IChemE Policy response

Low Emissions Technology Statement 2022 consultation: Department of Industry, Science, Energy and Resources, Australian Government

Consultation response from the Institution of Chemical Engineers (IChemE)

The Institution of Chemical Engineers

The Institution of Chemical Engineers (IChemE) is a not-for-profit, member-led qualifying body and learned society that advances chemical engineering's contribution worldwide for the benefit of society. We support the development of chemical, biochemical and process engineering professionals and provide connections to a powerful network of over 30,000 members in more than 100 countries.

Formation of a local IChemE association was established in the early 1960s. The Victorian Group of IChemE was formed in December 1962 and was closely followed by the establishment of the New South Wales and South Australian groups. In May 1967, the Australian State groups agreed to form the Australian National Committee, giving birth to the Institution of Chemical Engineers in Australia.

We support our members in applying their expertise and experience to make a contribution to solving major global challenges, and are the only organisation permitted to award the widely recognised Chartered Chemical Engineer status and Professional Process Safety Engineer registration.

This response has been produced by IChemE members in Australia and draws on the Institution's position on climate change published in November 2020.[1] Comment on the draft was sought from the Institute's broader global membership.

There are some aspects of the Statement that fall outside of the specific expertise of chemical engineers and therefore no comment has been made, however, elements that align with the Institution's position on climate change are supported.

IChemE in Australia and its global colleagues would welcome discussion and further collaboration with the Department for Industry, Science, Energy and Resources.

[1] https://bit.ly/3ptN8C9

Framing Remarks for this Submission

IChemE commit to work collaboratively as members, through education, research and sustainable engineering practices, in contributing globally to the transition to a net zero carbon world by 2050. To achieve this, IChemE commits to the principles in its Climate Change position statement.[1] This statement informs the Institution's approach to this transition. Aspects of this statement that are pertinent to this response include the position from IChemE that it:

- fully supports the aims of the Paris Agreement to pursue efforts to limit the global temperature increase to 1.5 °C relative to pre-industrial levels and to achieve this will require net emissions of carbon dioxide and other greenhouse gases to be reduced to zero.
- agrees serious action to combat climate change is urgent and must start immediately and accelerate. Based on 2019 levels, this requires reducing global anthropogenic greenhouse gas (GHG) emissions by at least 7.6% year on year to 2030 (as an interim target) or reducing total emissions by at least 50% each decade from now to 2050.[2]
- believes that we should make use of best available techniques to mitigate and adapt to the effects of climate change and that technologies must be chosen to ensure that they do not entrench the status quo but adapt to changing circumstances.

IChemE have prepared this submission with a technology perspective focus. The Institution understands that Low Emissions Technology Statements (LETS) are presented as the Federal Government's plan for delivering on the Net Zero commitment made to the UNFCCC in the lead up to the COP26 meeting in Glasgow, UK and as such it is Australia's Nationally Determined Contributions (NDC). LETS 2021 is strong on aspiration, but there needs to more details of delivered outcomes. LETS 2021 aims to drive towards the over-riding goal of a carbon-neutral economy by 2050, however the urgency of change and action now would benefit from more emphasis and detail to support this change.

[2] UNEP, Emissions Gap Report, Nov 2019, https://bit.ly/3BcUFN0

Existing priority technologies

Where can Government make the biggest difference and further incentivise investment in low emissions technologies, particularly the priority technologies identified in the Roadmap?

The LETS 2021 identifies seven priority technologies to support the roadmap to net zero emissions by 2050 and support economic growth. These are areas where it will be important for Government to make a difference and further incentivise investment. This paper will focus on the two technologies where chemical engineers bring the greatest expertise – hydrogen and carbon capture, utilisation and storage. It is important to note that chemical engineers are actively working in all of the seven priority areas including specifically to increase efficiency and reduce emissions.

Hydrogen

Understanding how the hydrogen gas market would interact with the existing natural gas market is critical, particularly given that the Roadmap envisages a zero-emissions gas market for the supply and consumption of hydrogen. The quoted stretch goal for clean hydrogen production is $2/kg. This is equivalent to 14.1 $/GJ gas (higher heating value, HHV). This target price is expensive relative to current wholesale gas market prices[3] and is reliant on significant reductions in hydrogen production cost to reach this level. In addition, if blending is to be considered, there are limits to how much hydrogen can be blended with existing natural gas transmission and distribution infrastructure. However, hydrogen has been present as a mixture (up to ~45%) with methane in natural gas for over 100 years in coal gas and town gas and therefore Australia can learn from others such as Hong Kong, UK and the US.[4]

If some level of sharing of the gas distribution network is planned, then the practical issues of this network sharing must be addressed. Concerns include:

- Consistent, measurable and controllable gas composition to manage the large difference in heating values between H_2 and natural gas. Changes in composition would affect metering and billing.
- Safety and performance of the supply, distribution and gas users (including the almost invisible flame in daylight).

To help resolve some of the above issues, the Government could investigate other pilot programmes of blending and domestic hydrogen supply around the world (e.g. BDR Thermea Group, Netherlands,[5] and HyDeploy, Winlaton[6] and Keele, UK[7]). Australia already has H_2 hubs (e.g. Bell Bay, including

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[3] Australian Energy Regulator, Gas market prices, https://bit.ly/3uhqSkN, [accessed 01/02/2022]
[4] Towngas, Gas Production, Hong Kong, https://bit.ly/3ufwN9Y [accessed 01/02/2022]
[5] BDR Thermea Group, Our Hydrogen Journey, https://bit.ly/3LbGhcC [accessed 01/02/2022]
[6] HyDeploy, HyDeploy Winlaton, https://bit.ly/3saDKqa [accessed 01/02/2022]
[7] HyDeploy, HyDeploy at Keele, https://bit.ly/3ubAJJ0 [accessed 01/02/2022]

Georgetown, or Whyalla), where pilot H_2 distribution systems could be trialled and in doing so provide confidence that a zero-emissions gas market is realistic.

A thorough safety evaluation embracing all hydrogen usages is essential, particularly considering the distribution and diverse uses of hydrogen envisaged in LETS 2021 and that parts of the supply chain are beyond industrial boundaries and control.

Widespread adoption of low carbon energy will require large-scale energy storage and distribution infrastructure. The costs associated with the storage, handling, and transport of low-carbon energy, such as hydrogen, are not insignificant. Although grid resilience is important, local generation (e.g. of hydrogen) at point of use offers economic and safety advantages rather than transport across distances (either export or domestic transport).

Hydrogen is regarded as a good vector for storing renewable energy.[8] The economic and safety issues with storage, distribution and transport of hydrogen are issues that can be addressed in part by the driving force for large-scale production with multiple usages located at the point of manufacture. Removal or reduction of the need to transport hydrogen (by pipeline, shipping or other means) reduces cost and some of the safety concerns. However, this highlights the importance of location of hydrogen production facilities and the need for technical standards for very large-scale production, handling and storage/bunkering of hydrogen intermediate products such as ammonia or methanol. An appropriate regulatory framework and investment in technologies will support the reduction of the costs of storage, handling and transport of low-carbon energy.[9]

In 2019, mineral exports accounted for $234 billion (47% of all exported goods and service, 12% of GDP). The main export in terms of earning was iron ore (41%).[10] If greater downstream processing of raw materials was to be carried out there would be economic benefits in terms of jobs and value but also then enabling Australia to produce commodities to support energy storage (e.g. through batteries).

The potential co-location of hydrogen production (from renewable sources) adjacent to locations of extractive industries could support the production of refined and intermediate products using low emissions processes. An example would be the reduction of iron ore using hydrogen. This would allow Australia to export direct reduced iron (DRI, sponge iron) rather than exporting both iron ore and hydrogen, to feed overseas electric arc steel furnaces. This reduces hydrogen transport and export costs.

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[8] IEA, The Future of Hydrogen: seizing today's opportunities, July 2019, https://bit.ly/3L19aYD
[9] Hydrogen Council and McKinsey & Co, Hydrogen Insights: a perspective on hydrogen investment, market development and cost competitiveness, February 2021, https://bit.ly/3sczrL2
[10] Australian Government, Value of Australian Mineral Exports: Australia's Identified Mineral Resources, 2020, https://bit.ly/3L0XIMM

In addition to co-locating hydrogen production with mineral refining, there are further opportunities for large, disruptive reductions in emissions. An example would be the use of waste thermal energy could make significant reductions in Australian emissions and action on these would need to start immediately.

Carbon capture, storage and utilisation

With further research and scale-up, CO_2 captured from point sources can be used to produce carbon-based fuels such as synthetic methane, methanol, or ethanol. This offers the potential to reduce current emissions from fossil fuels and have a positive impact on safety and carbon releases. These products also provide renewable, non-fossil fuel based carbon feedstocks which may be used to make products which currently rely on fossil fuels, such as polymers and pharmaceuticals.

How does Australia better support consumer and industry demand growth for low emissions technologies both domestically and internationally?

Development of consumer and industry demand is currently hindered by consumer inertia and low awareness, the need for a suitably skilled workforce in key locations, and slow translation of research to practical commercial outcomes and a lack of supporting policy frameworks.

Initiatives that would support demand growth include:

1. Policies and policy frameworks to raise awareness, support and incentivise uptake of low emissions technologies by households, commercial customers and industry.
2. Support a range of initiatives to develop skills in tertiary education and to upskill/ and reskill industry workforce, accessible across urban and regional areas where the opportunities lie.
3. Development and implementation of industry plans to reduce GHG emissions, with specific focus on industry sectors aluminium, steel and concrete.
4. Targeted programs to reduce GHG in agriculture and develop jobs and business in regional areas with renewable energy, hydrogen, and carbon capture and storage.
5. Provide support for “hub” style industry-academic collaboration, through hubs, CRCs, industry growth centres, and other innovative collaboration initiatives.
6. Provide targeted grants for R&D that supports the development of low emissions technologies within Australia.

IChemE could assist the Office in future consultation and development of these initiatives.

Alternatives to market-based mechanisms for carbon emissions include policies to incentivise uptake of low-emissions technology by consumers and industry. For example R&D grants and co-funding low-emissions technology. In addition, the remit of ARENA (Australian Renewable Energy Agency) and CEFC (Clean Energy Finance Corporation) should include priority areas, support the uptake of electric vehicles through grant schemes and/or reduce the tax rebates made to fossil fuels.

What are the global trends and competitive advantages that should be considered for the priority technologies?

Industrial hubs elsewhere in the world, such as Europe and Singapore, have been successfully developed to integrate industries and in doing so make use of circular economy principles.[11] In hubs of this nature, where operations are co-located, it is much easier to apply techniques such as pinch analysis to optimise energy production and usage. A crucial element of this is not just efficiency but understanding the minimum energy required.

Recently the NSW Government announced that it proposes to invest in hydrogen hubs in Illawarra and Hunter as part of the NSW Hydrogen Strategy.[12] The Australian Government is also investing (AUD$464 million) in support of the development of up to seven clean hydrogen industrial hubs in regional Australia, as well as design and development studies.[13] It is recommended that Australia increases its focus on green hydrogen (produced by an electrolyser powered by renewable energy) and not blue hydrogen (produced using natural gas). As the world moves to a low carbon future this will help ensure the country does not end up with a stranded blue hydrogen asset. Peer-reviewed research has indicated that the green hydrogen costs are likely to reduce and it is better than blue hydrogen in terms of both emissions and financial cost.[14,15]

There are mixed views on the effectiveness of carbon pricing and this is outside the main technical expertise of chemical engineering. However, the application of low emissions technology and robust life cycle analysis will lead to products with a lower carbon footprint. This may be increasingly important in the face of forthcoming carbon border adjustment mechanisms (CBAMs) which will impact Australian exports.[16]Technical and economic cost benefit assessments are routine in the development of products and processes. The impact of carbon pricing is currently unknown and will need to be assessed as the trend for carbon pricing develops, to understand the impact on innovation and implementation of low carbon technologies.

New and emerging technologies

What are the industrial sectors (other than steel and aluminium) that require technology innovation?

Technology innovation is crucial to numerous industrial sectors in Australia.

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[11] Witteveen+Bos, Results of circularity study on Singapore's Jurong Island presented, https://bit.ly/3GxjAfk [accessed 01/02/2022]
[12] NSW Government, NSW Hydrogen Strategy, October 2021, https://bit.ly/3ur9D0m
[13] CSIRO, Australian Clean Hydrogen Industrial Hubs Program (New Project added November 2021), https://bit.ly/32PpJpk, [accessed 01/02/2022]
[14] Longden et al, Green hydrogen production costs in Australia: implications of renewable energy and electrolyser costs, Aug 2020, https://bit.ly/3rusw0O
[15] Longden et al, *'Clean' hydrogen? – Comparing the emissions and costs of fossil fuel versus renewable electricity based hydrogen'*, *Applied Energy*, 306, Part B, 2021, https://doi.org/10.1016/j.apenergy.2021.118145
[16] The Australia Institute, Carbon Border Adjustments, June 2021, https://bit.ly/3AT4Ia4

- **Ethylene**

  Ethylene is the conventional starting material for 90% of the world's polymers. Traditionally it is an energy intensive process using fossil resource feedstocks. Carbon capture and storage is one mechanism to reduce carbon emissions. However, electrochemical methods have been developed to produce ethylene direct from CO_2.[17] This offers to utilise CO_2 at a significant scale and make use of low cost solar. There are examples of research projects to explore this.[18,19] If the ethylene is used for durable goods, then the CO_2 is stored for the lifetime of the component.

- **Packaging material manufacturing**

  The Federal Government's National Waste Policy Action Plan has shown leadership in the reduction of the export of Australia's waste to the developing world. However, the manufacture of packaging material from recycled material within Australia would encourage a circular economy associated with the plastics industry. The development of a Circular Economy is one of the UN SDGs (Sustainable Development Goals) and will be prioritised globally because of the need to reduce waste and environmental impact. The European Commission Circular Economy Action Plan is an example where technology innovation is considered from production, regulation and recycling.[20]

- **Low-carbon fuels**

  Low carbon fuels[21] offer a solution to support decarbonisation of international transport and shipping, and long-range remote road transport. Technology innovation is key for the development **of** these fuels, and should include hydrogen (and derivatives like ammonia and methanol), battery-electric and sustainable biofuels. There are technology innovations required to produce the fuels but this must be part of a system innovation to ensure that both the vehicle (ship, aeroplane or goods vehicle) is adequately adapted and the infrastructure is in place.

- **Petrochemicals**

  Australia's petrochemical production, which was strong in the period 1970 to 2000, is shrinking. However, the global demand for petrochemicals, particularly polyethylene and polypropylene is

[17] Jiao Y et al., *Promoting ethylene production over a wide potential window on Cu crystallites induced and stabilized via current shock and charge* delocalization, Nature Communications, 12, 6823, 2021, https://doi.org/10.1038/s41467-021-27169-9
[18] Fraunhofer IGB, CO2EXIDE – CO_2-based electrosynthesis of ethylene oxide, https://bit.ly/35WfAIl, [accessed 02/02/2022]
[19] Barecka MH et al, Economically viable CO_2 electroreduction embedded within ethylene oxide manufacturing, Energy Environ. Sci., 2021,14, 1530-1543, https://doi.org/10.1039/D0EE03310C
[20] European Commission, A new Circular Economy Action Plan For a cleaner and more competitive Europe, March 2020, https://bit.ly/336uOtC
[21] Low carbon fuels include a wide range of gaseous and liquid fuels that can replace fossil-derived transport fuels. They include biofuels, hydrogen and recycled carbon fuels produced from fossil wastes.

increasing and is expected to do so through 2030 to 2050.[22,23] Hydrocarbons used in the household paint and timber oil sector are growing strongly and the fraction of plastics in durable goods and non-durable goods (i.e., food packaging) is increasing and this does include biodegradable plastics. To deliver on the actions in the National Plastics Plan,[24] innovation in products and processing is needed in combination with initiatives to promote re-use and recycling.

The recent UN FAO report demonstrates that 82,800 tonnes (2.3% of Australia's annual consumption) of plastics is in the agricultural sector.[25] Only 7.1% is recovered. The majority of the plastic used in agriculture is polyethylene (81%).

There is a need to find new feedstocks for these products either from bio-derived chemicals or from CO_2 conversion. Australia's agricultural sector can produce the feedstock for plant-based polymers (e.g. based on cellulose or polylactic acid), however, the polymerisation and material properties need to deliver performance properties seen in petrochemical derived plastics.

- **Carbon capture and storage (CCS)**

  Although it is important to reduce overall CO_2 emissions, when this is not feasible, CCS provides an opportunity to reduce the impact. CCS is a priority in the Technology Investment Roadmap, however it remains technically and economically challenging.[26] While the government has announced over $300 million investment in CCS over 10 years, the application of this funds should continue to be assessed to ensure positive impact in the necessary technology and business model innovation.

  The concept of carbon storage hubs enables assembly of logically compatible and synergistic industries of world-scale competitive operating scale (e.g., both cement and hydrogen export facilities),[27] and should be a priority for the Government with suitable storage locations being identified.

- **Bioenergy with CCS (BECCS)**

  BECCS remains elusive at scale but as it plays a significant role in assumed decarbonisation pathways, it should be prioritised for technology innovation Most global decarbonisation scenarios include significant negative emissions in the latter half of the century - largely coming from

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22 OECD / IEA, The Future of Petrochemicals Towards more sustainable plastics and fertilisers, 2018, https://bit.ly/3snvpj9
23 McKinsey & Company, Petrochemicals 2020: A year of resilience and the road to recovery, May 2021, https://mck.co/34DhvRJ
24 Department of Agriculture, Water and the Environment, National Plastics Plan 2021, 2021, https://bit.ly/3B6uwiX
25 FAO, Assessment of agricultural plastics and their sustainability – A call for action, 2021, Rome, https://doi.org/10.4060/cb7856en
26 Salvi BL and Jindal S, Recent developments and challenges ahead in carbon capture and sequestration technologies, *SN Appl. Sci.* **1,** 885, (2019). https://doi.org/10.1007/s42452-019-0909-2
27 Global CCS Institute, Technology Readiness and Costs of CCS, March 2021, https://bit.ly/35Y8d3t

BECCS. To deliver this, innovation is needed to improve technologies in general, with particular focus on the opportunity to use municipal waste in urban areas.[28] To do this would require effective mechanisms to prevent the release of toxic gases.

- **Long term energy storage**

  Pumped hydro energy storage comprises around 96% of global storage power capacity and 99% of global storage energy volume. It is suitable for both short- (minutes to hours) and long-term (several hours to weeks) storage.[29] Beyond pumped hydro, Li-ion batteries also provide short-term storage. These two approaches work well separately and in combination but robust life cycle analysis is always appropriate to consider.[30] Australia has significant resources for battery materials and expertise in alternative battery technologies and now there is increasing use of home batteries and utility-scale (100 MW). For example, the industry group QVC in Queensland is planning to build multi-purpose pilot facilities to produce vanadium for redox flow batteries.[31,32,33] This collective initiative has received funding from the Queensland Government.

- **Oil refining**

  Australia oil refining capacity has decreased, with just two east coast refineries still operational. However, a continued market for liquid hydrocarbon-based fuels past 2050 is likely. To support a move away from fossil reserves, refineries have the potential to upgrade other sources of hydrocarbons to fuel quality. These could be biobased or municipal waste feedstocks.[34] Process and technology changes are needed for this change[35] but so are the skills to design, deploy and operate these facilities. Existing skills bring significant expertise and can be adapted and developed to new applications.

- **Coal mining and processing**

  Coal mines are a significant source of global methane emissions, estimated at 1,200 Mt CO_2e in 2018.[36] While coal production will decrease in the near term as global demand wanes, methane

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[28] Peter Cook Centre for Carbon Capture and Storage Research, Negative Emission Technologies in Australia – report on 2019 roundtable discussions, Melbourne, 2020, https://bit.ly/3HyQJbR
[29] Blakers A *et al,* A review of pumped hydro energy storage, *Prog. Energy,* 2021, vol 3, 022003, https://doi.org/10.1088/2516-1083/abeb5b
[30] Tietze I et al, Life-cycle impacts of pumped hydropower storage and battery storage. Int J Energy Environ Eng, 8, 231–245 (2017). https://doi.org/10.1007/s40095-017-0237-5
[31] Skyllas-Kazacos M and McCann JF, Chapter 10 - Vanadium redox flow batteries (VRBs) for medium- and large-scale energy storage, in Advances in Batteries for Medium and Large-Scale Energy Storage: Types and Applications, Woodhead Publishing Series in Energy, 2015, pp329-386, https://doi.org/10.1016/B978-1-78242-013-2.00010-8
[32] Aramendia I et al, Vanadium Redox Flow Batteries: A Review Oriented to Fluid-Dynamic Optimization. Energies, 2021, 14, 176. https://doi.org/10.3390/en14010176
[33] Mining Technology, Multicom receives approval for Queensland vanadium mine, Sept 2021, https://bit.ly/3JgZ8Bj [accessed 01/02/2022]
[34] IEA Bioenergy, 'Drop-In' Biofuels: The key role that co-processing will play in its production, Jan 2019, https://bit.ly/3gtgazt
[35] Le Grange P et al, Impact of biofeed retrofits, coprocessing on refinery amine units, SWSs and SRUs – Part 1, Hydrocarbon Processing, Jan 2022, https://bit.ly/333sovE [accessed 02/02/2022]
[36] IEA, World Energy Outlook 2019, https://bit.ly/3LtAI9F

emissions from operating and closed mines will continue for decades.[37] Attention needs to be paid to these emissions separately to the reduction in output from the mines. There are existing technologies to reduce emissions but abatement is less cost-effective than equivalent activities in the oil and gas sector.[38] Ongoing monitoring of facilities is important to understand impact.[39]

While coal extraction and use continues, it is essential that process emissions are minimised. This can be achieved through improved process efficiency (e.g. reduction in direct transport emissions), application of CCS and other systems to remove other greenhouse gases such as nitrogen oxides.

What are the most promising emerging low emissions technologies and why? Do they meet the four filters identified in the Roadmap to elevate to a priority technology?

Promising emerging low emissions technologies could be central to producing additional 40% reduction not identified in LETS 2021

NOTE: please refer to comment in "Feedback on the Low Emissions Technology Statement 2021" section.

- **Biofuels** - as discussed in the Bioenergy Roadmap[40], biofuels have significant potential in Australia with a possible contribution by 2030 of 1,900 ML per annum of sustainable aviation fuel and 2,600 ML per annum of road transport biofuels.[40] Widely adopted internationally outside Australia with the International Energy Agency (IEA) reporting 163 billion litres per annum in 2019 (pre COVID). The IEA Net Zero by 2050 report states that the development of biomass chains will result in an increase in liquid biofuel production from 3.5 EJ per day in 2020 to 12.5 EJ per day by 2050.[41]

  Biofuels can support the LETS 2021 big technology challenges by expanding onshore manufacturing of energy intensive products utilising biomass that recycles CO_2 from within the atmosphere. By-products can also be used for the manufacture of high value products such as

[37] Kholod N et al, Global methane emissions from coal mining to continue growing even with declining coal production, J Cleaner Prod, 256, 120489, May 2020, https://doi.org/10.1016/j.jclepro.2020.120489
[38] IEA, World Energy Outlook 2021, Oct 2021, https://bit.ly/34puuXw
[39] Sadavarte P et al, Methane Emissions from Superemitting Coal Mines in Australia Quantified Using TROPOMI Satellite Observations, Environ. Sci. Technol., 2021, 55, 24, 16573–16580, https://doi.org/10.1021/acs.est.1c03976
[40] ARENA, Australia's Bioenergy Roadmap Report, Nov 2021, https://bit.ly/3oxAYu5
[41] IEA, Global biofuel production in 2019 and breakdown for 2020, Nov 2020, https://bit.ly/3gFWqca [accessed 02/02/2022]

biomaterials, bioplastics and biochemicals, and offer a unique option to provide immediate impacts on Australia's transport emissions compatible with existing transport infrastructure. In some areas such as aviation (sustainable aviation fuel) biofuels are recognised as the only viable option to achieve significant greenhouse gas reductions by 2050.

- **Electrolysis of CO_2 using renewable electricity –** this can be utilised to produce either ethylene or ethanol, both of which can be used to efficiently store in chemical form renewable energy.

- **Low-carbon downstream processing** – This includes downstream processing of iron ore to sponge iron by reducing with hydrogen within Australia (also provides an export pathway for hydrogen) and vertical integration of battery production rather than just exporting battery minerals.

- **Alternative energy storage technologies** – these have potential to assist the grid in achieving full decarbonisation via a combination of lithium-ion, pumped hydro, hydrogen, and novel (but proven) technologies such as redox flow batteries or thermal storage.

- **Plant-based chemicals** – given Australia's well established agricultural industry, it is in a premium position globally to produce plant-based chemicals.

- **Energy from Waste** – Australian currently produces 540 kg of household waste per person annually.[42] Energy from Waste, which comprises a range of technologies (including combustion and digestion) that convert waste that would otherwise go to landfill into energy sources such as electricity, heat and fuel, is a potential technology.[43]

a. Abatement potential. How big are the potential emissions reductions from this technology?

- **Biofuels** can produce immediate substantial GHG emission reductions with existing vehicles and transport infrastructure. For example, ethanol production from traditional crops such as sugarcane has the potential to reduce GHG emissions[44] but alternate crops such as agave which utilise semi-arid land not normally suitable for crops, are also an option.[45] Biofuels produced from waste biomass feedstocks reduce GHG emissions by 75-100%; and biofuels produced from municipal solid waste feedstocks can reduce GHG emissions by up to 593%.[40] The implementation of

[42] Clean Up Our Waste, Australia's waste challenges go far beyond one day, https://bit.ly/3LmbqKt [accessed 01/02/2022]
[43] Zero Waste Victoria, Submission 216, p. 12. Infrastructure Partnerships Australia, Putting Waste to Work: Developing a Role for Energy from Waste, June 2020, p3. https://bit.ly/3srHeoz [submission accessed from https://bit.ly/3ovHyRU 07/02/2022]
[44] Butterbach-Bahl K et al, Bioethanol production from sugarcane and emissions of greenhouse gases – known and unknowns, *GCB Bioenergy*, 3, 2011, 277-292, https://doi.org/10.1111/j.1757-1707.2011.01095.x
[45] Yan X et al, Life cycle energy and greenhouse gas analysis for agave-derived bioethanol, *Energy Environ. Sci.*, 2011,**4**, 3110-3121, https://doi.org/10.1039/C1EE01107C

carbon capture with these technologies could further reduce GHG emissions. They can also promote the circular economy by recycling waste biomass, plastics and municipal solid waste and reduce landfill utilisation.

- **Electrolysis of CO_2 using renewable electricity** has large abatement potential as ethylene is the feedstock for worldwide petrochemicals and ethanol can be used in a fuel cell vehicle system (or in a conventional engine) and CO_2 could be sourced from point sources or direct from the atmosphere.[46]

- **Alternative energy storage technologies** enable the transition to a zero-carbon power generation by storing variable renewable energy production and as such their abatement potential could be substantial. Further development of pumped hydro and battery storage in combination can support greater use of intermittent renewables (wind and solar).

b. Economic benefit. What are the potential economic benefits for Australia of deploying this technology at a large scale? Benefits include creating and preserving jobs, especially in regional areas.

- **Biofuels** - the Bioenergy Roadmap[40] states that bioenergy could create $10 billion per annum of investment and produce 26,200 potential additional jobs in Australia by 2030. Furthermore, significant bioenergy technology opportunity could develop and support a new long-term manufacturing industry in Australia.

  Internationally biofuels have a demonstrated record for creating economic benefits. For instance in the US, the largest biofuel producer in the world, there were 68,684 direct US jobs and 280,327 indirect US jobs associated with the ethanol industry in 2019, which created $23.3 billion in household income and contributed $43 billion to the US national GDP.[47] In Brazil the second largest global producer, biofuels support 832,000 jobs.

  In addition, utilising waste biomass for biofuel can play an important role in supporting farmers and the sustainable forestry industry to remain viable and achieve additional productivity and income from existing land and plantations.

- **Low-carbon downstream processing** - the development of low-carbon technologies to support oil refining, petrochemicals and low carbon fuels in Australia will create both additional employment and higher value products for export. In addition to CCS, fuel switching (e.g. to clean

[46] Sanchez DR et al., How sustainable is CO_2 conversion to ethanol? – A life cycle assessment of a new electrocatalytic carbon utilisation process, Sustainable Energy Fuels, 2021, 5, 5866, https://doi.org/10.1039/D1SE01462E
[47] Renewables 2020: Analysis and forecast to 2025. International Energy Agency, 2020 - https://www.iea.org/reports/renewables-2020

hydrogen) and electrification have been identified as opportunities for decarbonisation in refining.[48,49]

While not necessarily emerging technologies, additional economic benefits can be gained from more traditional industries by preserving and enlarging the **plastics industry**, providing new opportunities to the remaining **oil refineries**, continuing the **paint industry**, and utilising the **agricultural industry** to produce chemicals such as ethylene, methanol, and ethanol. However, it is important to identify where impacts will be hardest felt in these industries and measures put in place to mitigate the impact in a fair and manageable way.

- **Carbon credits:** Under the Paris Agreement there are structures where the development and application of low emissions technologies in Australia may provide the opportunity to generate additional credits that could be traded between Governments.[50]

c. Australia's comparative advantage. Does this technology play to Australia's strengths? Our strengths include abundant energy and mineral resources, skilled workers, strong institutions and trusted trading relationships with major energy consumers.

- **Biofuels** - Australia has a unique comparative advantage to develop a successful biofuels industry. There are plentiful waste biomass feedstocks, generating over 78 million tonnes per annum which is predicted to increase to 99 million tonnes per annum by 2030.[51] Furthermore, there are significant tracts of semi-arid land unsuitable for normal agriculture that could be used to grow crops requiring minimal irrigation or fertiliser such as agave[52].

  Australia exports 71% of its agricultural produce which is generated from only 4% of land area.[53] To complement this, Australia already exports feedstocks used for biofuels production overseas, with 90% of canola exports used for biodiesel production in Europe and tallow exported to Singapore for processing into renewable diesel for use in the US.[54] These feedstocks could be

[48] World Resources Institute, Technological Pathways for Decarbonizing Petroleum Refining, Oct 2021, https://bit.ly/3HNEbgU
[49] Yugo M, Transition towards Low Carbon fuels by 2050: Scenario analysis for the European refining sector, Concawe, Brussels, Aug 2021, https://bit.ly/3rH0bV4
[50] Di Leva CE and Vaughan S, The Paris Agreement's New Article 6 Rules | International Institute for Sustainable Development, IISD, Winnipeg, Canada, Dec 2021, https://bit.ly/3HOeb55 [accessed 11/02/2022]
[51] A spatial assessment of potential biomass for bioenergy in Australia in 2010 and possible expansion by 2030 and 2050, Crawford et al, CSIRO Energy Flagship – GCB Bioenergy (2016)8, 707–722, doi: 10.1111/gcbb.12295
[52] Agave: A promising feedstock for biofuels in the water-energy-food-environment (WEFE) nexus Xiaoyu Yan et al. 2020 – https://doi.org/10.1016/j.jclepro.2020.121283
[53] Department of Agriculture, Water and the Environment (ABARES), Commonwealth of Australia. Australia does not have a food security problem, Canberra, https://bit.ly/3GYHS2d [accessed 10/02/2022]
[54] Grains Research & Development Corporation, Fact Sheet European Canola Market: Understanding the European biofuel market for Australian canola, Mar 2018, Kingston, Australia, https://bit.ly/3uL5aWx

processed in Australia to generate investment, jobs and GHG benefits locally. Also, the development of more efficient biofuel processes would also give rise to a technology licence export market.

- **Alternative energy storage technologies** - old mine sites remain a good option for pumped hydro in lieu of natural elevation changes - such as deployed at the old Kidston mine site.[55] While lithium-ion battery does certainly have a place in grid support and short-term storage, other technologies may be more appropriate for long-term, high volume, multi-hour discharge storage options. In addition, high voltage DC should be deployed for long-distance transmission of renewable energy to transport it from where it is abundant to the country's population centres - and potentially internationally.

- **Plant-based chemicals** – at the point of export, these bio-derived products could have a negative CO_2 footprint. This involves CO_2 sequestration during the growth of the biomass, and use of renewable energy in production process.[56,57]

d. Where Government can make a difference. Will Government investment help develop and deploy this technology? This includes whether Government action will help accelerate cost reductions.

- **Biofuels**

  Australia is currently responsible for less than 0.2% of global biofuel production. The Government can play a critical role in terms of developing the industry and local demand. Through wider adoption of biofuels, economies of scale, consumer confidence, and acceptance of biofuels and renewable liquid fuels technologies in the marketplace could all be developed. Examples of Government support may include:

  - requirements for biofuels in Government supply contracts including Defence (which would also aid fuel security especially in aviation),
  - procurement of 100% biofuels compatible vehicles (such as prime movers, buses, and flex fuel vehicles), and
  - industry incentives to adopt biodiesel and renewable diesel in sectors such as mining where significant excise tax rebates for fossil fuel diesel currently exist.

  Biofuel technology and operations would create Australian jobs and improve fuel security, reducing the dependence on imports and providing export opportunities.

- **Emerging technologies**

[55] https://genexpower.com.au/250mw-kidston-pumped-storage-hydro-project/
[56] Boerjan W et al, Towards a carbon-negative sustainable bio-based economy, *Front. Plant Sci.*, June 2013, https://doi.org/10.3389/fpls.2013.00174
[57] Renewable Carbon News, *Carbon Trust Endorses Braskem's Carbon-Negative Claims for Bio-based Plastic,* Oct 2018, https://bit.ly/3BfGHdc [accessed 11/02/2022]

A critical barrier to progress is the transition from low Technology Readiness Levels (TRL) (e.g., 6 or lower) where technology is at the research and development state to TRL 7 where a technology is effectively demonstrated at pilot scale.[58]

Government can help accelerate its development by funding pilot scale and demonstration scale plants. Some regions have realised greater TRL progression in some areas due to Government support. It is important to learn from others while also considering the local needs. Assessment of appropriate support needs to consider the system as a whole and sustainability in terms of emissions reduction, contribution to an Australian circular economy, feedstocks and skills.

Examples of technologies with current low TRLs include the electrochemical reduction of CO_2 to ethylene (TRL 2-4) or other chemical feedstocks (TRL 2).[59]

Recent estimates of biofuel technology indicate that TRL progression is very slow; at an estimated 3-5 years per TRL.[60] However, there are some biofuel technologies at advanced TRLs (namely bioethanol from sugar and starch and biodiesel from lipids/oils) but the use of lignocellulose feedstocks for hydrocarbons is typically TRL 5-7 with only a small number of developments reaching TRL 8 so far.[61,62]

For CCS, there are a wide-range of capture, transport and storage technologies at different TRL levels.[63] There is an opportunity to evaluate the most suitable for the region and support TRL progression through the most appropriate support mechanisms. As the scale of carbon capture increases, the cost of capture declines considerably up to an optimal capacity of 0.4-0.45 Mtpa of CO_2. Assessments have also been conducted on the maturity of BECCS as well as different types of battery technology.[64,65]

There is an increasing focus on how to transition to a low carbon chemicals industry where feedstock and high value products can be realised. Assessments of different processes and

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[58] Technology Readiness Levels Definitions and Descriptions, https://bit.ly/3sAIDt4
[59] Lee JH et al, Early-stage evaluation of emerging CO_2 utilization technologies at low technology readiness levels, Green Chem., 2020,22, 3842-3859, https://doi.org/10.1039/C9GC04440J
[60] IRENA, Reaching Zero with Renewables: Bioject Fuels, 2021, https://bit.ly/3JfED81
[61] IEA Bioenergy, The Role of Renewable Transport Fuels in Decarbonizing Road Transport: Production Technology and Costs, Nov 2020, https://bit.ly/3oyY2J3
[62] ETIP Bioenergy, Current Status of Advanced Biofuels Demonstrations in Europe, March 2020, https://bit.ly/3J8ZmKy
[63] Global CCS Institute, Technology Readiness and Costs of CCS, 2021, https://bit.ly/35Y8d3t
[64] Ricardo Energy and Environment, Analysing the potential of bioenergy with carbon capture in the UK to 2050, Aug 2020, https://bit.ly/3Gz4OVr
[65] Napp T et al, A survey of key technological innovations for the low-carbon economy, Grantham Institute, https://bit.ly/3J7VIRa

products provide examples of development which can support decision-making based on the prime needs and greatest opportunities for Australia.[66]

What other enabling technologies will be integral to deployment of low emissions technologies in Australia, and why? What could Government do to support their uptake?

Other enabling technologies have already been mentioned above. There are however initiatives that Government could do to support their uptake.

Development of a uniform set of rules for carbon accounting, will allow Australian export industries to determine their carbon per unit of material produced. This is important as carbon accounting on the supply chain for Australian exports will be normalised within a short timeframe (less than 10 years) and LETS 2022 should assist this process.

To effectively apply these carbon accounting rules, inventory data is required. Significant effort was made to generate an Australian Life Cycle Assessment (LCA) database[67] in the first decade of the century, but it is not clear whether this has been maintained since. A central initiative such as Government support, would play an important role in ensuring this is re-invigorated, kept up-to-date and accessible. Through this type of approach, good practice in the robust application of LCA will become embedded in the consideration of current and future projects.

Funding and support for case studies such as the progression towards electrification-hydrogen by Government would also help with the potential deployment of other emerging technologies.

International Partnerships

Aside from our established partnerships, how would you like to see Australia working with other international partners on low emissions technologies?

Australia as a nation is in an excellent position to contribute to low emissions technologies on a global scale. To do this effectively international partnership are required. A key example would be to work collaboratively with export partners for methods of exporting renewable energy in the form of chemicals. This may require development of technology at both ends of the export/import cycle such as methods to export H_2 in the form of chemicals or within an iron sponge intermediate.

The development of a rigorous carbon declaration (based on robust LCA information) process with Government auditing would also be critical as it would allow the Australian Government to provide a

[66] Dechema, Low carbon energy and feedstock for the European chemical industry, June 2017, https://bit.ly/3HDPg3S
[67] The Australian Life Cycle Inventory Database Initiative, http://www.auslci.com.au/ [accessed 05/02/2022]

guarantee on the carbon attached to any given export product. Equally for transparency, there should be assessment of the carbon attached in products imported to Australia.

More broadly by identifying and collaborating with key international partners, Government can enable rapid technology transfer into markets both within Australia and internationally.

Feedback on the Low Emissions Technology Statement 2021 (LETS 2021)

What information would you like to see to demonstrate how progress towards the stretch goals is being made? Does the impact evaluation framework have any gaps?

As stated at the beginning of this submission, IChemE do not believe that LETS 2021 is at all suitable for presenting the actions to ensure that Australia meets its NDC commitment. Given this position, the comments below are made acknowledging that Government wishes to pursue LETS.

If predicted progress is to be realised, it is critical to establish milestones to measure progress on each priority technology such as the percentage of power generation from renewables and the overall impact on GHG emission reductions.

A key deficiency is that LETS 2021 predicts that emission reductions through priority technologies will achieve only half of the required additional 80% reductions required to achieve net zero by 2050 (i.e. 40%). There is no specific detail provided on how the remaining 40% reduction will be achieved.

On the human capital side, the number of persons trained/graduated in low emission technologies with targets are also important. This aspect of energy policy development can often be taken for-granted, or not properly considered in the transition to LET.

What were you expecting in LETS 2021 that wasn't there?

LETS is presented as the Federal Government's plan for delivering on the Net Zero commitment made to the UNFCCC in the lead up to the Glasgow COP. However, there is insufficient detail to demonstrate clear, urgent actions which will be delivered by 2030, 2040 and 2050 to ensure that Australia meets its nationally determined contribution commitment.

There is no single solution to achieve net zero. A variety of technologies are required alongside each other to achieve net zero GHG emissions by 2050. Considerations of technology solutions must take a holistic view. It is essential to not only consider full lifecycle analysis but also evaluate safety and environmental (besides global warming) performance of a technology and its implementation.

Production of H_2 is one method of using renewable energy and receives significant coverage in the LETS 2021, however CO_2 utilisation, bioenergy and biofuels receive little or no coverage.

CO_2 utilisation technology allows the recycling of carbon into conventional hydrocarbons with an established market. The products can play the same role as H_2 and have benefits over pure H_2 in some applications.

Carbon feedstocks, consumer products and fuels are and will likely remain an integral part of modern society. Biofuels are already one of the most prominent and demonstrated technologies for transport fuel emission reductions in the world. Biofuels and bioenergy have a role to play in this technology mix and play to Australia's strengths. Negative emissions via bioenergy with carbon capture and storage is mentioned as an emerging technology and would benefit from more consideration.

LETS 2021 mentions clean ammonia as the only derivative of green hydrogen. Green methanol produced from atmospheric CO_2 is equally a net-zero emission derivative of hydrogen. Green methanol projects are more actively being developed overseas especially in Europe, and demand already exists for green methanol. For instance, international shipping companies already operate methanol fuelled ships and have commissioned construction of large methanol fuelled ships as part of their commitment for emission reductions. Ammonia is not currently used as a fuel.

LETS 2021 made no mention of a carbon budget which will be important as it integrates the carbon emitted between now and 2050 to meet the 1.5 ^{o}C or 2 ^{o}C caps on warming. As LETS 2021 has no timeline for reductions, it misses the benefit of action sooner rather than later as reductions in 2022 will be captured for the next 28 years.

Technical readiness is not mentioned at all in LETS 2021. This is crucial as the time intervals required for laboratory, pilot scale, and industrial implementation as well as the related technical, economic, environmental, safety and social assessments are a vital aspect of technology development. Although Figure 4 shows the cost reductions for solar with the comparison with computing power, this is not a suitable analogy as it does not consider basic differences between the two systems. For example, a computer draws less power today than it did 40 years ago, whereas the power generated with photovoltaics is proportional to the increase in scale. In addition, technical readiness is important as technologies need be at scale in the next 10 to 15 years, not the several decades as shown indicated.

Stronger consideration could be given within LETS to the required skills for the transition, and the appropriate policies to support workforce skills development.

Was LETS 2021 presented in a way that made it easy to understand and access?

[No response]

Are there any other opportunities and or challenges to low emissions technology development and deployment that should be considered?

Location and geographical context are important considerations for low emissions technology development and deployment. For instance, parts of the countries such as Western Australia and north Queensland are prime locations to capture and store solar energy, which can then be used to electrolyse water and produce green hydrogen with ready access to ports for export and pipelines for domestic use.

Challenge will remain with hydrogen unless there is a practical solution for storage. While hydrogen storage (referred to as Deep Storage on p58 an enabling technology for many aspects of the LETS) will be examined further in the 2022 LETS, without a realistic approach to hydrogen storage, many aspects of the scheme may prove to be infeasible. These include the stretch targets on H_2 production, the zero-impact gas market, and the competitive advantages of Australia’s solar resource.

Other General comments

The LETS programme would benefit from more focus on a schedule-based plan including aspects such as emissions reduction mandates, research funding and collaboration initiatives, incentive schemes, and Government subsidies.

The magnitude and rate of delivery of benefits arising from the adoption of low emission technologies is highly dependent on having co-ordinated infrastructure and integrated value chains.

While Australia has excellent skills in mining and processing of mineral resources, the skilled workforce required for production of clean energy technologies using these metals and minerals is limited. As such there is an opportunity to ‘re-tool and re-train' parts of the existing workforce (e.g., working in the coal sector) to be equipped for the energy transition, for example through scholarships and industry partnerships.