Hydrogen opportunities for dairy industries in Australia and 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 investigation is intended to lay the foundations so that dairy industries can engage with and plan for a hydrogen transition. 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.

This study found that both Australia and Uruguay are motivated to develop and domestic and export hydrogen industry. The Australian dairy industry is motivated by sustainable practice, which is demonstrated by 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, 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 Victorian and Uruguayan are pasture based rather than intensive (thus biomass is left in paddocks or effluent ponds) so the biodigester potential using effluent feedstock to produce biogas is unlikely to be realised.

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 element of the supply chain, which is energy intensive. In the near term (2020-2025), 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.

Key recommendations

- Investigate funding avenues to support the next phase of the dairy hydrogen project
- Establish a Victorian Great South Coast 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.
- Connect with the Uruguayan 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.
- Engage with dairy processors and third-party transport providers to establish their understanding of the hydrogen potential.
- Facilitate study tours and site visits to key hydrogen industry leaders or education centres (e.g., Hydrogen Education Centre, Hyzon and FrieslandCampina's hydrogen milk tanker) for dairy industry representatives.
- 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.
- Engage in ongoing community and stakeholder engagement to build and maintain social licence for hydrogen.
- Consider other international opportunities for collaborative learning, tertiary study and market development, particularly in global regions where Deakin University has established operations and relationships.

The demand for nutritious and sustainably produced food and fibre for the predicted world population of 9-10 billion people by 2050 brings shared challenges and opportunities.

The global initiative 'Pathways to Dairy Net Zero', along with the Australian Dairy Industry Sustainability Framework, demonstrates the recognised importance of the dairy industry's role in sustainable dairy production, including reducing 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.

Hydrogen

Hydrogen is seeing unprecedented and intensifying global support. Countries around the world are looking to hydrogen as a zero emissions fuel that can to help meet global carbon reduction targets by decarbonising transport and industry.

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 clean hydrogen and the durability of equipment were significant barriers. The development 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.

What is Hydrogen?

Hydrogen is:

- the smallest, oldest and most abundant element in the universe
- 14 times lighter than air, odourless, colourless, and tasteless
- non-toxic and non-poisonous
- usually bound up in in substances like water, natural gas, coal, and biomass
- produced via electrolysis or steam reforming from either water or fossil fuels
- zero emissions when produced via electrolysis from green electricity

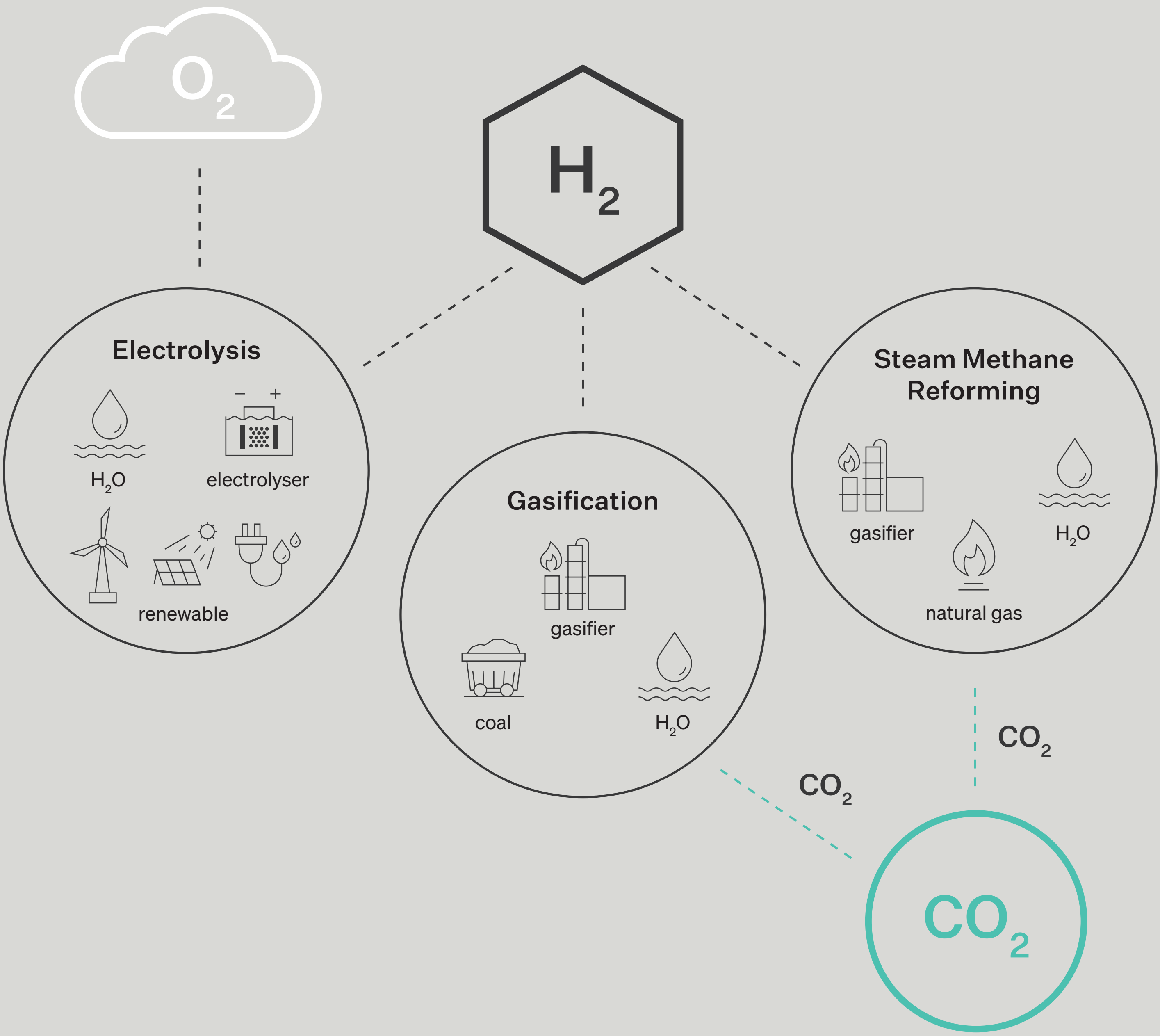
[i] https://hydrogencouncil.com/en/hydrogen-insights-updates-july2021/
[ii] https://www.industry.gov.au/sites/default/files/2019-11/australias-national-hydrogen-strategy.pdf, p. v

Why hydrogen?

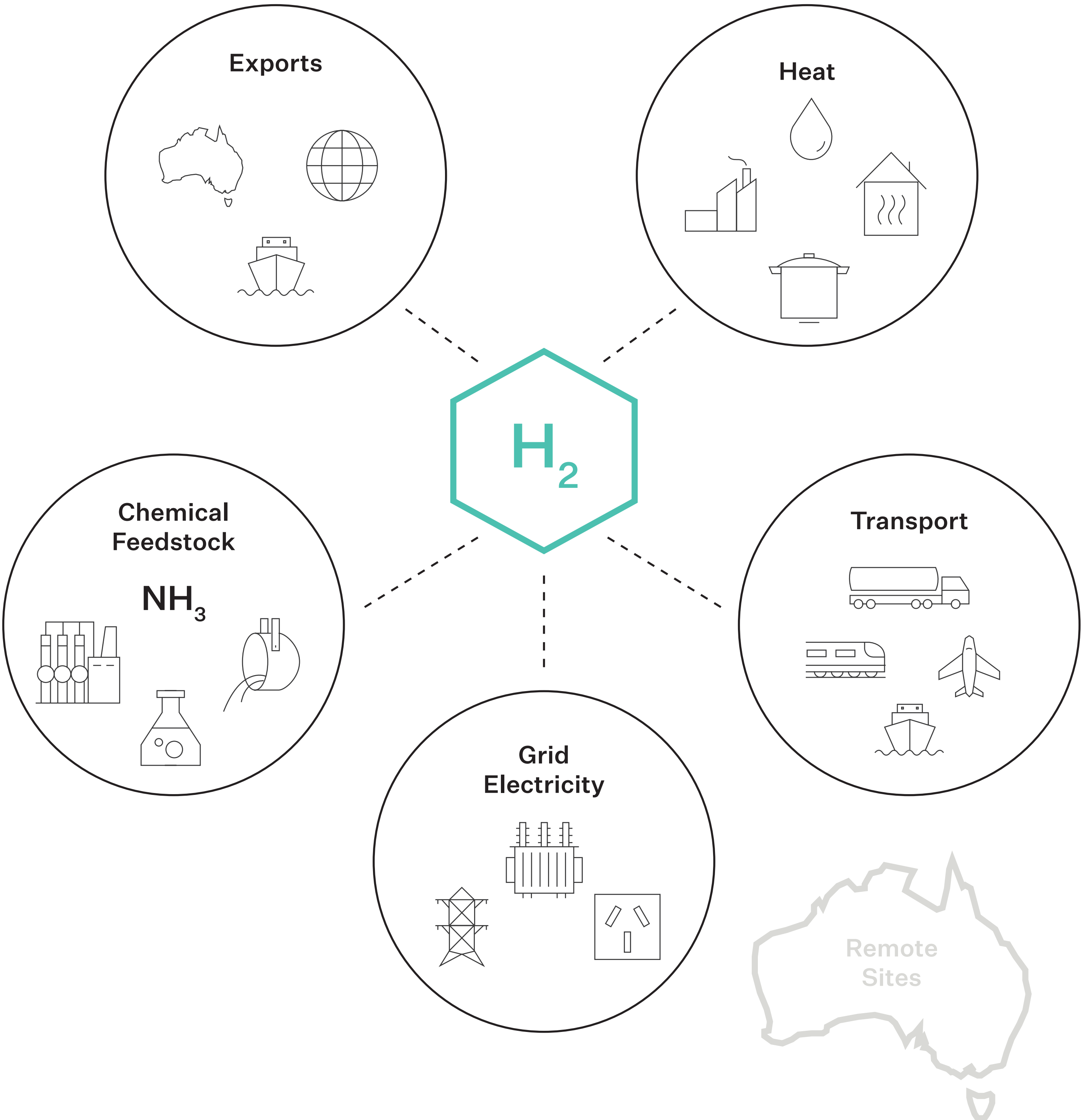
Hydrogen is:

- Unlimited: the most common substance in the universe and can provide energy to all parts of the economy.
- Sustainable: emits nothing but water vapour and heat; zero emissions if produced renewably.
- Flexible: use now or store for later as liquid or gas; fuel for cars, trucks, buses, trains and ships, heat homes, cook on stove tops or store excess solar energy.
- Powerful: higher density energy than batteries when compressed.
- Emergent: globally, the hydrogen industry is predicted to employ up to 30 million people and be worth around $US2.5 trillion by 2050.

How is hydrogen produced?



How is hydrogen used?



At a global level, the hydrogen market is predicted to reduce carbon emissions by 6 billion tonnes annually, employ up to 30 million people and be worth around $US2.5 trillion by 2050.

— Hydrogen Council, Hydrogen, Scaling Up, 2017
https://hydrogencouncil.com/en/study-hydrogen-scaling-up/

Hydrogen in Australia and Uruguay

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 clean 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[iii].

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. [iv] The projects range from large scale production, gas blending in natural gas infrastructure and hydrogen mobility. Deakin University's Hycel at its south west Victorian Warrnambool campus brings hydrogen researchers together with key industry partners to deliver a regional hub of hydrogen expertise and development.

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, 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. 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.

Transport is emerging as the near-term tangible application of hydrogen. 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.

[iii] https://www.industry.gov.au/data-and-publications/australias-national-hydrogen-strategy
[iv] https://research.csiro.au/hyresource/projects/facilities/

Dairy in Australia and Uruguay

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 across both livestock and cropping – both extensive grazing and cropping have provided the backbone to the agricultural sectors.

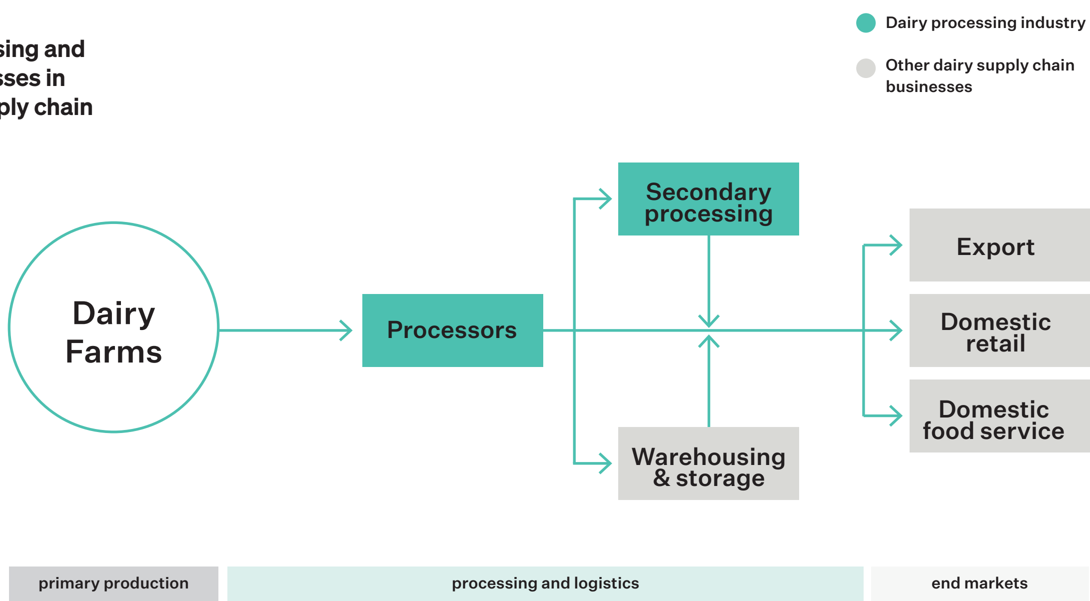
Dairy in Australia

- Australian Dairy Industry is a $13 billion farm, manufacturing and export industry and directly employs 43,500 approx. people
- Australia's fourth largest rural industry
- 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.
- 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.

Dairy in Uruguay

- Uruguay is the 7th largest exporter of dairy products in the world
- Despite having a population of 3.5 million people, in only 5% of its territory produces enough milk for more than 18 million people
- 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
- 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.

Dairy processing and other businesses in the dairy supply chain



Dairy and sustainability

The global initiative Pathways to Dairy Net Zero was launched in 2021, which aims to 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.

United Nations Sustainable Development Goals

- Goal 7: Affordable and clean energy
  Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 12: Responsible consumption and production
  Ensure Sustainable consumption and production patterns
- Goal 13: Climate action
  Take urgent action to combat climate change and its impacts

Australian Dairy sustainability

The Australian Dairy Industry Sustainability Framework 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.

Commitment 4: Reducing our environmental impact

- 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

Uruguayan Dairy sustainability

Uruguay is focussed on determining the possible impacts of climate change and its variability. The National Adaptation Plan outlines a path to agricultural sustainability. The plan integrates adaptation and mitigation to climate change policies with actions to increase food security. Strategies include:

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

Dairy's footprint

- Australian agriculture contributes approximately 15% of Australia's greenhouse gas emissions (GHGs) with the dairy industry contributing to 12% of Australian agricultural emissions[v].
- The dairy industry contributes close to 12% of Australia's agricultural greenhouse gas (GHG) emissions[vi]. 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.
- The greatest contributors to total farm emissions in Australia are enteric methane from ruminant (cow) digestion at 56% and pre-farm emissions sources at 14% (such as carbon dioxide from purchased feed and fertiliser production, as well as direct use of fossil fuels and electricity and gas.
- In Uruguay, emissions of the agriculture sector represent 75% of the total emissions of the country, from which 56% comes from enteric fermentation.
- The dairy industry accounts for 3% of the total energy consumption of the industries of Uruguay.

[v] Lundie, S., 2013. Carbon Footprint of the Australian Dairy Industry, s.l.: PE Australasia and UNSW Water Research Centre for Dairy Australia. Confidential report. Cited in Prasad, P (2019) Eco-efficiency for the Dairy Processing Industry, 2019 Edition. Dairy Australia

[vi] Prasad, P (2019) Eco-efficiency for the Dairy Processing Industry, 2019 Edition. Dairy Australia

Hydrogen on the farm

Hydrogen production from biogas?

A logical opportunity for dairy farms is to produce hydrogen from effluent via biodigester / gasification. Presently on farm anaerobic production of hydrogen 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.

- Most dairy farms in south west Victoria and Uruguay are pasture-based systems, where cows graze and excrete in paddocks rather than in feedlots.
- Effluent storage is a major consideration for farms, with 70% using ponding systems which store, treat and recycle nutrients back onto the farm.

Key point: There is potential to investigate biodigester hydrogen production with intensive farming systems but limited potential with pasture-based systems.

Hydrogen to reduce farm energy cost?

In Australia, 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.[vii] The remaining 20% of energy use arises from cleaning and effluent management, stock water, feed and sheds and lighting.[viii]

- The national average energy use on dairy farms is 48kWh/kL (kiloWatt-hour per kilolitre) of milk.
- Diesel and petrol are used to power farm vehicles such as tractors, utes and motorbikes; fuel costs for these account for about 2% of total operating farm costs.

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 (& processors) access to affordable and reliable energy is imperative for continued sustainability and enhanced growth in the agricultural sector.

Key point: At the moment, hydrogen is not available at a scale or price to be viable as an on farm solution for energy needs. For remote farms where fuel security and prices differ, hydrogen may be worth investigating.

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vii Dairy Australia (2018) Saving energy on dairy farms
viii Dairy Australia (2018) Saving energy on dairy farms

Hydrogen in dairy processing

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 in 2016/17 on energy supply across the sector. Across the dairy supply chain, dairy processing is roughly twice as energy intensive as on-farm milk production. In 2019/20 Australia's dairy processing sector consumed a total 10.9 Petajoules (PJ) of energy.

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. Energy requirements are dependent on the types of products manufactured – e.g.. milk powders require 1.7 times as much electricity as cheddar cheese and 6.0 times as much thermal energy due to evaporative processes.

A transition to renewable hydrogen could:

- Reduce emissions across the supply chain
- Reduce reliance on escalating utility and fuels costs
- Provide access to renewable energy source
- Position processors as leaders in carbon net-zero food/ agriculture supply chains

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):

- 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)

Hydrogen in dairy processing

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 processors 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 processor'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.

Issue / Opportunity	Context	Resolution
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 processors using their own 'workshop', these would need to be addressed prior to the introduction of FCEV to the processor's 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 the 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 processor's 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.

Hydrogen production onsite at dairy production plants

To ensure an economic supply of hydrogen to a manufacturing system, 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. Circular economy.

  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)
- Renewable energy produced onsite (wind / solar) for onsite energy uses, could also be used in the hydrogen production process.
- 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

The challenges:

- Capital costs of plant & equipment for onsite hydrogen production & 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 processing sites
- Upskilling of staff to manage and operate hydrogen production systems and equipment
- Regulations, permits, applications to operate.

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