



15 October 2024

Australian Government  
Productivity Commission  
4 National Circuit  
BARTON ACT 2600

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Dear Chair

### Opportunities in the circular economy submission

We are writing in response to the Productivity Commission’s consultation process inviting feedback in relation to establish opportunities in the circular economy.

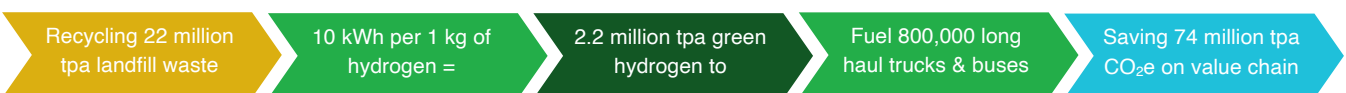
This response is provided in addition to separate responses we have previously provided to federal, state, and local governments built upon Xseed Solutions’ *Hydrogen for the Long Haul*® strategy developed to:

1. **Reduce** Australia’s carbon emissions by up to 12% through the 100% recycling of landfill waste as a valuable resource to accelerate the transition away from diesel fossil fuels. In so doing, being additive to and doubling the value to Australian communities from other recycling activities,
2. **Manufacture** Grade A+ hydrogen locally, a key Industry 4.0 product, with a circular economy focus to keep landfill waste at its highest value use for the longest possible time - optimising CO<sub>2</sub>e ecosystem reductions. Largely biogenic CO<sub>2</sub> and IMBYROCK are manufactured using HPAG facilitating additional localised high value agricultural and industrial business across Australia, and
3. **Enable** value chain ‘Hydrogen to X’ manufacturing business and employment opportunities across Australia to provide affordable Grade A+ hydrogen across Australia’s potential hydrogen highway.

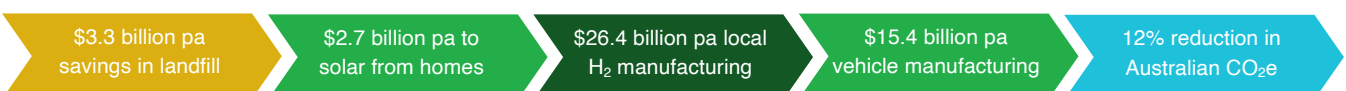
Xseed Solutions’ *Hydrogen for the Long Haul*® strategy is framed in an objective, scientific way to enable all consumer, business, and government stakeholders to action today many of the Federal Government policy agendas and targets. Framed as a major circular economy initiative whereby ‘residual waste’ is capable to be manufactured as products that are used accelerate the decarbonisation of multiple ‘hard to abate’ sectors.

As represented below, the Xseed Solutions’ strategy is to enable a \$49+ billion per annum domestic Waste to Hydrogen to X circular economy creating an extra 14,000+ Grade A+ hydrogen manufacturing jobs, plus further value chain roles. Delivering up to a 12% reduction in Australia’s CO<sub>2</sub>e emissions across multiple initiatives in the hard to abate sectors of waste, road transport, agriculture, manufacturing, and healthcare.

### Circular Economy



### Waste to Hydrogen to X



## A Significantly Beneficial Circular Economy Opportunity

Much has been written recently about the high energy requirements, significant distribution and transport costs, and water stressors that manufacturing electrolysis from hydrogen causes. Utilising a residual 'waste' feedstock readily available across Australia, that is capable to be manufactured into Industry 4.0 local products, used locally, create local jobs, remove frictions and inefficiencies in disposing of waste (to landfill) and in the demand to upgrade energy transmission lines. Importantly a circular economy initiative that improves Australia's energy security whilst creating economic prosperity. A domestically focused strategy that if actioned now materially reduces Australia's greenhouse gas emissions within the next ten years.

**Waste to Hydrogen (W2H)** technologies like **Hydrogen capable Plasma Assisted Gasification (HPAG)** enables the local recycling and manufacturing of landfill waste into ultra-low CO<sub>2</sub> intensive Grade A+ 'green' hydrogen, largely biogenic CO<sub>2</sub> and an inert, solidified rocklike material. A **Zero Waste** outcome, requiring little water and one-sixth of the energy requirements as compared to diverting precious water to produce electrolysis hydrogen. HPAG is deployable in communities with over 40,000 people, additive to recycling programs, creating local jobs, and localised hydrogen production application to a range of zero emission low carbon uses.

**In response to Information Request 1**, this strategy outline provides Australia one of the greatest and most significant circular economy initiatives. Whether it is HPAG or one of a dozen other W2H technologies being rolled out globally, we envisage the products manufactured builds a foundation primarily towards diesel substitutes for commercial and business vehicles, i.e. light commercial vehicles, trucks, buses, etc that is then capable to be built upon and extended for Sustainable Aviation Fuel (SAF), methanol, and other bio friendly plastics, agricultural and industrial manufacturing uses.

With Australia currently generating 22 million tpa of landfill waste into over 1,200 dispersed landfills, we have identified the tangible opportunity to develop today a platform to enable over 14,000 new jobs across all Australian urban, regional and First Nations communities. HPAG fully captures CO<sub>2</sub> it manufactures, as do many other W2H technologies. This provides a significant future facing technology advantage over traditional 'burning waste' incineration technologies that are effectively uneconomic internationally when you incorporate the CO<sub>2</sub> emissions, or technologies to capture those CO<sub>2</sub> emissions.

W2H technologies seeking to align with other recycling initiatives and enable circular economy outcomes encounter considerable misalignment and inconsistency across state and federal governments regarding current policy disharmony. Recycling 'waste' as a useful, recyclable resource requires aligned strategies and platforms that deliver meaningful action and progression into 2030 net zero targets. It requires local, state and federal government alignment, support and approvals that spans multiple government policies, including without limitation:

- Waste management,
- Plastics design and recycling,
- Hydrogen,
- Energy,
- Manufacturing in Australia,
- Jobs,
- Transport,
- Energy security,
- Climate,
- Biodiversity, and
- Circular economy.

**In response to Information Request 2**, these various strategies would materially benefit from an aligned, coordinated, harmonised and actionable policy suite that can deliver significant, nation-wide, beneficial impacts.

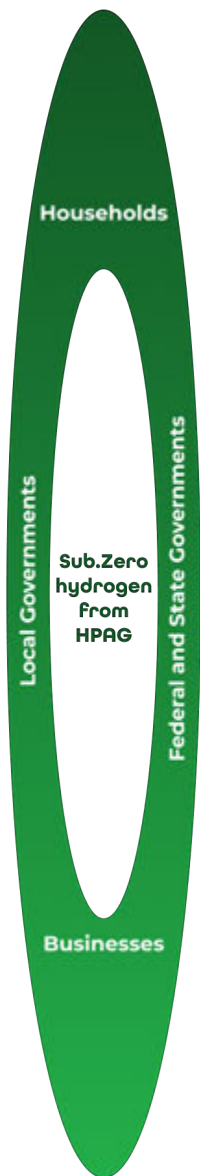
However, complexity is compounded when the following is considered when considering the end to end outcomes:

- Local governments control the decision making with respect to end use of 50% of the waste resources, each local government with different funding priorities and strategies,
- Local governments operate within frameworks established at state and federal level and look to one another for useful precedents. Whilst there is inconsistency in policy and legislation, the potential pace of change does not accommodate meaningful circular economy or climate transition pathways,
- State government policies, thresholds and authorisations differ distinctively across the policies outlined above, and
- Federally, this a domestically focused strategy operating as an enabler for both material decarbonisation (up to 12% GHG emission reductions) and manufacturing jobs (targeting a \$49 billion economic stimulus) across the nation.

Xseed Solutions is a market participant with an articulated strategy and ambition to assist local councils, residents and businesses achieve 100% landfill waste diversion, recycling landfill as an end of waste product that materially decarbonise Australian emissions. Stimulating investment in waste recycling re-energises regional and urban communities with new energy and industrial opportunities and in parallel engages significant regional contribution towards a national, climate positive hydrogen highway, consistent with circular economy.

We are delivering our strategy through a **Waste to Hydrogen to X (W2X)** eco-system with our recommendations based on the interactions and work with multiple stakeholders across numerous sectors.

We have provided eleven specific 'circular economy enabling' recommendations as summarised below and detailed further in Appendix A that we commend to the Productivity Commission to action as part of this consultation process. Eleven recommendations of a pathway to target a 12% reduction in Australia's greenhouse gas (GHG) emissions are summarised in the following diagram highlighting our specific recommendations, translating to tangible actions into economic, environmental and employment outcomes.





Our specific recommendations for the Productivity Commission, and Australian governments at all levels, to action include:

1. **Streamline policies and approvals** - Prioritise and streamline approvals processes for circular economy initiatives, including Waste to Hydrogen to X (W2X), across and within the three levels of government and the multiple government departments and the strategies involved (i.e. climate, hydrogen, waste, transport, energy, circular economy, regional planning, biodiversity, manufacturing).
2. **Climate Positive local council program** – Provide a funding framework for Sustainability Precincts that provide the opportunity for local councils to use current W2H technology to fully divert waste from landfill and generate economically sustainable products that enable self-production of stationary power and mobility fuel requirements, and in parallel, promoting scope 3 value chain reductions. Surplus hydrogen / derivatives can be sold to third parties, whereby surplus returns from the Sustainability Precincts are reinvested into local services and infrastructure.
3. **Stimulate a broader domestic Waste to Hydrogen to X sector** - Enable a broader domestic based climate positive hydrogen manufacturing strategy that accelerates benefits beyond encouraging export orientated electrolytic hydrogen being produced. Water is precious and a more efficient land use for solar and wind to manufacture hydrogen is encouraged, aimed at preserving Australia's biodiversity.
4. **Waste to Hydrogen doubles the value of recycled resources** – A domestic Waste to Hydrogen market could save \$3.3 billion in landfill management costs (i.e. \$150 per ton), creating a \$26.4 billion domestic hydrogen market, enhancing domestic energy security, and diverting the importation of diesel retailing at \$23.8 billion.
5. **Incentivise subzero carbon hydrogen domestic offtake** - Provide a tiered, \$2 per kg of hydrogen maximum subsidy to domestic purchasers of hydrogen and fast charge power where the energy origin has a “well to gate” carbon intensity less than 2.0 kg CO<sub>2</sub>e per kg hydrogen equivalent. This initiative should accompany a phasing out of the diesel fuel rebate.
6. **Business vehicle investment allowance** – To stimulate the W2X eco-system, provide a 50% investment allowance to 2030 to business purchasers of zero emission trucks and buses, phasing down by 10% every 2 years thereafter. These vehicles will range from heavy, medium, and light waste collection vehicles, public bus transport, general freight transport, government vehicle fleets and those vehicles used by suppliers to governments.
7. **Agriculture decarbonisation** – To 2030, expand the primary production immediate tax deduction regime to include low carbon intensive stationary energy renewable power solutions for solar, wind, geo-thermal, hydrogen, methanol, etc. A renewable energy eco-system sourced from waste enabling the partial decarbonisation of Australia's important agricultural products and stimulating new ones.
8. **CER to finalise waste and hydrogen ACCU rules** - The Clean Energy Regulator (CER) to urgently finalise and publish the regulations and requirements with respect to ACCU entitlements from the proposed 2021 Emission Reduction Fund (ERF) methods, together with those applicable to all aspects of the waste management, waste to hydrogen and hydrogen to X sectors.
9. **Modernise and harmonise Waste Hierarchy(ies)** – Modernise and harmonise the multiple Australian waste hierarchy frameworks to objective, quantified, CO<sub>2</sub>e intensity abatement outcomes, prioritising highest value, and scientific based environmental considerations.
10. **Rethink Zero.** – Encourage local Climate-Positive councils in establishing W2H facilities with community distributed networks with residents to enable the purchase of their excess household solar power at a higher return, including providing: rebates or discounts for zero waste local food businesses; W2H powered public transport; and local businesses encouraged to purchase W2H power or hydrogen for their own use stationary micro-grids or vehicle uses.
11. **Methanol efficient, energy carrier with flexible device solutions** – Extend the W2X eco-system to incorporate methanol as an efficient hydrogen carrier, whereby multiple technologies are available to

address consumer needs across a range of Zero Emission Vehicles, across regional Australia, and the agricultural sector from homestead stationary power through to long haul vehicle transport.

In respect of the international W2X opportunities, we provide the following summary comments that:

- **Size and commercial viability** – On average HPAG hydrogen is manufactured and capable to be available at affordably low LCOH and can be sold at a retail price equivalent to diesel, on an energy equivalent basis. By that we mean, given on average 5.4 lt of diesel per kg of hydrogen, HPAG hydrogen retailing at \$11 to \$12 per kg hydrogen is like \$2 to \$2.20 per lt diesel. Creating the demand and affordability, through maximising local manufacturing of hydrogen equipment and higher production volumes of hydrogen use technologies, like trucks and buses is forecast to drive down the long term cost of zero emission vehicles, like we have experienced over the years with solar PV.
- **Maturity** – HPAG is proven technology and can be combined with commercially available technologies to deliver localised Sustainability Precincts, as we are seeing overseas. Accordingly, the strategy and technology maturity are high. Market participants we engage with awaiting clear government direction at all levels and targeted financial support.
- **Relevance to government priorities** – We have outlined 11 key government policies, each of which are articulated as being priorities that this strategy aligns with.
- **Local benefits** – The strategy provides significant local benefits as outlined below potentially enabling in \$49+ billion economic benefits, 12% reductions in GHG and 14,000 new economy jobs. Many of which are local to the communities involved, given the distributed foundations of the network and strategy.
- **Current and future market or supply gaps** – As outlined, Australia has 22 million tpa of landfill waste capable to be manufactured to produce 2.2 million tpa hydrogen, sufficient to refuel and recharge 80% of the business vehicles in use today.
- **Type of support** – We have outlined 11 specific recommendations to provide the support framework to advance this strategy.
- **Defining criteria** – Should be defined by reference to harmonised and unified government policy at all levels. We have provided several recommendations on harmonisation and threshold criteria to consider.

**In response to Information Request 3**, the hurdles and barriers to a circular economy are four-fold:

1. **Enable more ‘green pathways’ and less ‘red tape’** (Recommendations 1, 3, 8, and 9) specifically the alignment of the multiple strategies and government departments with respect to interrelated circular economy initiatives into a streamlined approval process. As noted above there are at least 11 overlapping, often competing, and many times contradictory government policies in place across the three tiers of government.
2. **Together with foundational funding support** (Recommendation 2) to enable local governments to advance and stimulate decision making for Sustainability Precincts (Recommendations 4 and 10) developments.
3. **Stimulate end markets** Our Recommendations 5, 6 and 7 are focused on creating and stimulating demand for locally produced hydrogen, and hydrogen derivatives, into business vehicles to action ‘Australia’s Hydrogen Highway’.
4. **Keep the goal simple yet clear.** Article 6 of the EU Alternative Fuels Infrastructure Regulation (AFIR) as part of the EU TEN-T program is a tangible overseas example which can be adopted in progressing a clear strategy for Australia. For example, the Federal Government mandating:

*The construction of one multi-purpose Fast Charge and gaseous Hydrogen Refuelling Station (FC-HRS) every 250 km on the Australian core road network by the end of 2030, as well as one FC-HRS in every urban node. The stations will have a daily supply capacity of two tons of Grade A hydrogen with a carbon intensity below 0.4 kg CO<sub>2e</sub> / kg hydrogen for all modes of road transport.*

*The Federal Government will provide:*

- For local councils, 34% of the funding support for Sustainability Precincts recycling landfill municipal solid waste and manufacturing the hydrogen for the FC-HRS by way of equity (10%) and debt funding (50%, co-funded by State Governments), and*
- For businesses, (i) hydrogen subsidies to phase out the diesel fuel rebate for on-road vehicle use, (ii) business investment allowances for zero emission vehicle purchases, and (iii) extending the primary production immediate tax deduction for renewables investments.*

For context, 'urban nodes' refers to areas where different components of the transport infrastructures of the TEN-T, such as ports, passenger terminals, airports, railways stations, bus terminals and logistic platforms, are interconnected with each other. Equally relevant to Australia.

When one considers that on the Australian east coast there is around 12,000 km of core road networks, this mandates around 50 FC-HRS stations by 2030, plus additional FC-HRS stations at ports, passenger terminals, airports, railways stations, bus terminals and logistic platforms capable to be supported under a 'hub and spoke' model from 30 to 40 Sustainability Precincts. We have previously provided to the Federal Government a suggested matrix of targeted W2H production and FC-HRS towns, sites and facilities that would align with this recommendation.

**In response to Information Request 4**, we encourage the development of all ultra-low and low CO<sub>2e</sub> intensive hydrogen technologies, including hydrogen from electrolysis, that are assessed to be environmentally and economically sound and which consider optimised utilisation of resources to maximised, sustainable, community benefit. Such solutions naturally require broad community consultation to achieve the social license to operate.

Electrolysis projects need to be extremely large to be economic, with large upfront capital expenditures and considerable, long-dated offtake contracts to ensure financial viability. Very similar to the project characteristics of the outdated waste burning, i.e. combustion incineration industry. All these factors contribute to a high Levelized Cost Of Hydrogen (LCOH) for electrolysis hydrogen, currently estimated at over \$6.50 per kg of green hydrogen, or energy inefficient waste incinerators that rarely achieve carbon eco-system reduction outcomes below 2 t CO<sub>2e</sub> of abatement per ton of waste combusted.

We estimate a lower LCOH of HPAG produced hydrogen, with today's project challenge to encourage a more distributed network of offtake parties to transition to hydrogen or battery electric vehicles or energy uses across multiple sectors. We encourage a multifaceted strategy that extends its reach to domestic offtake parties to offset the associated transition costs. Aligned and targeted so as achieve many of the many governments' stated waste, hydrogen, and net zero objectives and to solve governments' strategies with respect to waste management, circular economy, biodiversity protection, and decarbonising hard to abate sectors like long haul and regional transport, agriculture, shipping, and construction.

The nature of constrained water resources and the contested nature of many high-water impact energy developments is a critical consideration for future energy projects. HPAG technology recycling waste to manufacture hydrogen, plus the related hydrogen and methanol pathways can play a critical role in the development of a domestic hydrogen industry in regional locations where water resources are scarce or already heavily utilised. This avoids the need of introducing another water stressor into regional communities, many who have been heavily impacted by drought in recent years.

For these reasons, 'transformational projects' can alternatively involve multiple, smaller initiatives, inter-linking and extending over multiple sites to deliver an integrated, combined network of major capacity. A

distributed network of Sustainability Precincts and FC-HRS overcomes the major constraints attributable with the higher additional costs of transporting hydrogen from production to refuel/use.

## **Governments' role in the circular economy**

We consider HPAG and Sustainability Precincts provides an ideal balance to urban contexts and to stimulate regional economies, enable advanced manufacturing and lower emissions across Australia's hard to abate sectors of waste, transport, agriculture, and healthcare, in a water sensitive biodiversity friendly manner.

We believe a fuller consideration of the incentives required to promote the downstream transition of Australia's bus, truck, and large vehicle fleets from diesel to hydrogen could provide greater economic and environmental benefits than purely subsidizing or developing a potential export market, or small, narrowly focussed trials.

We estimate at a high level, that a comprehensive roll-out in Australia of HPAG technology eco-systems could provide at least \$49 billion per annum in direct and indirect annual economic benefits. Investment costs are less than 50% of that envisaged to develop a similar sized export electrolytic hydrogen market.

A Waste to Hydrogen to X eco-system accelerates the path to both zero waste and net zero with higher carbon abatement outcomes for diverting waste from landfill. The bonuses being:

- **100% resource recycling** - action now on Federal Government Waste Plan Targets 3, 4 and 6 with plans to environmentally address landfill waste management;
- **Value enhancing** - turning waste into a resource, lowering of the cost of waste management and ratepayers waste costs;
- **Creates jobs** – enabling a broader Waste to Hydrogen to X economy creates at least 14,000 new direct jobs in manufacturing and recycling (away from landfill management). More importantly value chain employment is created in the broader manufacturing, road transport, hydrogen, energy, and agricultural sectors both in urban centres and across regional Australia; and
- **Action real zero outcomes** - actioning now tangible progress of up to a 12% reduction in Australia's annual carbon emissions. The equivalent Australian carbon emissions savings from an export oriented green hydrogen market, does nothing to address landfill waste, is estimated at around 1%.

We look forward to the opportunity to discuss the positive economic and environmental benefits arising from the use of HPAG, Sustainability Precincts, and other Waste to Hydrogen to X production technology further.

If you have any questions or require any additional details, please do not hesitate to contact Craig Allen

Kind regards

Craig Allen  
Director – Xseed Solutions



## Appendix A – Detailed Recommendation Considerations

### 1. Streamline policies and approvals

At present, we experience the lack of clarity of the rules and regulations and lack of a cohesive legislative framework across, within, and between governments that affect the waste to hydrogen sector. This arises as the W2X technology crosses hydrogen, waste, energy, transport, circular economy, carbon emissions and biodiversity strategies. This is limiting major investment and uptake opportunities. Often there are multiple siloed policies in place, sometimes conflicting, and often limited in detailed actions unsupported by legislation, the science itself, and confused with a variety of outdated waste hierarchy interpretations.

Overcoming the legislative hurdles, the W2X market will undoubtedly require stimulus, particularly in regional Australia. The flow on benefits though is considered worth the investment.

Current technology enables both the battery electric and hydrogen transport infrastructure and equipment supply aspects in these sectors to grow and develop at a rapid pace over the next 5 years. Both sectors are significant carbon emitters, but require government alignment and clarity around:

- Landfill management diversion technologies and the distinction between outdated and inefficient incineration technologies to more recent gasification, pyrolysis and/or vitrification technologies;
- Harmonisation with international trucking specifications and standards to avoid the need to develop a specific Australian trucking solution; and
- Greater recognition of the need for funding and stimulus of public electric and hydrogen public and private charging infrastructure.

This is compounded with investor uncertainty with respect to:

- legislation related to all aspects of “when is waste not waste”, hydrogen production, carbon credit generation, carbon reporting, health and safety, and tax;
- the transition process to hydrogen and technology transition;
- local innovations, adopting overseas innovation, and impacts on technology selection; and
- offtake / distribution and offtake pricing structures.

All this combined provides limitation and uncertainty with respect to proceeding with projects and technology innovation and imposes considerable focus on risk sharing and mitigation in offtake agreements.

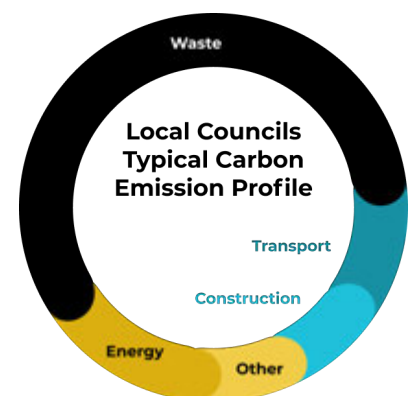
Simulation modelling on circular economic benefits assessed regionally and sector-wise may benefit an understanding of locally available solutions for waste diversion and hydrogen uptake opportunities.

### 2. Climate Positive local council program

In Australia, a majority of typical local council emissions are attributable to the landfill waste within its own region. Local councils are also often large consumers of energy, transport fuels, and construction materials. W2X facilities, or Sustainability Precincts, provide the opportunity for local councils to use current technology to fully divert its waste from landfill and self-supply all its stationary power and mobility fuel requirements, including promoting scope 3 value chain reductions. Surplus hydrogen can be sold to third parties and surplus returns from the Sustainability Precincts then reinvested into local services and infrastructure.

Strict probity rules and local council reluctance to invest in new infrastructure beyond traditional landfill management inhibits all councils, particularly regional councils from progressing this style of Zero Waste, Net Zero initiative.

Australian local councils are also currently confronted with significant climate related transition risks and potential funding shortfalls associated with significant future landfill rehabilitation costs that will impact the



cost of living for all Australians. As an example, one South East Queensland local regional council has a \$92 million landfill rehabilitation cost to fund before 2039, representing a future household cost of \$83 per year for 15 years, a tripling of current waste levies for those residents. All local councils should be taking steps now to transition away from landfill, securing pathways to fund and co-own infrastructure like waste to hydrogen that provides councils with a circular economy revenue stream to assist councils, households, and businesses alike in funding these future significant obligations.

Frameworks exist with the National Reconstruction Fund, ARENA, and other grant funding opportunities. Leverage these frameworks together with CEFC to initiate a specific Sustainability Precinct circular economy funding program for household Municipal Solid Waste (MSW) streams achieving (1) zero waste to landfill outcomes and (2) eco-system carbon intensity outcomes below a threshold, e.g. say 0.4 t CO<sub>2e</sub> per ton of landfill waste “well to wheel” whereby:

1. Local councils operate the Sustainability Precincts to encourage local employment and higher than 80% MSW landfill diversions by 2030;
2. Local councils agree to purchase sufficient Sustainability Precinct product offtakes to enable them to achieve net zero from a baseline that is inclusive of a council’s C&I and regional MSW streams;
3. CEFC provides or leads a Sustainability Precinct a 10-year loan to fund 60% of the capital cost;
4. For the remaining 40% equity requirement:
  - a. The Federal government (i.e. through NRF or ARENA) subscribes for a minimum 10% equity investment in the Precinct;
  - b. Local council equity investments up to 20% equity are matched equally by Federal and State equity funds (i.e. funding 60% of the project equity); and
  - c. Local councils are given first preference to top up its equity investment with the remaining 30%, otherwise it is offered to private investors.

In this way, local councils can choose to take a 50% equity interest in a Precinct that funds up to 20% of the total Precinct costs, achieves Climate Positive outcomes, promotes local employment, provides funds for required landfill rehabilitation, and stimulates regional value chain businesses and decarbonisation. Federal and State governments achieve multiple goal outcomes, including reduced CO<sub>2e</sub> emissions, zero waste, a localised, distributed network of carbon negative hydrogen and fast charge power for transport, localised employment, micro-grids for First Nation and regional communities, and blended equity and debt returns. NRF and/or ARENA anchor a 10% equity Precinct investment, and following government participation decisions, private market equity investors can participate anywhere from 0% to 87%.

### 3. Stimulate a broader domestic Waste to Hydrogen to X market

The purposes of government programs should be to support domestic decarbonisation and produce renewable hydrogen at scale in Australia to accelerate the development of Australia’s hydrogen industry, it is not appropriate to limit eligibility of programs purely to hydrogen electrolysis production projects.

The central target to consider adopting for all waste hierarchy and circular economy solutions is a \$ per CO<sub>2e</sub> emission intensity target, both “well to gate” and “well to point”. For hydrogen, it needs to be aligned with the International Energy Agency’s recent policy framework outlined in *“Towards hydrogen definitions based on their carbon intensity”*. The benefits of many technologies and hydrogen production and distribution systems are limited by energy and hydrogen losses associated with transporting the hydrogen from production to use. For waste, the issues of transporting waste long distances create similar leakages.

Some regulatory mandates that should be considered by the government include:

- **Sovereign risk factors** – China produces over 80% of the world’s solar and wind energy technology, and Australia imports over 83% of its crude oil. Domestic hydrogen manufacturing with a stimulated stationary and mobility energy market reduces that dependence materially;

- **Speed to market** – the best available technology today providing the lowest carbon impact, highest diversion from landfill outcomes and lowest specific energy/water/land resource impact per kg hydrogen or CO<sub>2e</sub> abatement per ton of waste;
- **Transport domain** – a methanol-based transportation and distribution infrastructure is vastly more cost effective and at a lower cost than a hydrogen-based transport infrastructure for the Australian context; and
- **Transport technologies** – we should invest effort to understand non-gaseous/non-liquid forms of hydrogen transport – a combination of regional/nodal designs that produce and consume energy locally, coupled with technologies that allow rapid transfer and transformation of hydrogen (metal hydrides, pipelines where practical etc).

Support should also address other equally important waste to hydrogen constraints limiting transformation. With the power industry, governments only need to address power production as the distribution system and the end user equipment/demand doesn't change significantly. To replace oil derived liquid fuels, one needs to address each of production, distribution, and end user take-up. For example, hydrogen is the logical replacement for fossil fuel derived fuels in long distance and heavy haul transportation and a large part of stationary power. This won't occur unless the Government addresses hydrogen and methanol distribution across all major long distance transport routes.

Based on today's technology a comprehensive hydrogen distribution system could be achieved today with around 80 hydrogen refuelling sites across Australia at a total refuelling cost of less than \$300 million. Most Precinct sites we have modelled are within 2 kms of a major transport route, and 1 km of existing diesel refuelling stations. This would enable a decarbonisation of over 5% of Australia's carbon emissions from 800,000 long haul vehicles. This outcome is significantly improved if the hydrogen manufactured into this distribution network is from waste that would otherwise go to landfill.

Carrier hydrogen is available for this stated purpose, with the need for projects not to be restricted by reference to a single physical location site. Only once a comprehensive distribution system is in place Australia has the foundations to change the heavy haul and long-distance transport and stationary power dependency upon fossil fuel derived fuels.

#### 4. Waste to Hydrogen doubles the value of recycled resources.

South Australian local governments lead Australia in the reporting and analysis of its waste recycling market. For 2020-2021 it reported that the value created from all recycled waste was \$477 million. At the same time, 360,700 ton of waste was being disposed to landfill annually. That 360,700 ton of landfill waste contains 36,070 ton of Grade A+ hydrogen, with an estimated minimum retail market value of \$440 million, together with other product and service revenue streams.

Extrapolating those study findings, more progressive W2H recycling ambitions across all councils would transform a \$3.3 billion waste landfill management cost to a W2X market realising a market potential of over \$26.4 billion (at a hydrogen retail price of \$12.00 per kg (see below)). Manufacturing 2.2 million tpa of hydrogen, from the 22 million tpa of landfill waste, creates a vibrant domestic hydrogen from waste market that enables other hydrogen to X businesses to flourish.

Using the Waste Plan metrics of 6.4 more jobs created from every 10,000 tpa of resource recovery, this creates new direct employment for more the 14,000 people. Importantly, these roles are across regional and urban Australia. In addition to enhancing Australia's energy security transitioning from 12 billion litres of imported diesel, it

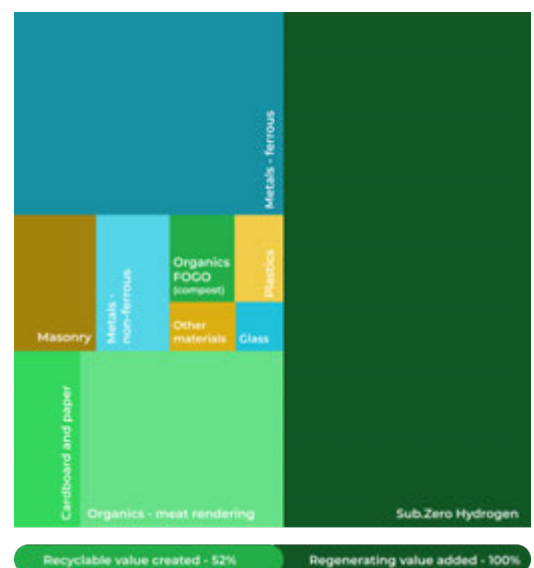


Figure 2: SA estimated market value of resource recovered material in SA during 2020-21

is estimated that significant more indirect energy, hydrogen, and manufacturing jobs would be created to enhance the supply chain that this stimulates.

An illustrative \$12.00 per kg retail hydrogen price (GST inclusive) is based at the lower end of the range of \$10.80 to \$26.00 per kg based on two perspectives:

1. Electrolysis green hydrogen currently retails in Europe, California, and South Korea at between €10 to €15.75 per kg (that is, A\$16.50 to \$26.00 per kg of hydrogen - refer [www.h2.live](http://www.h2.live)). These are prices after the application of EU hydrogen subsidies which we understand equate to around A\$5.00 per kg; and
2. On average in road transport vehicles, 5.4 liters of diesel are substitutable with 1 kg of hydrogen. With average diesel prices at around \$2.00 per litre, this equates to \$10.80 per litre on a diesel parity basis.

### **5. Incentivise subzero hydrogen domestic offtake**

The *Australia Institute* reports that Federal and State Governments provide \$11.1 billion in fossil fuel subsidies.

HPAG waste to hydrogen is estimated to have a well to gate carbon intensity of negative 12.7 kg CO<sub>2e</sub> per kg hydrogen. To incentivise domestic demand for low carbon intensive hydrogen, particularly hydrogen that is manufactured from waste, we recommend the Federal Waste Plan provides a tiered \$2.00 per kg hydrogen subsidy to domestic purchasers of hydrogen and fast charge power where the energy origin has a “well to gate” carbon intensity less than 2.0 kg CO<sub>2e</sub> per kg hydrogen equivalent. This initiative should accompany a phasing out of the diesel fuel rebate.

Hydrogen with a carbon intensity that is better than negative 10 kg CO<sub>2e</sub> per kg hydrogen would be entitled to the full \$2.00 per kg subsidy, the \$ per kg subsidy reducing by \$0.167 for each one kg CO<sub>2e</sub> per kg hydrogen increase in carbon intensity, reducing to \$nil per kg when the carbon intensity is above 2 kg CO<sub>2e</sub> per kg hydrogen equivalent.

This is accompanied with a phasing out of the diesel fuel rebate to target a cost neutral outcome. 100% of Australia’s household and business waste being used to manufacture 2.2 billion kg of Grade A hydrogen, this would have an expenditure impact of up to \$4.4 billion annually, well below the current diesel fuel rebate.

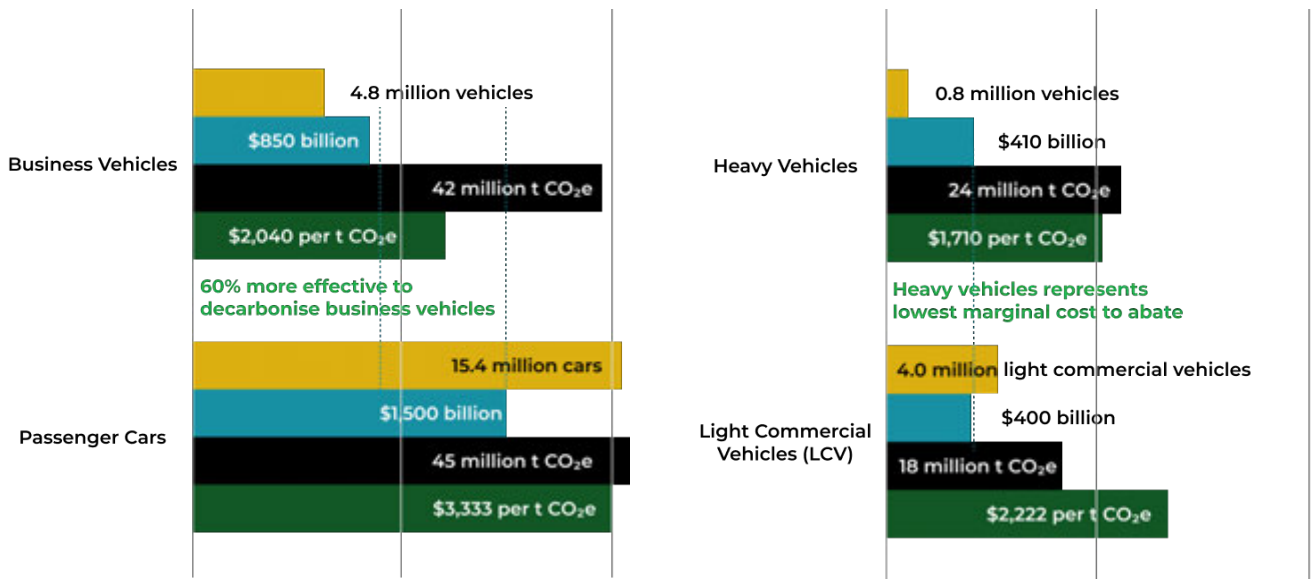
### **6. Business vehicle investment allowance**

Australia has 800,000 heavy vehicles that contribute 24 million tpa CO<sub>2e</sub>, around 5.2% of Australia’s total CO<sub>2e</sub> emissions. Around 50,000 new trucks and buses are sold in Australia each year with the majority of truck and bus vehicles manufactured locally utilising up to 60% Australian owned resources in the supply chain. An Australian market currently estimated to be worth \$12 billion annually.

Higher volumes and technology advances are anticipated to reduce the average zero emission vehicle cost over the next 3 to 6 years, with the average zero emission heavy vehicle cost still anticipated to be twice the cost of the diesel powertrain vehicle it is being transitioned from.

The introduction of higher fuel efficiency standards for heavy vehicles will stimulate new supply of heavy vehicles. On the basis, of a phase down to 2030, and 60% of the new vehicles production manufacturing remaining in Australia this represents a potential economic uplift of \$15.4 billion per annum in terms of higher zero emission vehicle production sales and greater Australian value content. This equates up to \$92.2 billion in economic contributions to 2030.

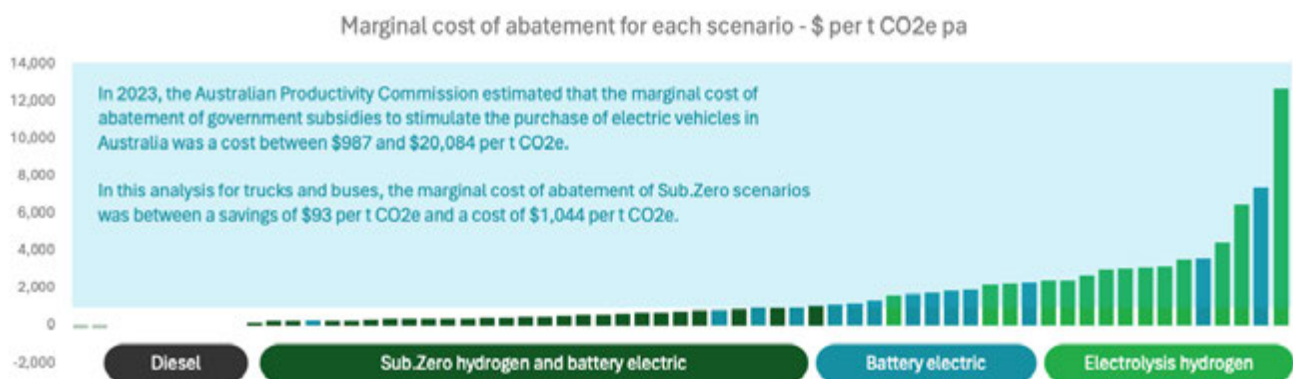
Hydrogen to X infrastructure is confronted with the challenges of establishing extensive hydrogen supply and refuelling infrastructure to encourage the transition to zero emission vehicles. HPAG and a distributed network of hydrogen production and refuelling capacity is ideally structured to provide that supply, to create the demand drivers for new vehicle production.



To assist vehicle owners in the cost of vehicle transition, that has the enhanced benefit of stimulating waste from landfill into hydrogen production it is recommended that a 50% investment allowance be provided to 2030 to business purchasers of zero emission trucks and buses, phasing down by 10% every 2 years thereafter. To 2030, it is estimated that this will reduce life cycle cumulative carbon emissions by 448 million t CO<sub>2</sub>e and cost \$72 billion, representing a marginal cost of abatement of \$160 per t CO<sub>2</sub>e – well below current subsidies and incentives provided to the passenger electric vehicle market.

As background, the Productivity Commission reported that it estimated that the marginal cost of abatement of government subsidies to stimulate the purchase of electric passenger vehicles in Australia was a cost between \$987 and \$20,084 per t CO<sub>2</sub>e. This does not stimulate the manufacture of electric cars in Australia, as no passenger cars, electric or petrol, are manufactured in Australia.

In Xseed Solution’s analysis for trucks and buses (refer separate Xseed Study), the marginal cost of abatement of W2X scenarios ranged between a savings of \$94 per t CO<sub>2</sub>e and a cost of \$1,044 per t CO<sub>2</sub>e. The below figure illustrates the Total Cost of Ownership (TCO) \$ per t CO<sub>2</sub>e emissions for each of the scenarios modelled, with a majority of Sub.Zero W2H TCO \$ per t CO<sub>2</sub>e scenarios less than the current government abatement subsidies for passenger electric cars.



## 7. Agriculture decarbonisation

Agriculture is estimated to consume 2.6 billion litres of diesel annually, emitting 9.3 million tpa CO<sub>2</sub>e. Aspects of the agriculture industry are hard to abate, and difficult to electrify, including remote stations, road transport and farming equipment. We have presented case studies that detail the benefits that a circular economy solution, diverting landfill waste across regional Australia towns to manufacture local hydrogen



and methanol would provide agricultural, farming, and pastoral organisations with significant decarbonisation and cost benefits.

As part of the circular economy approach, the industry would benefit from the recommended investment allowance (Recommendation 6) and hydrogen subsidy (Recommendation 5). To enhance the full decarbonisation of the fossil fuel component for the sector we recommend that the Federal Waste Plan expand the primary production immediate tax deduction regime to 2030 to include low carbon intensive stationary energy renewable power solutions for solar, wind, geo-thermal, hydrogen, and methanol. Utilising hydrogen and methanol from waste enables up to a 10% reduction in the carbon intensity of Australian beef, lamb, farmed prawns and other higher carbon intensity products so as provide a distinct low carbon export advantage as compared to other markets.

## **8. CER to finalise waste and hydrogen ACCU rules**

In 2021 the Federal Government announced a range of Emission Reduction Fund (ERF) methods for development, including for road transport, hydrogen refuelling infrastructure, hydrogen uses, carbon capture use, and different agricultural wastes as feedstocks to support enhanced biomethane. After 3 years, these all remain outstanding and this is now coupled with uncertainty as the outcomes from the existing landfill and methane abatement methods in place, and how they would apply to various waste to hydrogen technology outcomes.

At a time that the Carbon Safeguard Mechanism (CSM) is in operation, and uncertainty continues as to Australian Carbon Credit Units (ACCU) entitlement from these ERFs for the Waste to Hydrogen to X ecosystem, it is difficult for investors and affected CSM businesses to consider using ACCUs from 100% abated waste methane emissions.

We recommend that the Clean Energy Regulator (CER) urgently finalise and publish the regulations and requirements with respect to ACCU entitlements from the proposed 2021 ERF methods, together with those applicable to all aspects of the waste management and waste to hydrogen sectors.

## **9. Harmonise and modernise the Waste Hierarchy(ies)**

The Waste Hierarchy had its origins in 1975 from the early versions of the EU Waste Framework Directive. A complementary circular economy model was later developed, that often creates confusion as to objectives and outcomes from each approach.

The Australian Government Waste Plan has a reference to the waste hierarchy, but it does not clarify which of the multiple models and legislative outcomes in Australia it is referring to. Each state and local government in Australia has adopted its own unique interpretation of that original waste hierarchy that makes delivering lower cost regional solutions difficult, particularly when it comes to the permitting and planning assessments for multi-jurisdictional projects that often require inputs from three tiers of government. Enabling a hydrogen highway project between states utilising hydrogen from waste provides extensive complications from dealing with different waste hierarchy frameworks and interpretations.

All this is particularly confusing when it comes to the scientific and objective outcomes targeted from the regeneration of organic materials, recycling of products, the (re)manufacturing of others, like hydrogen and the recovery of energy (as electrons) from waste.

We recommend a harmonisation and modernisation of all the waste hierarchy(ies) in Australia requiring specific references to:

- Greenhouse gas (carbon) intensity outcomes of different solutions;
- An “end of waste” criteria, similar to the EU Waste Framework Directive, to specify when certain waste ceases to be waste and becomes a product, or a secondary raw material when it has undergone a recovery operation (including recycling) and complies with specific criteria, in particular when:
  - the substance or object is commonly used for specific purposes;

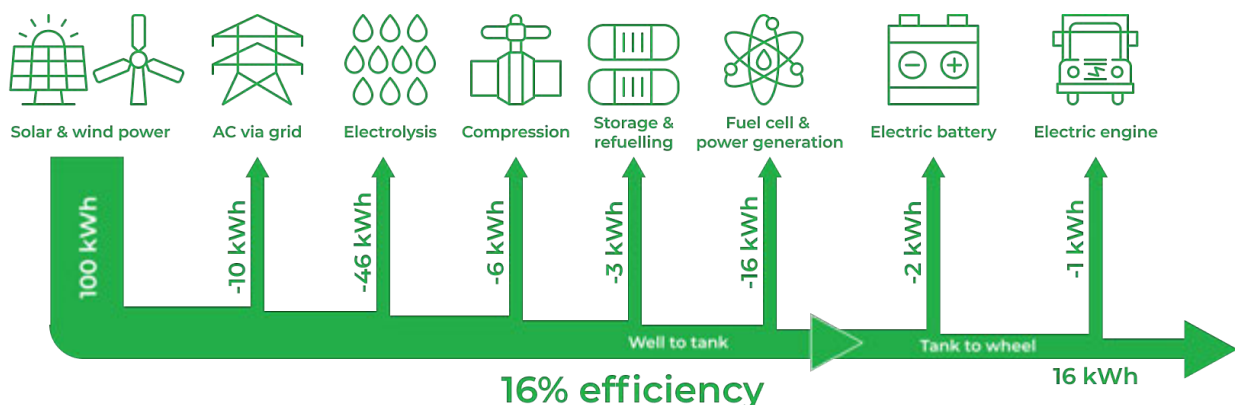
- a market or demand exists for such a substance or object;
  - the use is lawful; and
  - the use will not lead to overall adverse environmental or human health impacts.
- Distinguishing waste recycling and recovery related manufacturing technologies based on multiplicity of end uses, process energy efficiencies, carbon intensity outcomes, and biodiversity impacts. This is particularly the case in distinguishing between two very different outcomes from:
    - Waste recovery activities typically attached to electron production into single use energy generation, particularly when it has up 20% residual outcome to landfill;
    - Waste recycling activities manufacturing hydrogen gas, with hydrogen gas having a multiplicity of end uses for example a non-exhaustive list including from ammonia, fertilizers, chemicals, biogenic methanol, energy carrier, metallurgical processes, glass and other manufacturing outputs, and metal fabrication, with zero waste to landfill; and
  - Harmonisation of waste hierarchy concepts by reference scientific outcomes. All technologies have a role to play and need to be assessed on within the regional context it is to be adopted. For example, composting is often promoted as the only solution to deal with food and organic waste, whereas it has a small value-add; has limited carbon abatement; invokes extra collection and separation costs and requirements; has large land use; invokes significant transport emissions; and with high contamination risks of composting often overlooked when looking at composting in highly urbanised locations.

### Distinguish “waste to energy” incineration from waste to hydrogen

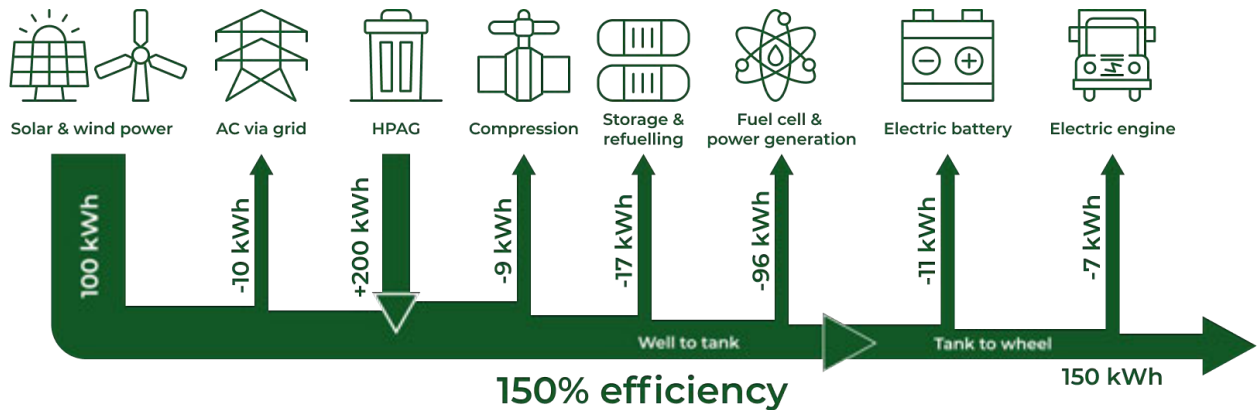
In broad terms, a clear distinction should exist as the waste hierarchy outcomes as it relates to the energy spectrum between:

- **Renewable power (electrons)** – That is the generation of continuous grid power that is often the only output from incineration or stand-alone gasification or pyrolysis technologies. Often these technologies have high emissions, sub-optimal carbon intensity outcomes, are energy inefficient and generate up to 20% fly ash residue still requiring disposal to landfill.
- **Hydrogen gas (molecules)** – That is the manufacture of hydrogen gas molecules from the waste, as the manufacture of hydrogen from water is already viewed as an acceptable technology pathway. This is particularly the case in HPAG’s circumstances that provides significantly higher energy efficiency outcomes than both incineration and electrolysis production.

The Federal government has embarked on a program to streamline hydrogen regulatory frameworks. This work does not necessarily overcome the inherent inefficiencies in the waste hierarchy nor delivering electrolysis hydrogen to the road transport sectors. Illustratively, electrolysis hydrogen that consumes significant scarce water in its production has a 16% energy efficiency outcome “Well to Wheel”, with a carbon intensity of 2 to 4 CO<sub>2</sub>e per kg of hydrogen “Well to Gate”.



This is to be contrasted with the manufacture of HPAG hydrogen from waste that has a 150% energy efficiency outcome “Well to Wheel” with a carbon intensity of negative 12.7 CO<sub>2</sub>e per kg of hydrogen “Well to Gate”. That is, an outcome that is over 6 times more beneficial than electrolysis hydrogen.



This high level of environmental effectiveness in terms of carbon intensity and energy efficiency outcomes are often overlooked when a subjectively ranked waste hierarchies are developed. The following table highlights some of the key aspects of each.

		Conventional waste incineration faces challenges that are mostly not fixable		Incineration (Wte)	
		Waste Incineration	Is there a fix?	HPAG = H <sub>2</sub> + power fast charging	Wte vs HPAG
Energy	Energy efficiency	Poor	No. No fix.	High. Eco-system optimises outcomes	Est ~43% of energy output
	Energy storage	Poor	Expensive and inefficient storage	Full (24h). High (72h). Medium (7d+)	Poor
Hydrogen	Hydrogen capable	No. Burns H <sub>2</sub> and C molecules	No. No fix.	Yes. H <sub>2</sub> -native process. Biodiversity benefits.	No.
	CO <sub>2</sub> emissions	100% emitted	Very expensive. Takes up to 60% of power produced	Designed with native CO <sub>2</sub> capture. Non-combustion CO <sub>2</sub>	100% emitted
Climate positive	CO <sub>2</sub> e abatement	Landfill waste diverted. Baseload power output.	Combine with renewables?	3.7 times H <sub>2</sub> output vs combination	Limited impact on own CO <sub>2</sub> e targets
Emissions	NO <sub>x</sub> & PM emissions	Poor	Very expensive	Up to 95% below EU regulations	TBC. Likely higher.
	Ash residues	Toxic	Very expensive	Zero. Vitrified slag construction material	Not "Zero Waste"
Investment profile	Investment risk	High. Singular revenues.	Concentrated capex investment. Low ROI.	Small. Scalable. Diversified revenues.	Capex and opex likely higher.
	Project Scale / Customer	Large. Centralised. / Low alignment.	No. No fix. / Unlikely.	Distributed. Localised. / Aligned.	High to/from transport and CO <sub>2</sub> e costs

In the EU, W2X technology adoption is rising rapidly, with waste to hydrogen projects now representing 4% of the targeted EU hydrogen production, coming from just 1% of the proposed hydrogen projects.

Today, most Australian green hydrogen projects being considered are utilising some form of water electrolysis technology. Reflecting on this trend, electrolysis hydrogen requires an ideal suite of project parameters with respect to:

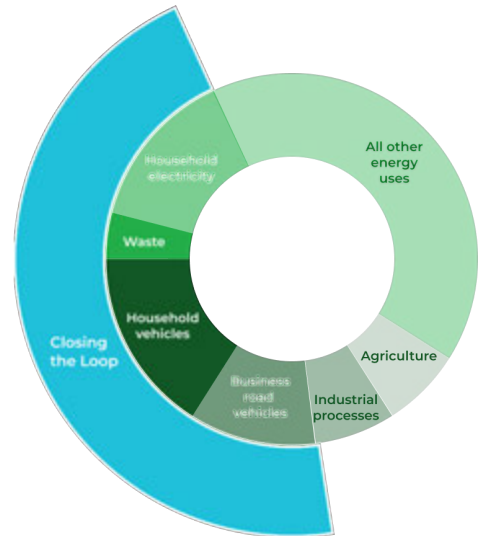
- large tracts of land to be available for the wind or solar to create renewable energy;
- an abundance of scarce water resources, requiring over 20 litres of water to produce 1 kg of hydrogen - HPAG requires less than 1% of water in its process to produce equivalent levels of ultra-low carbon hydrogen; and
- being limited to be located nearby to pipelines, shipping, or transport to transport the compressed or liquified hydrogen to minimise distribution costs and energy losses.

HPAG flexibility means that many of these electrolysis hydrogen disadvantages are not applicable to HPAG.

**10. Rethink.Zero.**

Beyond electrifying one’s home with affordable solar electricity, we are encouraging local councils with Sustainability Precincts to buy residents excess household solar power as a pathway to provide households with lower council rates, cheaper real zero public transport, reasonably priced zero emission freight trucks on our roads, and to simplify our collective journey to zero waste. Xseed Solutions’ **Rethink.Zero.** initiative is detailed online at [Rethink Zero.](#)

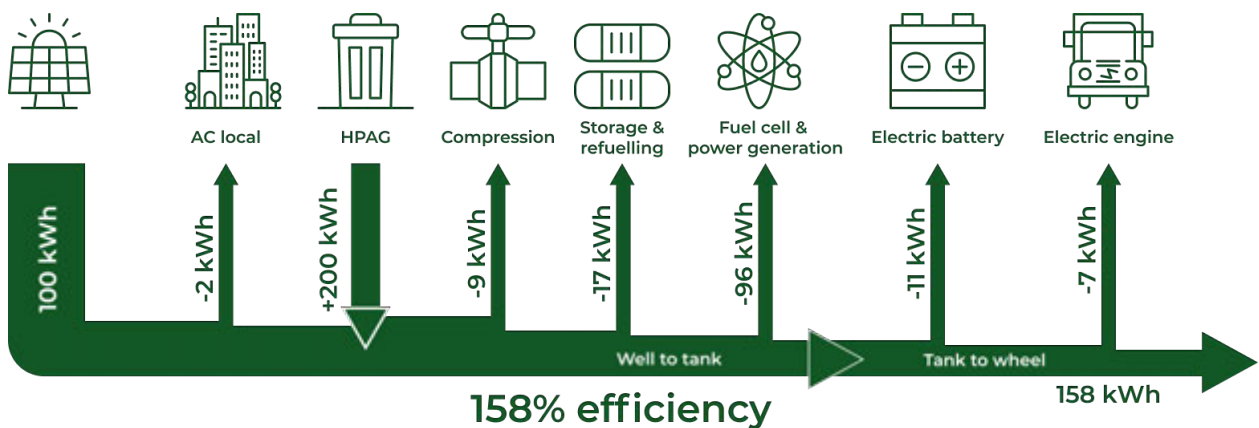
Less than 30% of Australian households have solar. Many have excess solar energy that is being sold into grid network at less than \$0.05 per kWh, whilst paying \$0.30 per kWh or more. Hydrogen from waste facilities require renewable power which is best sourced locally.



Based on producing 2.2 billion kg of hydrogen with renewable power and using the CER’s estimated cost per MW of solar farms of \$1.1 million per MW;

- Using electrolysis would require a solar farm investment of \$69 billion delivering 63 GW of renewable power, noting that this solar farm would cover 160,000 ha, an area six times the size of Whitsunday Island;
- To be contrasted with HPAG hydrogen manufacturing, the solar investment is closer to \$11 billion as it requires one-sixth of the renewable power, or 11 GW of renewable power. At full capacity, this could be accommodated on 13% to 18% of the over 200,000 ha of roof areas of Australian homes, aligning with the ‘Electrify Everything’ initiative. This would require community distributed renewable power generation to be permitted across Australia.

Local councils with zero waste to hydrogen facilities using excess household solar power provides cost of living relief to households and reduces the 10% in transmission losses from long distance solar farms. Reduced transmission losses are estimated to improve overall efficiency of zero waste to hydrogen by 8% to 158%.



**Rethink.Zero** encourages local councils in establishing Sustainability Precincts towards being Climate Positive to promote with retail energy providers Rethink.Zero plans for residents whereby the Precincts buy residents excess household solar power for use in the Precincts. Involving energy retailers may assisted in providing funding pathways for households, with participating households being paid a higher feed-in rate than currently received, but lower than the cost to establish new long-distance infrastructure. Assuming that purchase rate was \$0.125 per kWh this provides an income stream to households of \$100 per excess solar panel energy generation, or \$2.7 billion to households as an input to the manufacturing of upwards of \$26.4 billion in Grade A+ hydrogen.



In addition to supplying hydrogen to decarbonise Australia's road freight transport, councils could consider pathways to enhance benefits for its residents from co-owned facilities. These could include:

- rebates or discounts for local businesses, particularly restaurants, food retail and agriculture, with food and organic waste to participate in waste to hydrogen supply and off-takes;
- local residents encouraged to use Sub.Zero hydrogen and fast charge powered public transport;
- local businesses encouraged to purchase Sub.Zero power or hydrogen for their own use stationary or vehicle uses.

Boosting the *Rewiring Australia* model, this pathway provides those residents participating in the plan with higher returns to lower their overall household running costs. Using local infrastructure reduces the biodiversity impacts, energy losses, and costs of constructing renewable energy facilities at long distances.

### 11. Methanol Flexible Device Solutions

Australia's bioenergy sectors developing biofuels from biomass and related agricultural waste products is progressing, particularly in terms of Sustainable Aviation Fuels (SAF) and methanol directed at shipping decarbonisation. Methanol is an efficient hydrogen carrier, enabling the equivalent of 12 road tankers of hydrogen molecules to be transported in one tanker of methanol. We encourage the enhanced infrastructure use of largely biogenic sourced methanol, capable to be manufactured at Sustainability Precincts.

When the driving distance between many towns and cities in regional Australia is at least four hours, repurposing existing station diesel infrastructure for utilising methanol provides an efficient, lower case transition pathway for many residents, business owners, and refuellers. Repurposing existing infrastructure for a lower carbon impact outcome.

Technology readily exists to convert methanol to hydrogen or power on a small scale required in homesteads or vehicles. Methanol stored and used at a homestead to produce peak stationary power, provide power backup, and hydrogen or fast charge refuelling and recharging for vehicles provides a versatile safer option for regional Australia and the agricultural industry.

The large distances associated with serving renewable fuels to agricultural customers requires consideration of a range of carriers, and customer requirements. When production and distribution systems are considered together with Customer Application Devices (CADs), it is essential there is;

- A comprehensive production and distribution infrastructure;
- An attractive suite of commercial fuel / energy options that suit the CADs;
- The commercial pricing structure is neutral / sustainable.

When incorporating methanol as an efficient hydrogen carrier, multiple technologies are available to address consumer needs across a range of Zero Emission Vehicles (ZEV) including:

- Battery Electric Vehicles;
- Hydrogen Fuel Cell Vehicles (HFC);
- HFC with Methanol fuel hydrogen generator;
- Direct Methanol Fuel Cell Vehicles;
- Hydrogen / Diesel Dual-Fuel Vehicles; and
- MCCI\* Modified Diesel Engine Vehicles.

Distribution networks should ideally maximise choice and flexibility for technology transition. The use of methanol as fuel distribution supply source enables:

- All requirements above from the one fuel;
- Minimised and simple infrastructure to deliver the product; and
- An immediate start to advance net zero transition implementation.

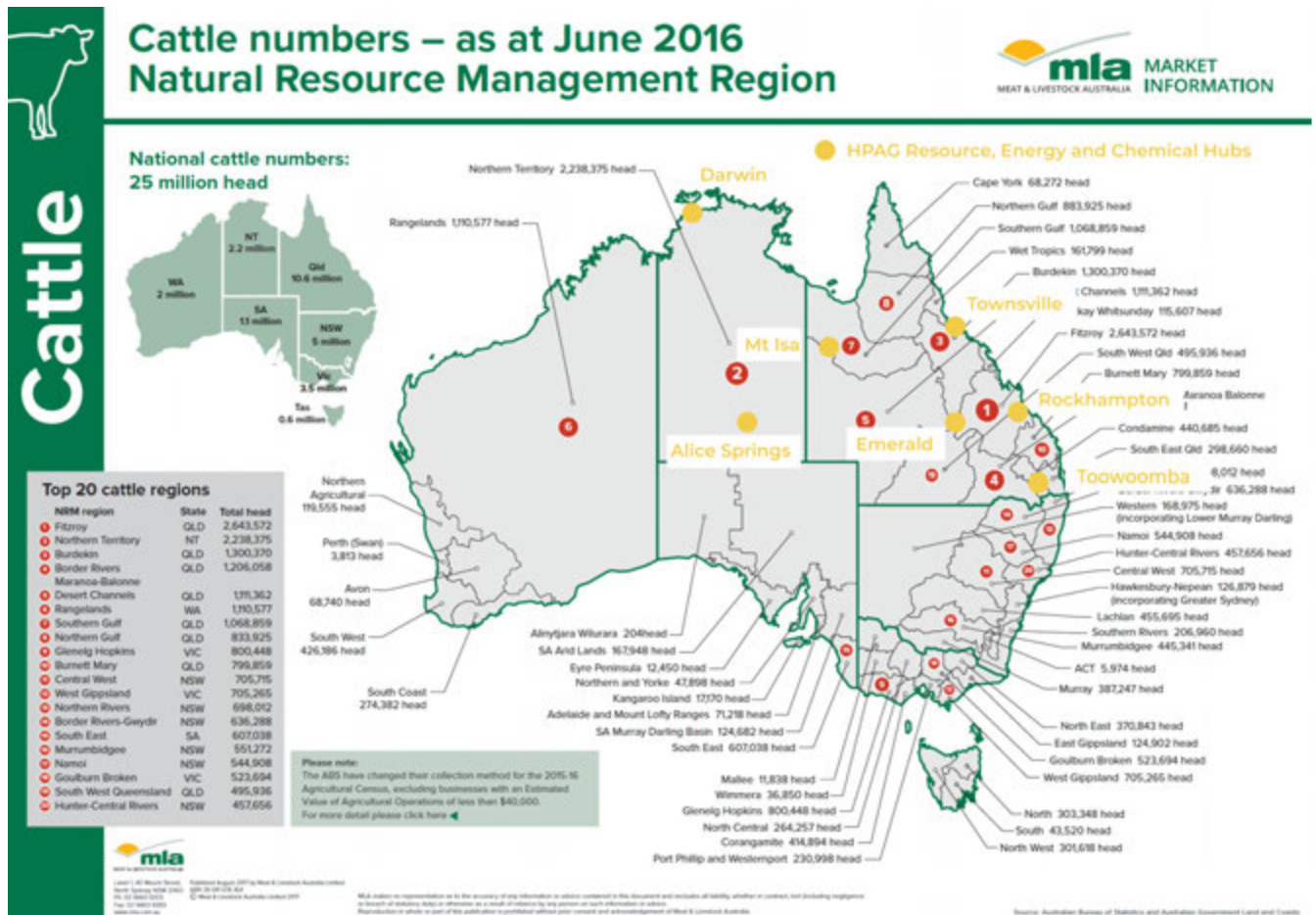


## Appendix B – Case Study - Australia’s Agricultural Industry

Australia’s 25 million head cattle industry operates across large areas of regional Australia.

Focusing on Agricultural and Land sector’s fuel, energy, and the circular economy opportunities. Based on recent industry reporting it is reported that 5% to 9% of cattle / pastoral owner’s CO<sub>2</sub>e emissions arise from fuel uses, largely:

- diesel or gas for stationary power production at homesteads, feedlots, and farms;
- diesel use for the long haul transport of cattle between stations and to market; and
- diesel or petrol for other heavy vehicle, light vehicles, and ancillary equipment usage.



## A Circular Economy Solution

Based on extrapolating publicly available data it is estimated that annual diesel use equates to 25 lt per head of cattle, or 625 million litres of diesel annually across the entire Australian sector, contributing to 1.7 million tpa of CO<sub>2</sub>e emissions.

For Queensland and the Northern Territory’s 11.7 million of cattle (see MLA estimates above), this equates to an estimated 290 million litres of diesel and fuel usage annually. At the same time, eight of the closest regional towns (ie. Roma, Emerald, Proserpine, Mackay, Rockhampton, Townsville, Toowoomba, and Darwin) to many of these stations, feedlots and farms dispose of 309,000 tpa of household waste to landfill. An estimated total of 1.2 million tpa CO<sub>2</sub>e emissions when combining these regional towns landfill waste and the cattle / pastoral sector’s diesel fuel use in these two states.

As a base case scenario, we envisage a circular economy eco-system that reduces annual CO<sub>2</sub>e emissions by 0.8 million tpa, or 75% annually from current levels – Xseed’s Great Barrier Reef Hydrogen strategy. For participating pastoral and cattle companies utilising carbon negative resources this could equate to around

a 14% annual CO<sub>2e</sub> abatement reduction. An average 14% reduction in the carbon intensity of some of Australia’s premium red meat enhances both the sector and its’ product’s sustainability appeal to end consumers.

Great Barrier Reef Hydrogen’s focus on household landfill waste availability in stages that is capable to be processed utilising HPAG technology to produce an estimated 30,900 tpa of hydrogen:

- an equivalent of 155 million liters of diesel (eg. over one-half of the estimated sector usage); or
- 623,000 MWh of peak or back-up power, more than twice that power capable to be sourced as weather dependant renewable solar/wind.

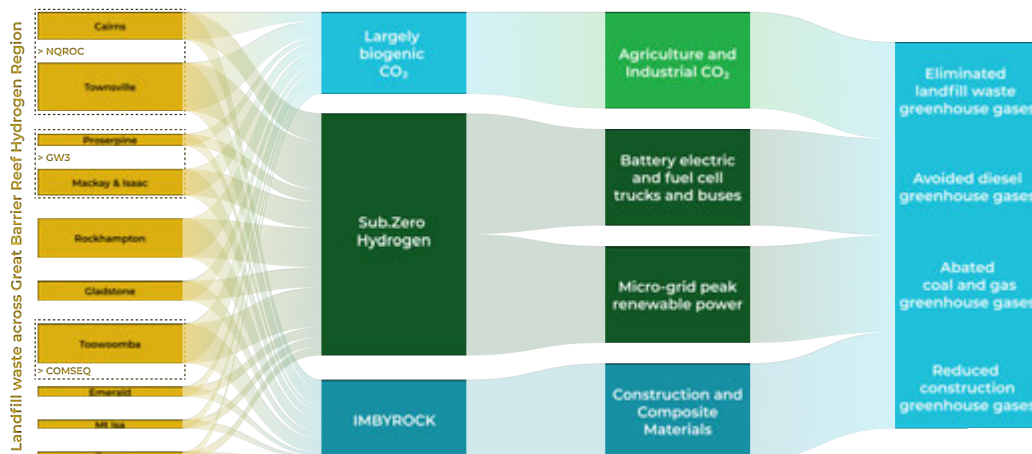
Across regional Australia, given available land areas and solar availability, renewable energy can be more closely located adjacent to HPAG generation facilities - reducing power transmission losses over other hydrogen production technologies.

### Carbon Negative Hydrogen with Growth Options

HPAG hydrogen is estimated to have a “well to gate” carbon intensity of negative 12.7 kg CO<sub>2e</sub> per kg hydrogen (ie the hydrogen produced and used is carbon negative). This is to be contrasted with electrolytic hydrogen using solar or wind carbon intensity ranging from 1 to 4 kg CO<sub>2e</sub> / kg hydrogen. HPAG technology uses less than 1% of water (scarce in regional Australia) and 17% of the renewable power required to produce electrolytic hydrogen.

This base initiative could be combined in many ways and be expanded over time with:

- Additional suitable biomass and Commercial & Industrial waste streams to increase this hydrogen generation potential;
- Combined with on station and feedlot site solar or wind together with battery and/or methanol/hydrogen as a peak and back-up storage medium;
- When using the biogenic CO<sub>2e</sub> captured it can be used to promote agricultural sector opportunities in terms of value add production, employment, and domestic self-sufficiency. Some examples we envisage include utilising the biogenic green CO<sub>2</sub>:
  - with the residual heat for urban vertical farming;
  - to stimulate high value algae production;
  - broadening agricultural greenhouses reducing agricultural land usage;
  - enabling local protein production; and
  - enhanced food security;
- Additional waste inputs from Queensland regional towns like Cairns, Mackay, and Gladstone; and
- Expansion into regional Victoria, South Australia, Western Australia, and Tasmania. New South Wales opportunities are more limited based on current policy settings.



## Appendix C – Hydrogen capable Plasma Assisted Gasification

Hydrogen is the most abundant chemical substance, constituting roughly 75% of all normal matter. It is colourless, odourless, tasteless, non-toxic, and highly combustible.

Photosynthesis gives us cheap hydrogen. Photosynthesis uses sunlight and CO<sub>2</sub> to "crack" the strong hydrogen-oxygen bond in water and produce the oxygen we breath. The "leftovers" are stored as hydrocarbons in plants, that in the end make up most of our non-recyclable waste.

Energy systems are evolving globally driven to achieving CO<sub>2</sub>e reduction targets, increasingly embracing hydrogen as part of the reduction solutions. Coupled with that are actions to maximise the circular economy principles that are seen as a key pillar to achieve many of these reduction targets.

The simple objective of the circular economy is to maintain resources at their highest possible value for the longest possible time. Pre-dating the "circular economy", was the concept of the "linear economy". The simple notion that we all "take, make, consume and waste". This linear notion of waste was further extended with the waste hierarchy concept that prioritised waste management into the famous 3 Rs "reduce, reuse, and recycle" before "recovery" was added as a last resort before the disposal of waste to landfill.

The emergence of overlapping principles has led to many government policies addressing the crowded "recycle and recovery" phases. Limited distinction is drawn in that arena between technologies and processes suitable for technical resource recovery, vs those suitable for biological resource recovery. In so doing policies and rules can often ignore the various innovative, and emerging biological, chemical, mechanical, and thermal recycling and recovery processes that will occur.

The confusion also extends to electrolysis, where significant energy is applied to extract the 11% hydrogen content of water, itself a scarce resource and required in large volumes to produce electrolysis hydrogen. This is to the detriment of technologies that extract the 10% content of hydrogen from otherwise non-recyclable waste. The confusion is also easiest to illustrate with the simple burning of waste, or "incineration", that was remarketed in Australia as "waste to energy". In so doing, we have lost sight of the four vastly different processes, technologies, and outcomes that these different processes encompass:

- **combustion**, the burning of resources with oxygen at between 800 and 1,450°C creating toxins and ash. In the EU, the combustion process is used in 99.5% of all incinerators;
- **pyrolysis**, the thermal degradation of organic materials in the absence of oxygen at between 250 to 700°C;
- **gasification**, those thermal-chemical processes at between 500 and 1,600°C used to recover the chemical value of the resource; and
- **plasma**, a physics process where ionized substances becomes highly electrically conductive. Utilising extremely high temperatures (over 5,000°C) to break-down hazardous contaminants such as PCBs, dioxins, furans, and pesticides, into their atomic constituents. Highly efficient, the gases created are cleaned, with a vitrified residual slag created.

Refer to the EU Best Available Techniques (BAT) Waste Incineration for detailed guidance as to the technology differences.

New technologies more prevalent in the EU and the US built on the pyrolysis, gasification and plasma spectrum are leading to opportunities for integrated low carbon electricity and fuel systems, referred to as "Power-to-Hydrogen". Hydrogen's simplicity provides it with a multiplicity of uses, coining the term "Hydrogen to X" in many markets. Very few, if any, Australian policies in the waste sector recognise the potential of this resource to be recovered environmentally and economically efficiently to provide low-cost green hydrogen. Rather, policies are currently anchored in the outdated waste to energy or combustion incineration technology.

### HPAG as disruptive technology will replace combustion incineration

In the context of the EU's drive towards net zero, incinerators that simply burn waste to generate baseload power, are becoming increasingly difficult to progress whereby all CO<sub>2</sub> emissions from the incinerated waste are emitted to the air and not captured. In that way when considering the greenhouse gas impacts, the incinerators that burn waste are only marginally better for the environment than landfilling waste. Incineration also results in around 20% of the burnt waste remaining as ash, that often ends up in

landfill anyway. New overseas incinerators are increasingly being required to capture and use the CO<sub>2</sub> produced, and when you consider this adds materially higher capital expenditure, together with drawing away 60% to 80% of the baseload power produced required to operate the CO<sub>2</sub> capture equipment, it further marginalises any incinerator project's economics.

Three key overseas changes include (1) the UK Environmental Agency mandating that around 95% of CO<sub>2</sub> produced by incinerators is to be captured and then stored or used that is likely to be extended to the EU in the coming years. (2) The EU has directed that as incinerator CO<sub>2</sub> emissions are contributing to EU greenhouse gas emissions the incinerator operators are required to pay for the cost of the CO<sub>2e</sub> emissions under the EU Emissions Trading System (ETS). (3) The EU took action years ago in producing the EU Taxonomy to state that incinerators are not sustainable environmental solutions, nor contribute beneficially to the circular economy, and for that reason have denied green or sustainability funding options to incinerators, much the same that has occurred with funding of the energy coal industry.

Additionally, increasing regulatory pressure on environmental performance (bottom ash and fly ash containing Per- and polyfluoroalkyl substances (PFAS) and Persistent Organic Pollutants (POPs), flue gas emissions of NO<sub>x</sub>, particulate matter, and other pollutants), high water footprint, low carbon emission outcomes and large capital expenditure requirements are seeing combustion incineration being replaced by newer technology. We support these changes made in a fully informed, measured and considered way.

After 40 years of development, **Hydrogen capable Plasma Assisted Gasification (HPAG)** processes have now emerged to produce two important molecules for the functioning and decarbonisation of our society, climate positive Grade A+ 'green' hydrogen (H<sub>2</sub>) and largely biogenic carbon dioxide (CO<sub>2</sub>).

Disruptive technologies significantly alter the ways that businesses, consumers, and industries operate. We envisage HPAG technology disrupting the combustion incineration sector given its preferential environmental, biodiversity and economic benefits.

**Scalable, modular.** Importantly, overcoming the shortcoming of incineration, the HPAG processes have been developed to be scalable, modular, process efficient and cost effective enabling environmentally safer localised developments (with lower transport costs and energy leakages). HPAG's small plant footprint (less than 3,000 m<sup>2</sup>), low environmental impacts and limited inter-dependencies provides maximum optionality for smaller regions and for locations nearby to resource recycling centres, landfills, power transmission and distribution infrastructure, existing pipelines, and transport routes.

**Aligned with recycling and FOGO.** The modular design approach to scale up the input supply also mitigates the need for contractual guarantees of large waste volumes. This avoids the needs for all encompassing lock-in waste feedstock contracts (and associated gap penalties) that operate counterintuitively to our aspirations to increase recycling targets and embracing emerging FOGO composting ambitions. All aimed to divert landfill waste and reduce carbon emissions.

**90% lower emissions.** The integrated HPAG pyrolysis, gasification and vitrification processes utilise plasma torches and generate extremely high temperatures, radically lowering the levels of emissions - up to 90% less in absolute terms and far below EU BREF standards that many combustion incineration plants struggle to meet.

**No ash, with captured CO<sub>2</sub> emissions.** HPAG processes produces no ash, in contrast to the 15 to 25% Incineration Bottom Ash (IBA) and 2 to 5% hazardous 'fly ash' (Air Pollution Control residue - APCr) produced by combustion incineration (weight being a percentage of initial waste treated). Incineration also emits large amounts of post-combustion CO<sub>2</sub> with its flue gas, as opposed to early-stage CO<sub>2</sub> that HPAG processes splits out from the syngas and are captured for downstream uses, e.g. creating green methanol.

HPAG as an enabler for the circular economy is capable to promote and encourage development and facilitate significant public benefits from one or more of the following circular economy sustainability hubs:

- **Energy hub**, the green hydrogen recovered as a gas is available for supply locally to be used in a variety of forms in other downstream activities or processes, including:
  - Diesel replacement in long haul transport, contributing towards reducing upwards of 5% of Australia's carbon emissions from this sector,
  - Fast charge power generation,
  - 24/7 365 day available local grid connected power generation;

- **Chemicals hub**, when recombined with the largely biogenic CO<sub>2</sub> produced it is an enabler for the downstream production of:
  - e-methanol for road and shipping transport, another high carbon emissions sector,
  - sustainable aviation fuel for airlines, being utilised to reduce jet fuel carbon emissions,
  - e-ammonia,
  - e-urea,
  - industrial grade low carbon intensive CO<sub>2</sub> as a replacement for other CO<sub>2</sub> production;
- **Greenhouse hub**, when utilising the biogenic green CO<sub>2</sub> and the residual heat for urban vertical farming, agricultural greenhouses reducing agricultural land usage, local protein production and food security; or
- **Cell glass hub**, utilising the vitrified slag known as IMBYROCK from the HPAG process, that is also able to be further treated downstream to produce cell glass. IMBYROCK is available as a construction material substitute and cell glass is available as a cement substitute.