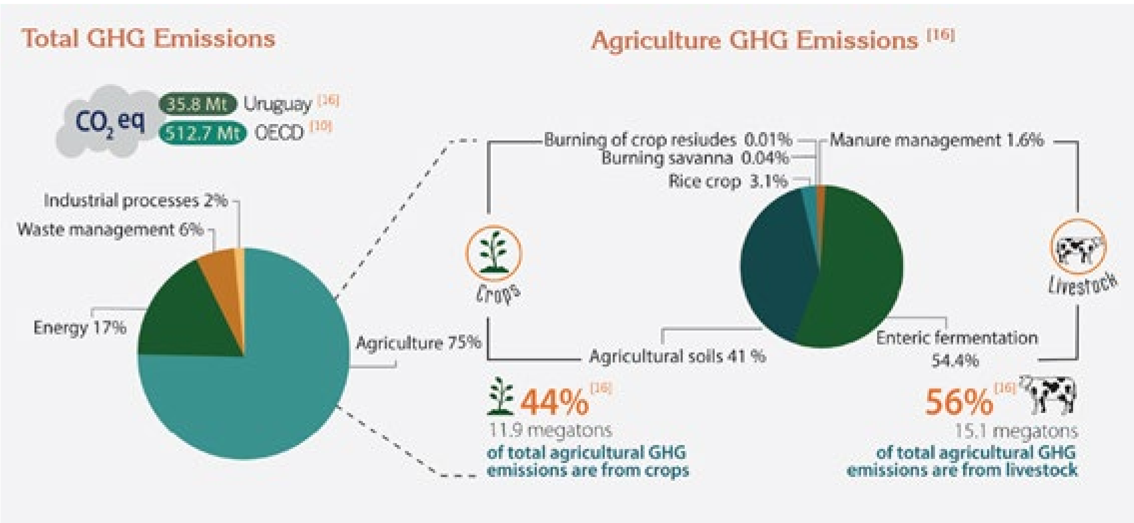


Figure 28. Green House Gas emissions, total and agriculture
Source: World Bank (2015)

Other areas where GHGs emissions are generated in the sector, are the heavy transport of raw milk and dairy products in the transport and energy consumption in the industries. The former uses mainly gasoil for the trucks and the latter a combination of gasoil, fuel oil and wood. These emissions could be partially or totally reduced by incorporating green Hydrogen as a renewable source of energy.

Energy consumption of the dairy industry

According to the National Energy Balance of 2020, the dairy industry accounts for 3% of the total energy consumption of the industries of Uruguay.

Table 13. Energy consumption of the industries of Uruguay

ktoe	2013	2014	2015	2016	2017	2018	2019	2020
Slaughterhouse	81.4	89.1	74.5	77.8	70.1	74.3	78.4	65.6
(%)	6%	5%	4%	4%	3%	4%	4%	3%
Dairy	64.4	58.4	57.9	58.7	50.3	56.8	55.4	69.4
(%)	5%	4%	3%	3%	3%	3%	3%	3%
Mills	31.5	59.6	61.2	63.8	61.0	61.2	58.8	55.1
(%)	2%	4%	3%	3%	3%	3%	3%	3%
Food – other	135.8	103.3	101.4	99.3	91.1	89.7	91.1	97.7
(%)	10%	6%	5%	5%	5%	4%	4%	5%
Tobacco and beverages	35.3	45.7	34.4	39.7	39.4	36.8	38.1	37.1
(%)	3%	3%	2%	2%	2%	2%	2%	2%
Textile	12.3	11.7	10.1	9.1	11.9	12.1	13.4	8.5
(%)	1%	1%	1%	0%	1%	1%	1%	0%
Leather	18.3	13.6	12.4	12.0	11.5	13.1	13.8	7.1
(%)	1%	1%	1%	1%	1%	1%	1%	0%
Wood	74.5	106.6	94.5	105.5	105.5	123.2	136.4	142.5
(%)	6%	7%	5%	5%	5%	6%	7%	7%
Wood pulp	705.0	909.4	1,197.1	1,296.0	1,335.9	1,313.2	1,301.7	1,316.5
(%)	52%	57%	65%	66%	67%	65%	64%	65%
Chemistry, rubber and plastics	50.1	64.8	80.6	83.9	97.0	108.7	111.4	103.1
(%)	4%	4%	4%	4%	5%	5%	5%	5%
Cement	93.4	81.2	95.7	89.1	96.6	100.3	90.6	89.1
(%)	7%	5%	5%	5%	5%	4%	4%	5%
Other manufacturing and construction	42.9	52.2	39.7	39.1	35.4	38.0	40.8	38.3
(%)	3%	3%	2%	2%	2%	2%	2%	2%
TOTAL	**1,344.9**	**1,595.6**	**1,859.5**	**1,974.0**	**2,005.7**	**2,027.4**	**2,029.9**	**2,030.0**

Fuente: BEN 2020

According to the latest survey of energy consumption of industries carried by MIEM, the energy mix of the dairy industry is as follows:

Table 14. Energy consumption of the dairy industry

Energy consumption dairy industry of Uruguay	Consumption (ktoe) as of 2018
Wood	19
Electricity	14
Fuel oil	19
Gasoil	0.2
Natural Gas	1.1
Total	**53.3**

Source: MIEM - Consumos de energía en la industria: datos 2018

According to data received from INALE on the interview carried for this study, the dairy industry spent USD 61.6 million on energy in 2016, latest data available from the central bank of Uruguay's data (In Spanish: BCU). This expenditure is met half by dairy farms ("primary sector" in the table below) and half by the industrial process. For the former, boiler fuels represent over two thirds of the energy expenditure, whereas for the latter, the biggest expense is electricity and gas, accounting for over 40% of the total.

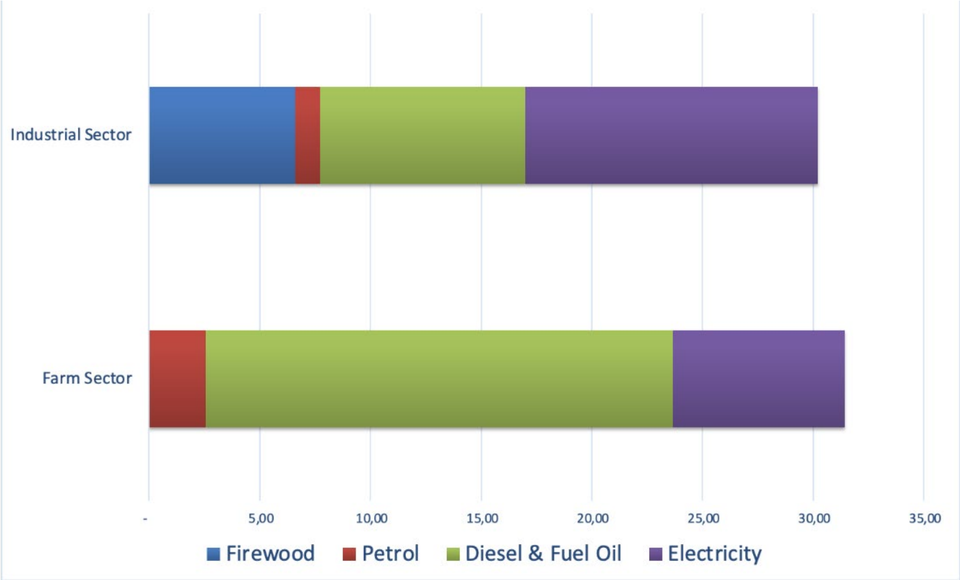


Figure 29. Dairy Industry Energy Consumption (USD million 2016)
Source: calculations of INALE based on BCU data

Table 15. Dairy industry expenditure on energy USD Ks 2016

Category	Farm Sector	Industrial sector	Total
Firewood	0,02	6,59	6,61
Petrol	2,54	1,12	3,66
Diesel & Fuel Oil	21,09	9,28	30,38
Electricity & Gas	7,76	13,21	20,98
Total	31,42	30,21	61,63

Source: calculations of INALE based on BCU data

As portrayed, as of 2016 the dairy industry spent approximately USD 3.7 million on transport related fuels. OPEX-wise, green hydrogen would have to compete with these figures.

Transport

According to the Inter-American Development Bank (BID, 2018), forestry and its related activities are the most dynamic subsector in the period analysed, with a rate of annual growth of 6%. Meanwhile, agriculture grew at 3%, also above the industry average. The livestock subsector (which includes beef and dairy cattle) showed the lowest rate, with a growth of 1% annual between 1988 and 2015. As a consequence, silviculture and agriculture have gained weight within the sector.

This is very important for logistics since these subsectors are the most intensive in transport. Most of the activity is largely supported by an increase in productivity, given by changes in use soil and location of productive activities: increases in forestry and agriculture to the detriment of livestock production[cxlviii], and also by technical change and innovation.

As a result, the agricultural and agro-industrial Uruguayan sector shows a very different profile than two or three decades ago, with significant increases in the levels produced and exported, changes in land use and relocation of activities and markets, also with different actors and ways of organizing the productive process. These transformations impact on the logistics processes, with a significant increase in loads and the demand for infrastructure services.

Table 16. Road transport volume (tons.) / tons per km / average distance

Cadenas	Volumen de Cargas		Toneladas – KM		Distancia Media
	Toneladas	%	Miles	%	Km/t
Carne vacuna	**3.321.893**	**13,8%**	**494.264**	**10,3%**	**149**
Ganado	2.756.604	11,5%	399.901	8,3%	145
Productos Cárnicos	565.289	2,4%	94.363	2,0%	167
Leche y lácteos	**2.463.583**	**10,3%**	**118.064**	**2,5%**	**48**
Remisión de leche	1.973.649	8,2%	76.627	1,6%	39
Productos lácteos	489.934	2,0%	41.437	0,9%	85
Granos	**5.959.753**	**24,8%**	**1.195.634**	**24,9%**	**201**
Secano y derivados	4.889.596	20,4%	777.411	16,2%	159
Arroz	1.070.158	4,5%	418.222	8,7%	391
Forestal	**12.267.179**	**51,1%**	**2.985.703**	**62,3%**	**243**
Madera	11.764.852	49,1%	2.790.069	58,2%	237
Productos industriales	502.327	2,1%	195.634	4,1%	289
TOTAL	**24.012.408**	**100,0%**	**4.793.665**	**100,0%**	**200**

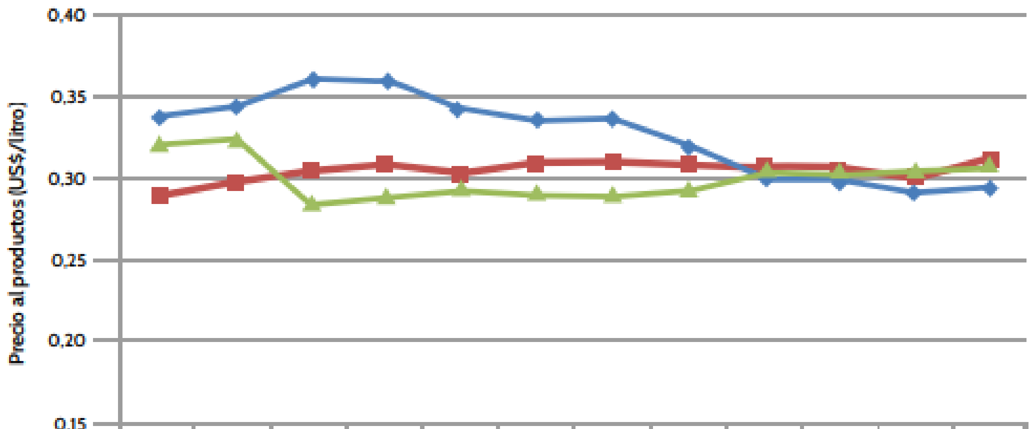
Source: Inter-American Development Bank (BID, 2018)

The logistics costs of the four agro-industrial chains ascended to US $ 1,050 million. Half of the costs correspond to the agricultural chain, 38% to the forest chain, 9% to the meat chain and 3% to the dairy chain. If we look inside the activities' logistics, just over two-thirds of the costs corresponds to transportation, 21% to storage, 8% to services ports and 3% to other activities. Of the total transportation costs (US $ 707 million), almost half correspond to the forest chain, 36% to the agricultural, 12% to the beef and the remaining 4% to the dairy. On the other hand, from total collection costs (US $ 223 million), 99% corresponds to the agricultural chain and only 1% to the forestry. Almost two-thirds of the cost of services ports correspond to the agricultural chain, and almost a fourth, to the forest chain, which are the chains that export most volume.

The destination of milk to industrial plants in Uruguay fell in 2009 due to the 2008 drought, but since then it grew without interruption until 2013, when it reached the all-time record of just over 2,018 million litres. This growth, close to 20% in some years, an unprecedented figure, it is explained by investments and the application of technology, that increased productivity, with growth of production even on a declining surface.

2010	1.552	
2011	1.843	19%
2012	1.936	5%
2013	2.018	4%
2014	2.014	0%
2015	1.974	-2%
2016	1.949	-1%
2017	1.924	-1%
2018	2.063	7%
2019	1.970	-5%
2020	2.078	5%

Figure 30. Milk remission (millions of litres)
Source: INALE (2021)



	Ene.	Feb.	Mar.	Abr.	May.	Jun.	Jul.	Ago.	Set.	Oct.	Nov.	Dic.
2018	0,34	0,34	0,36	0,36	0,34	0,33	0,33	0,32	0,30	0,30	0,29	0,29
2019	0,29	0,30	0,30	0,31	0,30	0,31	0,31	0,31	0,31	0,34	0,30	0,31
2020	0,32	0,32	0,28	0,29	0,29	0,29	0,29	0,29	0,30	0,30	0,30	0,31

Figure 31. Evolution of the price received (USD/litre of milk equivalent)
Source: INALE (2021)

Growth was driven by rising prices, which allowed growers to get good economic results despite the increase of several of the components of their production costs and the climatic conditions. In 2014 the price of milk was US $ 0.42 per litre, while 4 years earlier it was US $ 0.32 / litre, an increase close to 40%. However, that scenario changed in 2015 and 2016, with significant drops due to the significant increases in world prices that generated an increase in the supply from various countries (stimulated by high prices), which was not absorbed by demand. The price fell all over the world. In Oceania, one of the main exporters, the decline in 2016 was 42% with compared to the 2014 price.

This situation affected the prices paid by the industry for its raw material, generating several issues, such as the closure of two large companies (Ecolat and Schreiber Foods). In this context, domestic consumption, despite being only about 30% of the final destination of the products of the industry, was significant in the overall performance of chain. During these years, domestic demand was relatively stable, with a trend barely ascending or descending, depending on the product.

Due to its highly perishable nature, the milk is sent to the industrialization plants authorized based on agreements or contracts between the producers and industrial companies. The raw material is transported in refrigerated tank trucks directly from the drums to the plants. All these farms have cold tanks, and the milk is collected once a day. The Trale company transports the milk that goes to the plants of Conaprole. It is an independent private company of the cooperative, but closely linked to it. The other companies have their own fleet of trucks, although smaller companies use to contract the service from third parties.

In industrial plants, milk is processed for two destinations: 1) pasteurized fluid milk for consumption, or 2) production of dairy products, mainly powdered milk (whole and skim), butter and yogurt. Trale also transports and distributes pasteurized milk and Conaprole's dairy products, both for the domestic market as well as for export.

Fluid milk for direct consumption is transported to the points of sale in enabled refrigerated trucks. This product also has low seasonality, with the third quarter of the year (July-September) as in higher annual consumption (27%). In contrast, the lesser consumption is in the first quarter, with 22% of the annual total.

The origin of fluid milk for direct consumption is concentrated in the south of the country (Montevideo and San José add up to 75% of that offer). Fluid milk consumption is associated with the urban centers Montevideo- accounts almost 50%.

Dairy products go to the domestic market or to the export. The final selling points of the internal market vary from large stores to smaller size supermarkets and small warehouses. These products do not have a marked seasonality, except for yogurt, which concentrates 60% of its sales between the months of October and March. As in the rest of the chain, 71% of the domestic market is originated in the area south (San José, Canelones and Florida, with 33%, 25% and 13% production, respectively). Products for export also have their origin in the south of the country. San José, Florida and Canelones concentrate 28%, 23% and 20% of production, respectively. From the total volume, 86.7% leaves the port of Montevideo, followed by Chuy (4%) and Fray Bentos (2.5%) of exports. The length of time dairy products remains in chambers of the establishments where they are made is quite variable, especially in the case of exportations.

The almost 494,000 million litres per year produced annually that are not sent to Conaprole plants, have as their main destination nine industrial plants from eight companies, in addition to other smaller plants, that are responsible for approximately 6% of that volume. On average, milk travels 39 km to reach the point where it will be processed[cxlix]. An important part of the route of the trucks that transport milk is carried out by country roads, notwithstanding other significant part which is done by national routes. From the total fluid milk internal consumption, 87% is originated from the Conaprole plants. It is estimated that fluid milk intended for domestic consumption travels an average distance of 27 km.

Table 17. Transport indicators of dairy industry

PRODUCTO TRANSPORTADO	INDICADORES LOGÍSTICOS		
	MILES DE T	MILES DE T-KM	DISTANCIA PROMEDIO km/t
LECHE			
remitida a plantas	1.974	76.627	39
Subtotal leche	**1.974**	**76.627**	**39**
PRODUCTOS LÁCTEOS			
leche fluida para consumo interno	194	5.263	27
industrializados para el mercado interno	70	6.318	90
industrializados para exportación	225	29.856	132
Subtotal productos lácteos	**490**	**41.437**	**85**
TOTAL	**2.464**	**118.064**	**48**

Source: Inter-American Development Bank (BID, 2018)

Milk remission to the plants represents the largest volume transported, almost 2 million tons per year, at an average distance gave 39 km. The average distance travelled by the pro industrial pipelines is 85 km. This average hides strong differences. Fluid milk for consumption implies a volume of 194,000 tons and a distance of 27 km, while dairy products that are destined for export mobilize approximately 225,000 tons at an average distance of 132 km. In an intermediate position there are dairy products for the local market, with a volume of 70,000 tons and an estimated distance of 90 km. For the whole of the chain, each ton of product moves towards an average of 48 kilometres.

The cost of sending milk to industrial plants is US $ 20.3 million and is the highest in the chain. It represents almost two-thirds of the total. Followed on relative importance of the logistical cost of transporting dairy products for export, accounting US $ 4.7 million. In this group of products, the cost of port services is relevant. The logistics cost per ton of export products is US $ 36, against US $ 17 of products for the domestic market, and US $ 11 and US $ 10 for fluid milk and sent to the plant, respectively.

Case study: Uruguayan dairy farm

The following conclusions were drawn following a visit to a farm located in the dairy region, on the department of Florida:

- There is a very low gross margin over the investment (internal rate of return) low operational margin.

- In terms of importance, 75% of the total costs are linked directly or indirectly to feeding the cows.

- Only 1.5% of the costs is related to electricity, which comes already from renewable sources.

- There are heat recovery systems for milk cooling installed to save energy (energy efficient use).

- The farmer has environmental concerns (effluents management and GHGs emissions)

- There is an opportunity for green hydrogen as fertilizer and to power heavy machinery (fuel).

Uruguay hydrogen dairy conclusions

Uruguay has an outstanding opportunity to generate a second transition on its energy production and consumption. After the profound modification of the energy matrix during the las 15 years, nowadays almost 97% of the energy generated in the country comes from renewable sources: either wind, solar or hydro. Yet, because of the use of fossil fuels, the transport and industrial sectors still represent an important portion of the total GHGs emissions of the country. In this sense, the generation and utilization of Green Hydrogen constitutes the next step in the sustainable development of Uruguay.

After analysing the opportunities for the application of hydrogen energy for the Dairy sector, we can highlight that there is no evidence of an advantage of hydrogen in the primary sector. This is because electricity represents only 1.5% over total costs of a dairy farm. However, it would be interesting to analyse the use of Green hydrogen to produce ammonia and use it as a fertilizer (urea). Moreover, it might be important if it could be used as a substitute of diesel for heavy machinery. However, farmers have many concerns before investing in energy generation and there are not incentives for farmers to do so. Hence, the best option for the primary sector is to apply hydrogen as a substitute of fossil fuels and fertilizers but not the auto generation.

On the other hand, there is a clear opportunity on the transport sector. In particular, on the dairy sector heavy vehicles can that still use petrol, can replace this source of energy by hydrogen. Despite being a sector that do not represent a high portion of the total tons transported by kilometre, the length for milk to be transported is interesting. As an average, fluid milk is transported 39 km and all fluid milk and industrial dairy products 48 km. These means that the autonomy required for trucks in the dairy sector is not high. Thus, the 118.064 thousands of tons/km could be partially or totally carried buy hydrogen trucks.

In terms of the milk processors, the energy consumption represents over US $60 million dollars a year. Half of this expenditure is represented by broilers for drying fluid milk and the main energy sources are wood and fuel oil. This is followed by electricity and gas with more than $US20 million dollars a year. In this sense, hydrogen represents a very interesting opportunity in order to reconvert the dairy industry into a more sustainable sector.

Moreover, for the medium to long term, there is an interesting opportunity on generating green fertilizers local. This important input for agriculture and dairy farms could represent more than 100.000 TON of hydrogen. Uruguay could become and exporter of fertilizers to the region and the rest of the world due to its ideal location and ports.

Summary of key findings

Factors influencing a hydrogen transition

Appetite for hydrogen investment

- Australia is motivated to become a hydrogen leader, for in both domestic use and export. Australian Federal and State Governments are actively investing in hydrogen pilots, demonstrations, and commercialisation opportunities.
- Australia has a national renewable energy target of 20% by 2030, and this will also help drive growth in sustainable energy supply in manufacturing.
- Uruguay is motivated by energy security, with 97% of electricity being derived from renewable sources, and there is an opportunity to turn surplus electricity into hydrogen.

Increasing focus for dairy supply chain sustainability

- The Australian dairy industry is motivated by sustainable practice, demonstrated by the Australian Dairy Industry Sustainability Framework and the support of Pathways to Dairy Net Zero.
- Dairy companies may be driven to reducing energy intensity and emissions due to market and supply agreements driven by trade partner emissions goals and consumer preferences for low carbon footprint supply chains, regulatory frameworks that imposes carbon pricing and volatile fuel and power prices.

Regional advantage

- The south west Victorian region is well positioned to become a hydrogen hub, to align supply and demand due to renewable energy capacity, Deakin University's Hycel Technology Hub and road and rail connectivity.
- Uruguay is positioning to become a green hydrogen exporter in the near and mid-term, with investments in the Port of Rotterdam feasibility and the Hydrogen-2-Uruguay Strategy.

Integral factors for a successful hydrogen transition

- Hydrogen is in the emerging stages and initial strategic pieces, such as this feasibility study, will facilitate a shared conversation between key stakeholders and inform action in the near to medium term.
- Hydrogen will become a fuel of the future only if communities believe it is necessary and safe, therefore market and community education and social licence building is integral to ready communities for the transition
- While the trajectory for development and maturation of hydrogen infrastructure for residential and industrial application straddles the coming decades, there is a need in the immediate future to concentrate on skill building and education to ready Australia's future hydrogen workforce.
- There is a need and appetite to bring together key community stakeholders to educate and generate community conversations about the hydrogen opportunity for dairy and broader agriculture/ rural industries.
- To create step change, commercial parties require additional inputs and strategy to facilitate independent assessments of the feasibility of the hydrogen transition.

Hydrogen – on the farm

- The suitability of biodigester potential using effluent feedstock to produce biogas is unlikely to be realised in Australia presently due to the pasture-based nature of most dairy farm systems: animal excretion predominantly occurs in paddock and dairy effluent ponds lack the economies of scale for useful production volumes of hydrogen gas.
- Hydrogen does not present an attractive solution to reducing emissions on farm, as the greatest contributor to farm emissions are from enteric methane from ruminant (cow) digestion (56% of emissions).
- Farmers are already proactively reducing emissions through efficiency gains and a shift to renewable energy (predominately reducing grid electricity through solar power) and so far, farmers have not investigated hydrogen as a necessary near-term option.

- The economic feasibility of hydrogen as a fuel source is dependent on future price and availability of current energy sources (e.g., diesel, grid electricity, natural gas). There may be potential application to more remote farms where fuel prices are higher.

Hydrogen – in processing

- The increased cost of energy has been a major driver for some dairy processors to reduce energy use.
- For most dairy manufacturers, 80% of their energy needs is for thermal processes (i.e. heating and drying milk, hot water for cleaning) and the remaining 20% used for electrical requirements. Electricity and thermal energy are generated both externally and on-site, typically using fossil fuels including coal, oil, natural gas and LPG, whilst a small number of plants supplemented their energy supply using biogas.
- Although very common in Europe, Anaerobic Digesters are still scarce in Australia, and have been trialled unsuccessfully by a number of dairy manufacturers over a 20-year period.
- In the near term (2020-2025), hydrogen applications such as heavy haul and return to base transport and light commercial vehicles (forklifts) are expected to be competitive with fossil fuel alternatives. If used for heat and power in processing hydrogen is not expected to be a competitive energy source until the longer term (2050) due to the current high use of natural gas.
- The dairy industry is very proactive in looking at opportunities to reduce its greenhouse gas emissions and increase efficiencies, but their focus has been on stationary element of the supply chain, which is energy intensive, rather than in the transport.
- A potential of hydrogen needs to be considered within the mix of current purchasing power agreements and the energy mix.

Hydrogen in supply chain logistics

- Hydrogen offers potential to deliver step change reductions in Green House Gas (GHG) emissions toward carbon net-zero food & fibre supply chains. Transport is a critical player in supply chains and to date often not visibly prioritised in agricultural sector strategies and supply chain GHG reduction targets – arguably because commercial enterprises require a level of confidence in a tangible pathway to achieve goals and targets.
- The most advanced application of hydrogen is in transport and indeed, the near-term tangible application of hydrogen in both Uruguayan and Australian dairy systems is in heavy vehicle transport. A hydrogen powered milk tanker demonstration is already occurring in the Netherlands.
- The energy needs of the processing component of the supply chain are particularly complex, which make assessing the feasibility of hydrogen on a monetary level difficult at this early stage. A tailored assessment, based on an individual company's needs, ambitions and projections is required.
- The path to total cost ownership for hydrogen powered vehicles is difficult to project due to the infancy of the hydrogen industry, however, hydrogen heavy and medium duty trucks and buses are projected to achieve cost competitiveness earlier than other applications, estimated at 2025.

Next steps

The hydrogen transition will be aided by industry education that focuses on foundational hydrogen knowledge and tools so that decision makers can engage in conversations, planning and interrogation regarding hydrogen feasibility and application. This study has identified that heavy vehicle transport is the near-term opportunity for hydrogen application in the dairy industry.

Recommendations

Australia – Great South Coast (GSC) region

Dairy Industry

- Investigate funding avenues to support the next phase of the dairy hydrogen project
  - Engage with dairy processors and third-party transport providers in the GSC region to establish their understanding of the hydrogen potential.
- Facilitate study tours and site visits (both local and international) to key commercial hydrogen initiatives and education centres for dairy industry stakeholders.
- Pursue pilots or collaborative initiatives with commercial entities to advance the application and adoption of hydrogen technology in heavy vehicles, such as milk tankers and long-haul trucks.
- Investigate regions with intensive dairy operations to further explore on-farm biogas production of hydrogen from methane.

Great South Coast, Victoria

- Develop a regional roadmap for the development and adoption of the hydrogen industry in Southwest Victoria.
- Develop and implement a regional action plan to establish and maintain social licence for hydrogen technology. include community and key stakeholder education
- Explore options for hydrogen technology to generate ammonia for local production of urea and fertilizers.
- Establish a regional steering / working group for ongoing coordination and considerations to guide the further development of hydrogen for the food and fibre sector across the GSC:
  - Ensure collaboration and coordination across the region and industry.
  - Oversee food & fibre market needs and gap analysis
  - Remain abreast of relevant regional activities and beyond in hydrogen to ensure shared learnings and potential synergies or collaborations are leveraged.

Hycel and hydrogen tech and innovation hubs

- Develop targeted communications on the findings from this report, including potential opportunities, to engage broader stakeholders with the view to seek and align future funding options to enable the following
  - Ongoing development of hydrogen research & technology, particularly fuel cells
  - Regional pilots that advance and/or demonstrate the technology
  - Regulatory standards
  - Safety and training
  - Community education and social licence
- Consider further international opportunities for collaborative learning and market development, particularly in global regions where Deakin University has established operations and relationships.

Further collaboration & engagement

- Share targeted findings of this report with broader food & fibre industry stakeholders to inform the potential opportunities for hydrogen technology adoption.
- Continue Uruguayan connection with a focus on economics of hydrogen in the dairy sector and addressing future market access opportunities and challenges through working groups touch points.

Uruguay

- Connect with the H2U working group to share findings of this report and to connect with developments such as of offshore hydrogen generation with wind energy associated and URSEA: regulation of production, transport, commercialization, export, etc. of green hydrogen.
- Advocate for a long-term strategy for the development of hydrogen.
- Continue to strengthen the link with Australian hydrogen institutions (including Hycel) to collaborate in future projects.
- Support the development of a hydrogen cluster (ecosystem) that promotes the generation of new projects.
- Continue the follow up with CONAPROLE (largest dairy industry in Uruguay) to discuss the potential of hydrogen as a substitute of wood and fuel oil in the industry and gasoil in the transport sector.
- Future PhD in renewable energy and the impact of green hydrogen production.
- Investigate the possibility of other PhD candidates, including the Dairy Industry for the application of green hydrogen.

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