Committee for
GIPPSLAND

NET ZERO COMPATIBLE USES FOR LIGNITE

Acknowledgement of traditional owners

The Committee for Gippsland acknowledge the Traditional Custodians of Country and recognise their continuing connection to the land, water, air and sky, culture and community. We pay our respects to their Elders past and present. We acknowledge that the opportunities in 'Net zero compatible uses for lignite' are on traditional lands, including those lands of the Gunaikurnai, Bunurong, Wurundjeri, and Taungurung nations as well as other Traditional Owner Groups in Victoria who are not formally recognised.

About the Committee for Gippsland

The Committee for Gippsland (C4G) offers a positive and influential voice for Gippsland helping to create a thriving and sustainable future for the region.

As Gippsland's lead industry representative voice to government, C4G brings together groups representing an array of business and industry views and interests, to collaborate on regional priorities to benefit Gippsland communities.

C4G actively engages across industry and throughout the region. Its membership is diverse and includes emerging and established industries such as energy, agriculture and health, and small to medium businesses as well as organisations that provide support services, education and professional services, to help drive a positive future for Gippsland.

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Executive summary

Advanced carbon materials play an increasingly important role in modern society. Carbon products have many crucial uses, including in agricultural production and soil remediation, renewable energy generation and storage, construction, transport, clean air and water, biomedicine, consumer electronics and many more.

Victorian lignite is a world class source of carbon from which sustainable, high value products can be produced. Victoria has an opportunity to establish a high value carbon-based industry in the Latrobe Valley as lignite power generation is phased out. Carbon neutral or even carbon negative products from this valuable resource would create well paid, high-tech jobs, which will compensate for the loss of regional income. These include advanced materials and strategically important chemicals such as urea.

New clean carbon industries would be accelerated by the Hydrogen Energy Supply Chain (HESC) project. A commercialised HESC would convert lignite to clean hydrogen for various uses, and a carbon dioxide stream for utilisation in agriculture and industry and then permanent storage deep offshore. The HESC would give new clean carbon industries access to crucial inputs at marginal cost, including raw and dried lignite, hydrogen, nitrogen and carbon dioxide.

Gippsland is well equipped to host new clean carbon industries. The region has a unique combination of advantages including vast lignite resources, offshore carbon storage, established energy, port, road and rail infrastructure, access to markets, a skilled workforce, and a community with a history of hosting major industries.

Decisive action is needed to realise this opportunity. A clean carbon industry should be an important part of Gippsland's transition to a net zero economy, and will require concerted and sustained effort from the public and private sectors, and the regional community. Governments at all levels should act now to establish a commercial blue hydrogen industry, fund research and development of clean lignite technologies, grow community support for clean carbon industries, and attract commercial investment.

Gippsland can become a clean manufacturing powerhouse

Lignite is a highly prospective feedstock for manufacturing advanced materials and agriculture inputs in the Latrobe Valley.

Carbon fibre materials have high tensile strength, low densities, and good thermal and electrical conductivity. They are used for their superior qualities in the manufacture of aircraft, automobiles, boats, machine parts, sporting equipment and wind turbine blades, to name a few.

Graphene is nearly transparent, chemically inert, and conducts heat and electricity better than any metal, and is about 100 times stronger than steel. Its unique properties create the potential for wide range of applications, including reinforcement of lightweight polymers and concrete, transparent electronic devices and protective coatings, gas detectors, ion conductors, hydrogen storage and nanofiltration membranes, with many new applications under development.

Carbon quantum dots are a microscopic form of graphene which behave as light emitting semiconductor crystals. They have potential applications in energy conversion and storage and biomedicine, including in photovoltaic devices, rechargeable batteries, super-capacitors, biosensors and high-performance light-emitting devices.

Activated carbon contains tiny pores that increase the surface area available for adsorption* or chemical reactions. It has many applications including in water treatment, air cleaning, CO_2 capture, pharmaceuticals, chemicals, and food and beverage production.

Activated carbon monoliths are a specialised form of activated carbon with superior adsorption* qualities that results from a large number of parallel channels. This unique configuration is produced from lignite without using chemical binders, representing a distinct advantage for lignite over the use of conventional activated carbon feedstocks.

Humic acid is used in agriculture and horticulture to reduce fertiliser application rates, enhance efficiency of nutrient use, replace synthetic plant regulators, increase water stress tolerance, decrease disease incidence, stimulate early growth and flowering, and as an animal feed supplement. Humic acid is currently produced from weathered lignite in the Latrobe Valley. Research is underway to produce humic substances at lower cost from run-of-mine lignite containing high value humic substances, which could unlock a large-scale industry.

Soil improver Lignite and char, produced through lignite pyrolysis, can be applied directly to soil to improve its structure and water holding capacity. As-mined lignite is already a commercial product and will be important for use as topsoil additive in mine site remediation, as the Latrobe Valley power stations are retired.

Intensive horticulture Gippsland could establish a major food growing industry based on intensive greenhouse production which takes heat and CO_2 waste streams from the production of blue hydrogen at minimal cost, to grow valuable crops year-round.

Ammonia is produced by combining nitrogen and hydrogen under high temperature and pressure. Hydrogen production from lignite with carbon capture and storage (CCS) is an attractive proposition for Gippsland, as set out in the *Gippsland Hydrogen Roadmap*[1]. Ammonia is used as a chemical feedstock, most notably in the production of synthetic fertilisers. It has potential to be used as hydrogen carrier which can be transported over long distances as an alternative to liquified hydrogen. Ammonia could also be used as bunker fuel to reduce emissions in the shipping industry.

Synthetic fertilisers are critical agriculture inputs. Nitrogen, carbon dioxide (CO_2) and sulphur are by-products from blue hydrogen production and are essential feedstocks for ammonia, urea and other synthetic fertiliser production.

* Adsorption is the attraction of molecules onto the surface of a solid.

Victoria could establish a clean carbon-based industry in the Latrobe Valley as lignite power generation is phased out.

New industries would create jobs where they are most needed as the coal-fired power industry declines. They are some of Gippsland's best prospects for a just transition. They would replace the high-volume, high-emission burning of coal for electricity with a range of products that will require low-volume, low-emissions uses in high-value industries.

The Hydrogen Energy Supply Chain project

Victoria has one of the most advanced clean hydrogen export projects under development; the Hydrogen Energy Supply Chain (HESC). In March 2023, the Japanese Government committed funding of approximately $2.35 billion to progress commercial demonstration of the HESC. Blue hydrogen with Carbon Capture Utilisation and Storage (CCUS) would unlock significant economic benefit to Gippsland and Victoria.

These opportunities are most likely to attract investment if the current work to commercialise the Hydrogen Energy Supply Chain (HESC) succeeds. This is because the HESC would establish a supply chain of products from which all these products can be made (raw lignite, dried lignite, hydrogen, nitrogen and carbon dioxide).

They would draw on Gippsland's extraordinary resource endowment, including lignite, carbon storage, water, biomass and renewable energy. They would also utilise its skilled workforce as it transitions out of coal power.

Existing industries in Gippsland can benefit from a range of products produced locally from Victorian lignite, while additional industries could locate in the Latrobe Valley to take advantage of lignite as a raw material and the carbon storage service that the HESC will catalyse, using depleted gas fields and saline aquifers in the Gippsland Basin.

Gippsland has major advantages to support clean manufacturing

Natural Resources

Lignite

All of Gippsland's clean manufacturing industries described in this report use Victorian lignite as primary feedstock. Lignite is Victoria's largest resource with 33 billion tonnes being economically recoverable[2] – compared to the 3 billion tonnes that have been consumed in 100 years of power generation[3]. While its large-scale, unabated use for power is in decline, its potential as a low-cost feedstock for a diverse, low carbon, and high value industry, has grown.

Unlike black coal, lignite is not exposed to global commodity price volatility. This is because lignite has a high moisture content and is therefore best utilised near the point of origin; as-mined, it is not suitable for export.

Another advantage is that, unlike black coal, lignite mining has negligible fugitive methane emissions.

Renewable energy resources

Gippsland has Australia's highest potential to support an offshore wind industry, which would generate electricity in the shallow and windy waters of Bass Strait. Onshore, there is potential to produce wind and solar power.

Biomass

Blending biomass with lignite for blue hydrogen production can reduce net carbon emissions further, towards zero or even negative levels. Biomass in various waste forms, such as waste timber from plantations and biowaste from agriculture, could be sourced within the region for blending with lignite.

Water

Power plants in the Latrobe Valley currently use a combination of river and ground water. Some of this water could be reallocated to meet water requirements for blue hydrogen production at a far lower rate than current power station requirements. The inherent water in lignite can be captured in the drying step to partially offset the water needs for hydrogen production. In the event that these sources were to be constrained, desalinated water piped from the coast could be used, and would cost a small proportion of the cost of hydrogen[4,5].

Large carbon storage potential

The Gippsland Basin has the largest carbon storage potential of any east coast basin. Two advanced proponents are progressing Gippsland basin CCS projects. The Victorian Government's CarbonNet has the potential to inject over 5 million tonnes per annum (Mtpa)[6]. ExxonMobil's Southeast Australia CCS Hub will repurpose depleted fields and infrastructure, also with potential for over 2 Mtpa injection[7].

Green hydrogen potential

In the longer run, Gippsland has resources which could be used to establish a large green hydrogen industry, using off-shore wind power and desalinated water. The hydrogen could be piped to the Latrobe Valley and complement blue hydrogen as a feedstock for value-adding industries. A commercial scale blue hydrogen project will provide foundation volumes to underwrite investment in hydrogen infrastructure, and stimulate demand. This would lower costs for future green hydrogen developments.

Established infrastructure

Ports

The Port of Melbourne and the Port of Hastings are accessible to Gippsland to support an industry development and facilitate exports. The HESC project has already established a pilot liquefaction facility at Hastings.

Road and rail

The region offers established rail and road links to access Melbourne, key ports, and agricultural hubs in central Victoria.

Transmission infrastructure

Existing pipeline easements could be used for pipelines to transport hydrogen and ammonia. Existing gas pipelines could also be refurbished to transport hydrogen or ammonia.

A skilled workforce

Skilled workforce

The Latrobe Valley offers a skilled workforce with potential to adapt to new industries. A manufacturing industry based on lignite and blue hydrogen could enable a just transition for workers impacted by coal generation closures, by offering well paid and interesting jobs in new high-tech industries, in addition to continued jobs in lignite mining, and preparation.

Education and training

Gippsland has several education and training institutes with the capacity to re-train the local workforce, and support research to develop and commercialise novel lignite-based products.

Strong social licence

Gippsland has a long history of hosting large industries and has a proud history of gas extraction and energy generation.

Established industry

Several large energy and resource companies have a presence in Gippsland.

New clean industries can facilitate a just transition for Gippsland

Lignite has provided Victorians with reliable inexpensive power and underpinned economic growth and prosperity in Gippsland and the Latrobe Valley for more than 100 years. It has created high paying jobs that attracted skilled workers, built communities, and stimulated investment in vital infrastructure and industries.

Decarbonising our economy to minimise the impact of climate change is now more important and urgent than ever before. The Victorian government has set ambitious targets to lower emissions and increase renewable energy.

Australia's most emissions-intensive power station, Hazelwood, was decommissioned in 2017. The scheduled closure dates of two of the remaining three power stations – Yallourn and Loy Yang A – have been brought forward by their owners, and Loy Yang B is expected to close well before the official 2047 date. These closures, starting with Yallourn in 2028, will present a major challenge to the Gippsland community. A complete shutdown of the lignite-based economy would have a major impact in the Latrobe Valley and the wider region.

A loss of direct jobs in energy would affect demand for goods and services from local businesses, which would cause indirect job losses and migration out of the region. This contraction of the economy, workforce and population would place large social and economic strains on individuals, households, towns, and reduce revenue for local government services.

As lignite power generation is phased out, large scale demand for lignite will fall away. This creates an opportunity to consider other product streams from this valuable natural resource that do not emit carbon dioxide (CO_2) in the production process or have the capacity to capture and reuse or store the carbon to achieve zero emissions.

Gippsland will benefit from clean industries

Gippsland has a great opportunity to leverage its unique features, to attract investment and skilled workers into the region, and stimulate the economy.

New clean material and chemical industries will derive revenue to offset losses from power plant closures. It can create well paid, high-tech jobs, to replace an estimated 1400 direct jobs due to power plant closures, and many more indirect jobs. Horticulture in greenhouses is labour intensive, so can provide jobs at all skill levels.

Local industries could benefit from the many low carbon products produced from Victorian lignite, while hard-to-abate sectors, such as cement, can benefit from the establishment of CCS infrastructure.

CCS will protect jobs in industries that would otherwise be high emitters and incompatible with net zero. It will require a skilled workforce to design, construct, operate and maintain CCS infrastructure and unlock new low carbon industries like blue hydrogen, creating more jobs and revenue for the region.

Transitioning to renewable energy will not be practically possible for many workers currently employed in the fossil fuel industry, because of mismatches in production locations. Workers who want to transition to renewables may need to relocate closer to renewable energy zones.

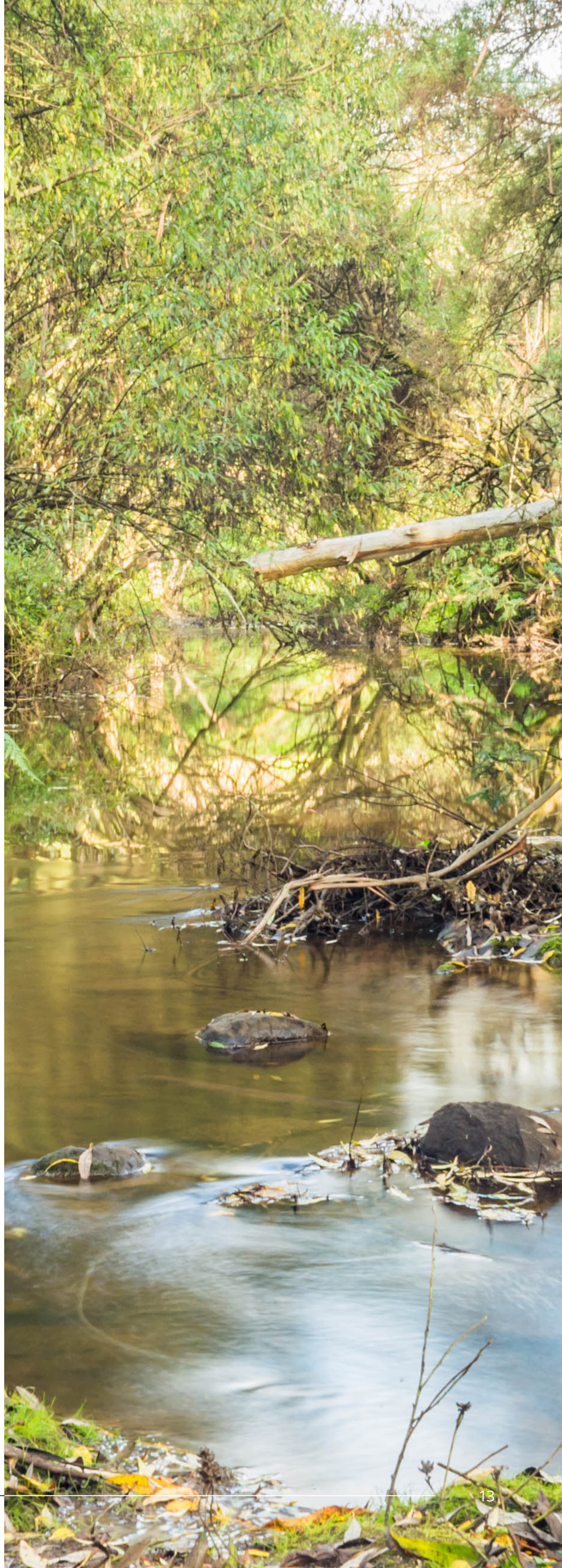
Victoria and Australia will also benefit

A blue hydrogen industry development would attract significant foreign investment and connect Victorian hydrogen to international markets. International funding and market opportunities would accelerate local hydrogen supply and demand.

Fertilisers are globally tradeable so domestic prices would track international prices, as they already do. On-shore synthetic fertiliser production from lignite can provide a stable supply of fertilisers, that are not exposed to high gas prices, thereby boosting Australia's food security and shortening extended and vulnerable supply chains.

A large range of exciting, new advanced materials, could boost exports and provide valuable feedstocks that could launch high-tech Australian industries such as solar cells, wind turbine blades, battery components, super conductors, and transistors.

Resource royalties paid by the three power generators in the Latrobe Valley to the Victorian government equals $80 million per year[8]. A new clean industry built on Victorian lignite can offset some of the royalty losses due to power station closures.



Victorian lignite is a versatile resource with many potential applications

As mined (or raw) lignite can be used directly in several applications. For example, it is used in agriculture as topsoil additive or soil improver.

Lignite can be processed into higher-value product streams, e.g., dried lignite, humic substances, char, hydrogen and CO_2. These product streams can be used in their own right, as building blocks for a range of new industries, and as feedstocks and carbon abatement pathways to enable existing industries to decarbonise and grow sustainably.

Primary lignite processing can produce diverse feedstocks

Mining, feed preparation and lignite gasification with carbon capture and storage form the foundational process steps to supply feedstocks to a range of high value industrial applications.

Lignite pyrolysis provides an alternative hydrogen production pathway that is complimentary to lignite gasification. It also provides a solid carbon by-product, char, which is valuable in its own right.

Lignite mining

Lignite is currently mined at the rate of about 30 million tonnes per year to produce 100 PJ of power at Loy Yang A and B in the Latrobe Valley. Lignite feed requirement for a blue hydrogen development is small compared to current lignite demand for power generation. A hydrogen industry producing 250,000 tonnes or 31 PJ of hydrogen per year would consume between 4.2 million and 10 million tonnes of lignite depending on the plant configuration.

A hydrogen-from-lignite industry, with CCS, provides economies of scale in mining. High value industries that require even smaller volumes of lignite would benefit from lower mining costs.

An area in the Latrobe Valley has been identified that could be mined without constraining the rehabilitation of mines following the closure of coal-fired power stations.

Pre-treatment: Crushing, blending, drying and sizing

Most of the high value lignite applications discussed in this report require crushing of mined lignite to a specified particle size distribution (PSD) and drying to a minimum moisture content. Water could be recovered from the drying process and used in the production of hydrogen.

Economies of scale can be gained through facilities serving multiple processes. While PSD and moisture specifications for applications may differ, flexible feed preparation infrastructure could produce a range of feed grades for multiple applications.

There are several prospective drying technologies. The energy requirement, water recovery potential, and technical requirements such as gasifier feed volume, feed moisture specifications and PSDs, will be critical in determining the optimal drying technologies for each application.

Gasification

Gasification of lignite with oxygen produces a product stream of hydrogen and CO_2. Hydrogen and CO_2 are separated to produce pure hydrogen. The Hydrogen Energy Supply Chain (HESC) pilot (2021-22) has proven this technology to be technically feasible.

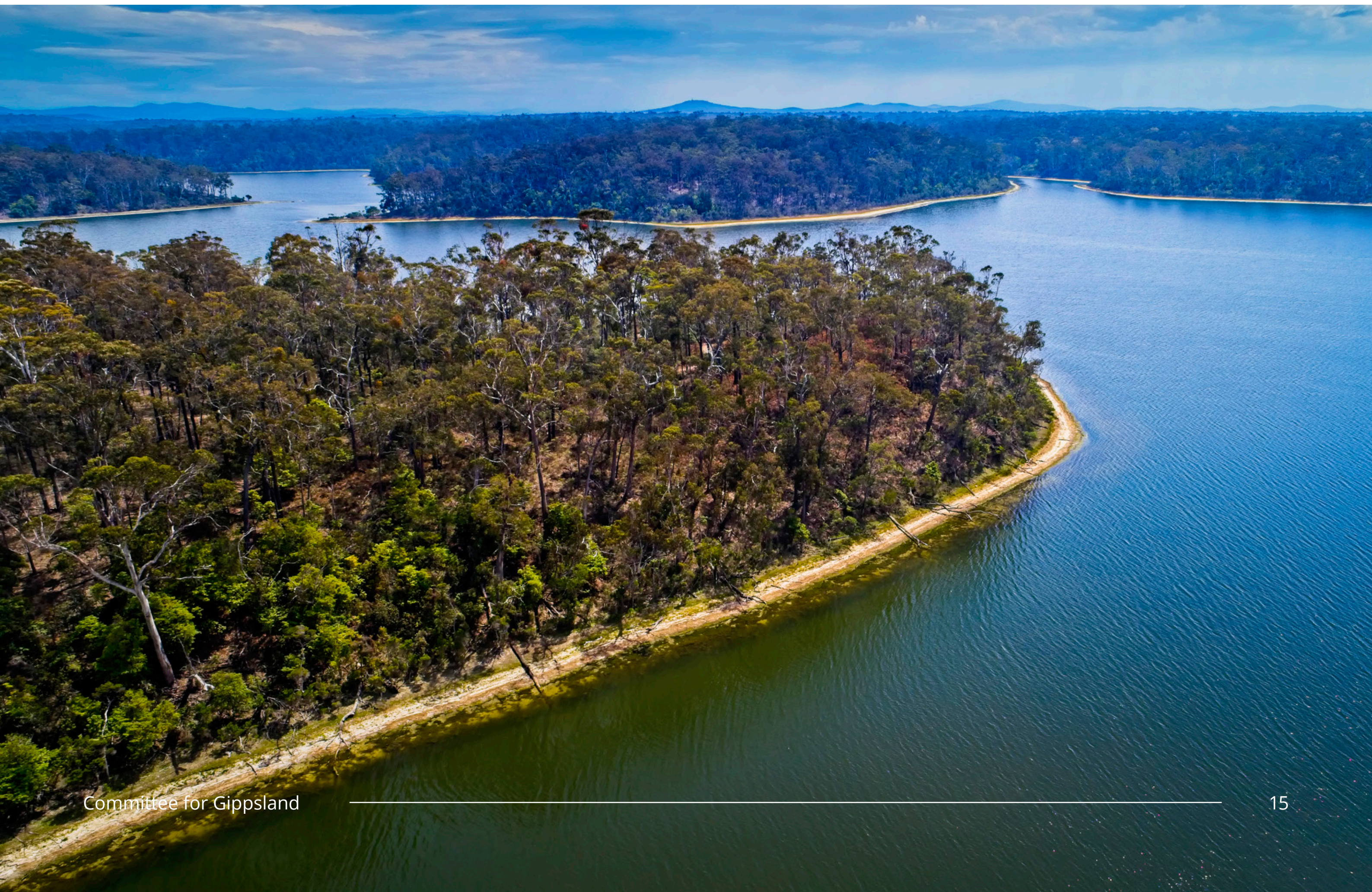
Gasification requires a pure oxygen feed stream. Air is separated into its main components, oxygen and nitrogen, using renewable electricity or onsite generated electricity, in which the emissions are captured as part of the production process. Nitrogen can be used in feed preparation as a combustion suppressant. Excess nitrogen produced from air separation can be used in ammonia production.

High grade waste heat from gasification is recovered and used for lignite drying and production of hydrogen. Excess waste heat can be exported for use in nearby industries such as greenhouses or other industries requiring heat for their processes. Sulphur from lignite is recovered and can be sold as an agricultural input.

In 2020-22, the $500 million Hydrogen Energy Supply Chain (HESC) pilot project successfully produced, liquified and shipped hydrogen produced from Latrobe Valley lignite.

In March 2023, the Japanese Government committed funding of approximately $2.35 billion to progress commercial demonstration of the HESC project. The stage 1 final investment decision (FID) is expected to be made in 2025, with first commercial production expected in 2029.

While Stage 1 can provide some domestic supply of clean hydrogen for demonstration purposes, future expansions can increase Victoria’s export capacity and provide domestic supply at scale to establish hydrogen-based industries.



Carbon capture

Capture of CO_2 is integral to the hydrogen production process and uses well-established technology. Permanent storage of the captured CO_2 is essential, not only for blue hydrogen production, but also to support Victoria's broader decarbonisation goals (e.g., for use in cement making and for negative emissions, involving direct air capture of CO_2 using renewable power).

The HESC has the capacity with current technology to reach net zero emissions and potentially net negative emissions with the addition of a small amount of waste biomass.

Blue hydrogen can establish a foundation CCS industry, providing CCS access to other industries and lowering the cost of transport and storage. By blending biomass into lignite, gasification with CCS provides a sequestration pathway for waste treatment that could result in net zero or net negative emissions for blue hydrogen production.

The Gippsland Basin is Australia's most prospective CO_2 storage resource.

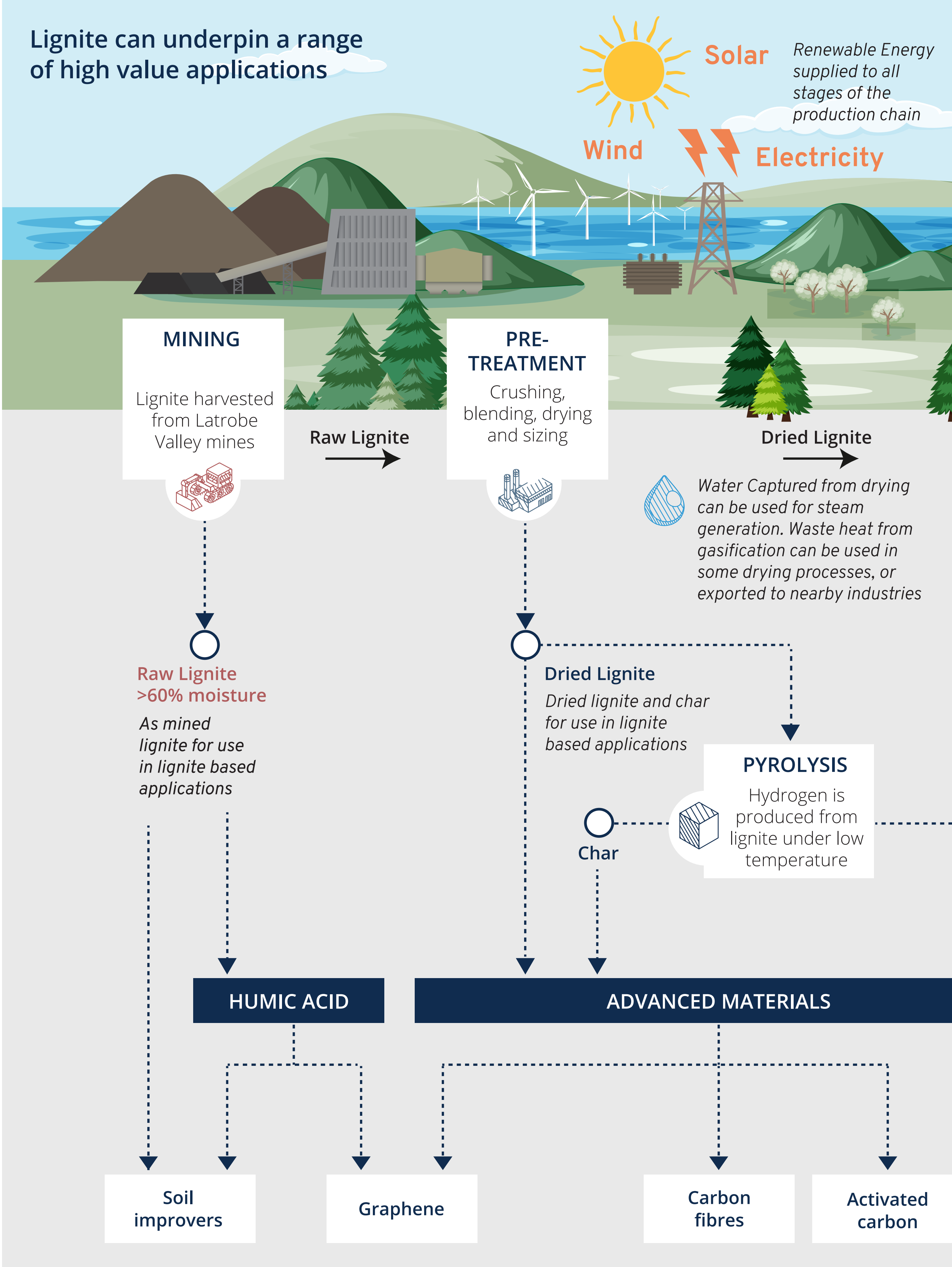
Of all the potential sites for CO_2 storage in Australia, the offshore Gippsland Basin has the largest storage capacity and the lowest cost for transport and storage. It is of strategic importance because it is the preferred storage site for Latrobe Valley emissions[9]. Gippsland has two advanced proponents developing CCS projects. Both ExxonMobil and CarbonNet (Government owned) are developing CCS projects for the Gippsland Basin.

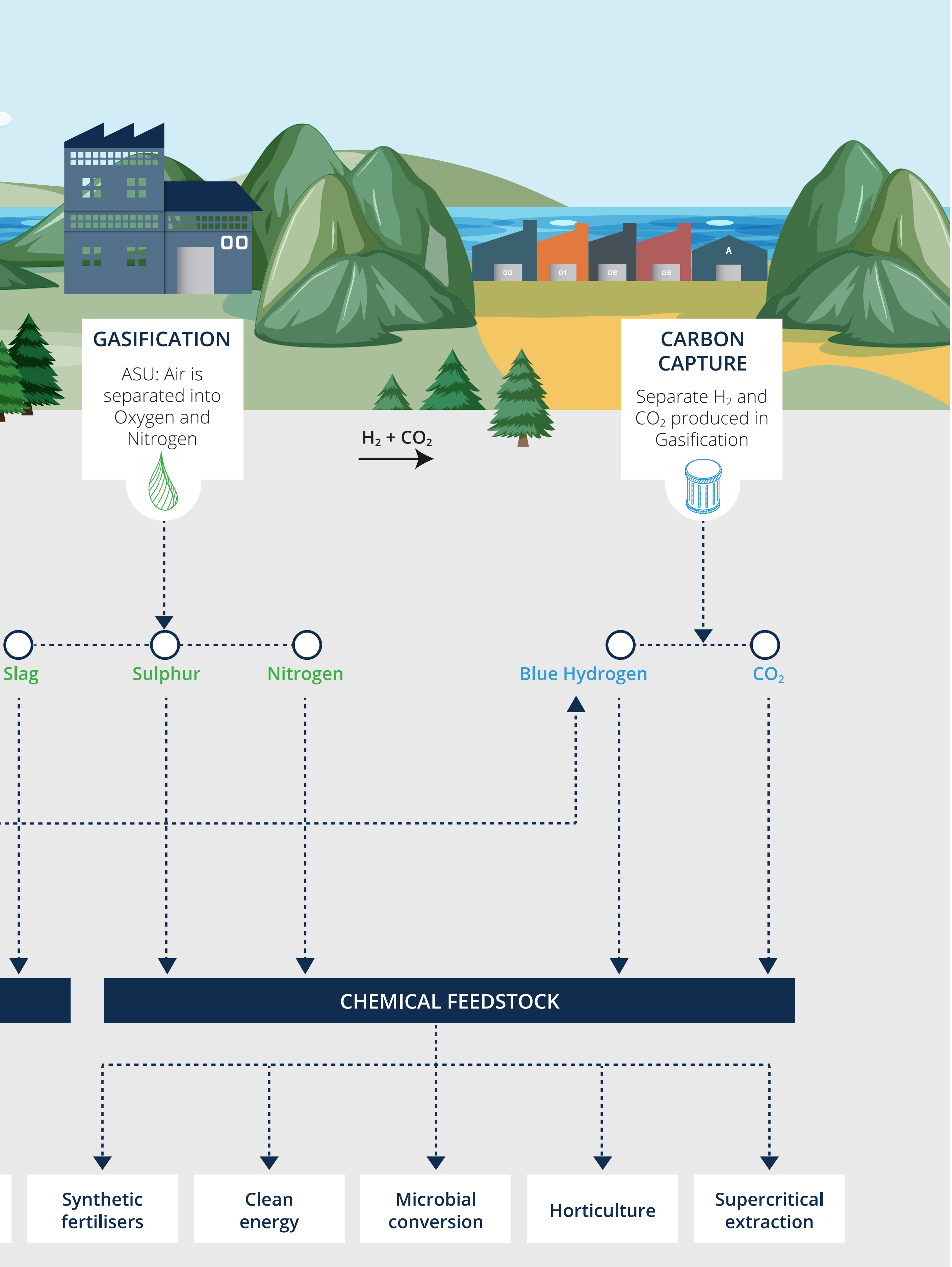
Pyrolysis

Pyrolysis operates at lower temperatures than gasification to produce a range of products including hydrogen, char, and liquid hydrocarbon products. Less hydrogen is produced than by gasification, but char can be used in various value adding applications.

The output of pyrolysis can be used to produce advanced carbon fibres, activated carbon and graphene-based products. Compared to dried lignite, using char as feedstock in lignite-based applications generally requires fewer processing steps since the char has undergone some thermal treatment during pyrolysis.

Whilst the recovery rates of hydrogen are lower for pyrolysis than gasification, most of the carbon stays in a solid form (the char) which, when the feedstock is blended with biomass, can achieve net zero without carbon capture.


Lignite can underpin a range of high value applications
Solar
Renewable Energy supplied to all stages of the production chain
Wind
Electricity
MINING
Lignite harvested from Latrobe Valley mines
Raw Lignite
PRE-TREATMENT
Crushing, blending, drying and sizing
Dried Lignite
Water Captured from drying can be used for steam generation. Waste heat from gasification can be used in some drying processes, or exported to nearby industries
Raw Lignite >60% moisture
As mined lignite for use in lignite based applications
Dried Lignite
Dried lignite and char for use in lignite based applications
PYROLYSIS
Hydrogen is produced from lignite under low temperature
Char
HUMIC ACID
ADVANCED MATERIALS
Soil improvers
Graphene
Carbon fibres
Activated carbon


GASIFICATION
ASU: Air is separated into Oxygen and Nitrogen
$H_2 + CO_2$
CARBON CAPTURE
Separate H_2 and CO_2 produced in Gasification
Slag
Sulphur
Nitrogen
Blue Hydrogen
CO_2
CHEMICAL FEEDSTOCK
Synthetic fertilisers
Clean energy
Microbial conversion
Horticulture
Supercritical extraction

A range of new industries can be created

LIGNITE BASED INDUSTRIES

Next generation carbon products from Victorian lignite can impact many aspects of modern life, covering food production, renewable energy generation and storage, automotive and aerospace, clean air and water, biomedicine, and consumer electronics.

Research is currently underway to assess the technical and commercial feasibility of producing a range of lignite-based products at commercial scale.

It is possible that lignite-based industries could be developed without a blue hydrogen industry. However, blue hydrogen provides the economies of scale in mining and feed preparation, as well as the CO_2 transport and storage infrastructure, making it easier for other low-emission lignite-based industries to become established. It is also a feedstock to many other chemical and material products.

Using as-mined lignite as feedstock

Lignite

Lignite as-mined can be applied directly to soil to improve soil structure and increase water holding capacity. As-mined lignite is already a commercial product and will be an important ingredient for the artificial topsoils used in mine site remediation as the Latrobe Valley power stations are retired.

Humic substances

Humic substances (humic acid and fulvic acid) are used in horticulture and agriculture to promote plant growth. Humic substances are also added to animal feed to support growth and weight gain, milk production in cows and egg production in poultry.

Humic acid is used in agriculture and horticulture to[10]:

- Reduce fertiliser application rates, enhance efficiency of nutrient use
- Replace synthetic plant regulators
- Increase water stress tolerance
- Decrease disease incidence
- Stimulate early growth and flowering

Humic acid is currently produced from weathered lignite in the Latrobe Valley. Research is underway to produce high-value humic substances from as-mined lignite, which would reduce production cost significantly and unlock a large-scale industry.

Other research indicates that humic acid from Victorian lignite is a rich source of carbon quantum dots, with the potential to be further upgraded to graphene oxide and graphene.

Using dried lignite and char as feedstock

Many lignite applications require some feedstock pre-treatment to separate volatiles contained within lignite from the solid carbon material (char). Char, produced through from pyrolysis provides an alternative feedstock to dried lignite. An advantage of using char is that most volatiles would have been separated during pyrolysis and captured as saleable products such as hydrogen and hydrocarbon liquids.

Graphene products

Graphene is a two-dimensional monolayer sheet of carbon atoms arranged in a honeycomb network. Graphene is nearly transparent, chemically inert, and conducts heat and electricity better than any metal.

Graphene is about 100 times stronger than steel of the same thickness. Graphene's unique properties creates the potential for wide range of applications, including reinforcement of lightweight polymers and concrete, transparent protective coating, gas detectors and flexible, transparent electronic devices, with many new applications under development.

Graphene is used to produce:

- Conductive ink
- Chemical sensors
- LED lighting
- Airplane/automobile components
- Solar cells and battery supercapacitors
- Flexible display touch panel
- High speed transistors

Graphene oxide is a water-dispersible form of graphene that is easily applied onto a substrate and then converted into graphene. Applications for graphene oxide include use in transparent films, flexible electronics, solar cells, chemical sensors, batteries and capacitors.

Graphene oxide can be formulated as an ink and 3D-printed to form complex shapes and then converted to graphene, for use as catalyst supports or tissue engineering scaffolds.

Graphene oxide is a precursor for graphene, used in:

- Hydrogen storage
- Ion conductors
- Nanofiltration membranes

Carbon quantum dots are a microscopic form of graphene oxide which behave as light emitting semiconductor crystals. They have a broad range of potential applications in the field of energy conversion and storage, and in biomedicine. Lignite is high in the blue spectrum quantum dots, the most valuable.

Carbon quantum dots are used in:

- Photovoltaic devices
- Rechargeable batteries
- Biosensors
- High-performance light-emitting devices
- High-density hydrogen storage
- Super-capacitors with high energy densities

Production of graphene largely involves splitting of graphite into individual sheets, either mechanically or chemically. Extraction of graphene from graphite, via graphene oxide or microdots using a solution-based method, is widely used. This method involves toxic and potentially explosive chemicals.

Recent research has shown that graphene oxide and quantum dots can be extracted from dried lignite or char, produced through pyrolysis.

Advanced carbon fibres

Carbon fibres contain at least 92 percent carbon and have diameters of 5-10 microns (μm), with high tensile strength, low densities, and good thermal and electrical conductivity. Thousands of carbon fibres are bundled together and formed into woven textiles, then fabricated into composites for use.

Carbon fibre composites are strong lightweight materials used in:

- Aircraft
- Automobiles
- Boats
- Machine parts
- Sporting equipment
- Wind turbine blades

Research has demonstrated that carbon fibres can be produced with up to 50 per cent carbon from Victorian lignite. More research is needed to develop improved lignite extracts and optimise carbon fibre production conditions to meet industry specifications.

Activated carbon

Activated carbon is a form of carbon processed to contain tiny pores that increase the surface area available for adsorption or chemical reactions. It is used to filter contaminants from water and air, and is found in many applications in water treatment, air cleaning, CO_2 capture, pharmaceuticals, chemicals, and food and beverage production.

With growing concerns over environmental pollution and the negative effects of air and water pollution on health and the environment, there is increasing demand for effective solutions to purify air and water. Activated carbon is widely recognised as a highly effective material for removing impurities from air and water, making it a popular and growing market.

Activated carbon is used in:

- Water treatment
- Air cleaning
- CO_2 capture from the atmosphere
- Pharmaceuticals, chemicals
- Food and beverage production

Activated carbon is typically produced from bamboo, coconut husk, willow peat, wood, coir, coal, or petroleum pitch. While the activated carbon market is relatively mature, Victorian lignite could become an attractive feedstock for specialised activated carbon products. For example, Monash University has recently patented and licensed a novel method for producing activated carbon monoliths from Victorian lignite. Activated carbon monoliths consist of large number of parallel channels than provides high contact efficiencies and significantly lower pressure drop than powders or granules. This unique configuration is produced without using chemical binders, representing a distinct advantage for Victorian lignite over manufacturing monoliths from conventional activated carbon feedstocks.

Manufacturing of carbon monoliths is under way for use in water treatment. A variety of other opportunities exists, including scrubbing CO_2 from the atmosphere at low cost.

GASIFICATION-BASED INDUSTRIES

By-product streams from gasification include hydrogen, nitrogen, carbon dioxide, sulphur and waste heat. While hydrogen is the primary high value product, the by-products could be combined or used directly in inter-related industries to produce valuable products that could be consumed domestically and globally.

Hydrogen

While renewable electricity will be the dominant supply of clean energy under a net zero economy, electrification cannot decarbonise all fuel uses or sectors. Hydrogen can play a critical role as a clean energy source for hard-to-electrify applications such as long-distance transport, industrial heating, and in chemical manufacturing.

Growing clean hydrogen supply and demand is a 'chicken and egg' challenge. There is a need to simultaneously develop supply, market demand and key infrastructure to transport hydrogen from source to use.

Blue hydrogen from lignite with CCS will create a stable clean hydrogen source and distribution infrastructure, which will stimulate local demand and support the introduction of green hydrogen as it becomes available. Gippsland's earliest opportunities to supply domestic demand could come if existing uses of grey hydrogen convert to blue hydrogen and derivatives, e.g. industrial chemicals, ammonia and urea.

Ammonia

The Haber-Bosch process is the primary method in producing ammonia from nitrogen and hydrogen. Blue hydrogen from lignite gasification produces excess nitrogen, which can be utilised in ammonia production. Global ammonia markets are well established, unlike hydrogen trade, which is still in its infancy.

Synthetic Fertilisers

Synthetic fertiliser production from ammonia is the most prospective near-term domestic use of hydrogen in the Latrobe Valley for several reasons.

Low technical risks: Ammonia and fertiliser production are established industrial processes. Market demand is currently met through imported fertilisers produced from grey hydrogen with high CO_2 emissions.

Production synergies: Nitrogen, sulphur and CO_2 are by-products from blue hydrogen production and are essential feedstocks for ammonia, urea and other synthetic fertiliser production.

Locational advantage: Onshoring production provides a more secure supply of an essential input to an industry that is crucial to Gippsland and Victoria. The Latrobe Valley can service nearby agriculture regions, being well connected through established transport infrastructure.

Domestically produced urea provides a lower emissions alternative to imported urea

Urea is used as an agricultural fertiliser. Without urea (or alternative synthetic fertilisers) crop production could fall by 30-40 per cent. Urea production currently releases considerable CO_2 to the atmosphere, and urea releases both N_2O and CO_2 to the atmosphere after application to soil. N_2O is a greenhouse gas with a global warming potential 265 to 298 times that of CO_2 over a 100-year period.

Most of the CO_2 from applied urea is mineralised in the soil; it is a minor source of emissions compared to CO_2 from production and N_2O from application[11,12]. Domestically produced urea can include a commercially available fertiliser additive that has been proven to reduce N_2O emissions by 40 per cent and increase urea efficiency, resulting in decreased application rates hence lower emissions. Most offshore imports are produced from emissions-intensive grey hydrogen and are unlikely to include an inhibitor agent to suppress GHG emissions.

CO_2 utilisation

To qualify as a low emissions technology, the CO_2 produced in gasification must be captured and prevented from reaching the atmosphere. Hydrogen production from lignite gasification will require a proven carbon capture, utilisation and storage (CCUS) solution. In the utilisation process, captured CO_2 is converted into products with higher value.

This includes:

- the direct use of CO_2 in glasshouse horticulture to boost plant growth,
- production of valuable extracts using supercritical CO_2 as a solvent,
- use of CO_2 as chemical reactant to produce products that will have no or limited CO_2 release into the atmosphere, for example urea,
- direct injection of CO_2 into fresh concrete using Canadian technology, CarbonCure[13]. Once injected, the CO_2 undergoes a mineralization process and becomes permanently embedded in the concrete, and
- microbial conversion of CO_2 and hydrogen to produce food grade protein and bioplastics.

Although most captured CO_2 will be stored, converting a portion into higher value products would help to offset the cost of CCS.

Bio-sequestration and gasification with CCS

Bio-sequestration is a natural process that involves removing CO_2 from the air and storing it in organic matter, for example as trees in plantations. Bio-sequestration requires substantial land use. Most carbon is captured within the first 15 years of establishing a plantation.

Biomass gasification with CCS provides a mechanism to permanently capture and store sequestered plantation carbon at large scale and derive revenue from hydrogen produced in the process. The same land can then be replanted every 10-15 years and the CO_2 captured and permanently stored underground can be ‘banked’ at each harvest interval. Sequestration projects can receive carbon credits every time that trees are replanted. Replanting, harvesting, gasification and permanent CO_2 storage at an interval of ~15 years minimise the risk of the loss of CO_2 contained in the biomass to fire or other natural disaster is minimised.

Lignite-based products can support existing industries to decarbonise and grow sustainably

Existing industries in Gippsland can benefit from a range of products produced locally from Victorian lignite, while CCS infrastructure provides a sequestration pathway for excess biowaste.

More research is required for many of these applications to prove their technical and commercial feasibility.

	WASTE HEAT	CO2	RAW LIGNITE	CLEAN HYDROGEN	CCUS
 HORTICULTURE	✓	✓	✓		
 AGRICULTURE		✓	✓	✓	✓
 FOOD PROCESSING		✓	✓	✓	
 TIMBER AND PAPER			✓	✓	
 SUSTAINABLE BUILDING		✓	✓	✓	✓

HORTICULTURE

Waste heat can provide heat and moisture in greenhouses to accelerate plant growth.

CO_2 applied directly in greenhouses promotes plant growth. While some CO_2 will be released to the atmosphere when plants decompose, most of the organic matter will be utilised as compost. Excess biowaste can be blended with lignite to recycle CO_2 back into the production chain. CO_2 currently used in glasshouses is produced by burning natural gas or LPG. CO_2 from blue hydrogen would provide an alternative supply for growers in Gippsland.

Raw lignite can be used as a seedling medium, while humic acid can promote plant growth.

AGRICULTURE

Lignite and humic acid can be added directly to improve soil structure and water holding capacity. When used in combination with chemical fertilisers such as urea or superphosphate, humic substances reduce the amounts of fertilisers required by as much as half, leading to much better environmental outcomes. Humic acid is used as a feed supplement for animals.

Clean hydrogen or ammonia can be used to power heavy farm machinery.

Fertilisers made from clean hydrogen and CO_2 could reduce reliance on imported fertilisers, typically produced from grey hydrogen without CCS.

While some biowaste may be best utilised as compost to improve soil carbon, gasification with **CCUS** provides a negative emissions pathway for excess biowaste or biomass.

FOOD PROCESSING

CO_2 can be used in supercritical fluid extraction to extract essential oils, colourants and antioxidants from locally produced fruits, vegetables and flowers. Vanillin, an artificial vanilla flavourant could be extracted from lignite by using CO_2. CO_2 and hydrogen could produce food grade protein through microbial conversion.

Lignite can be used to make activated carbon for water purification and food and beverage production.

Clean hydrogen can provide industrial heat in dairy production.

TIMBER AND PAPER

Raw lignite can be used as a seedling medium and substrate, for artificial topsoil. Humic acid can be used as soil improver to establish plantations.

Clean hydrogen can provide Industrial heat in pulp and paper-making.

SUSTAINABLE BUILDING

Direct CO_2 injection into concrete can reduce CO_2 emissions during construction[13].

Advanced carbon materials such as carbon fibre produced from **lignite** can replace the use of steel, which is emissions intensive to produce.

Slag from gasification can be used as supplementary material in concrete to replace a portion of cement, or used as road base, reducing the volume of gravel derived from quarrying operations.

Cement production can be decarbonised by capturing and storing CO_2 (a by-product) through the **CCUS network**, and **hydrogen** can provide high temperature industrial heat to replace natural gas.

Negative emissions can be achieved when spent timber from the building industry is gasified, and the resulting process CO_2 is captured and stored.

Global demand for advanced carbon materials is growing

Product demand is largely driven by growth in end-use industries and the unique product features that makes these products highly sought after.

For example:

Humic acid: increasing need for organic fertilisers and bio-stimulants, and increased demand from China to meet the needs of their growing pharmaceutical industry[14].

Graphene: increased use in aircraft and vehicle production and on-going R&D into new applications[15].

Carbon quantum dots: increasing adoption of quantum dots in display devices due to advantages of quantum dots over conventional displays[16].

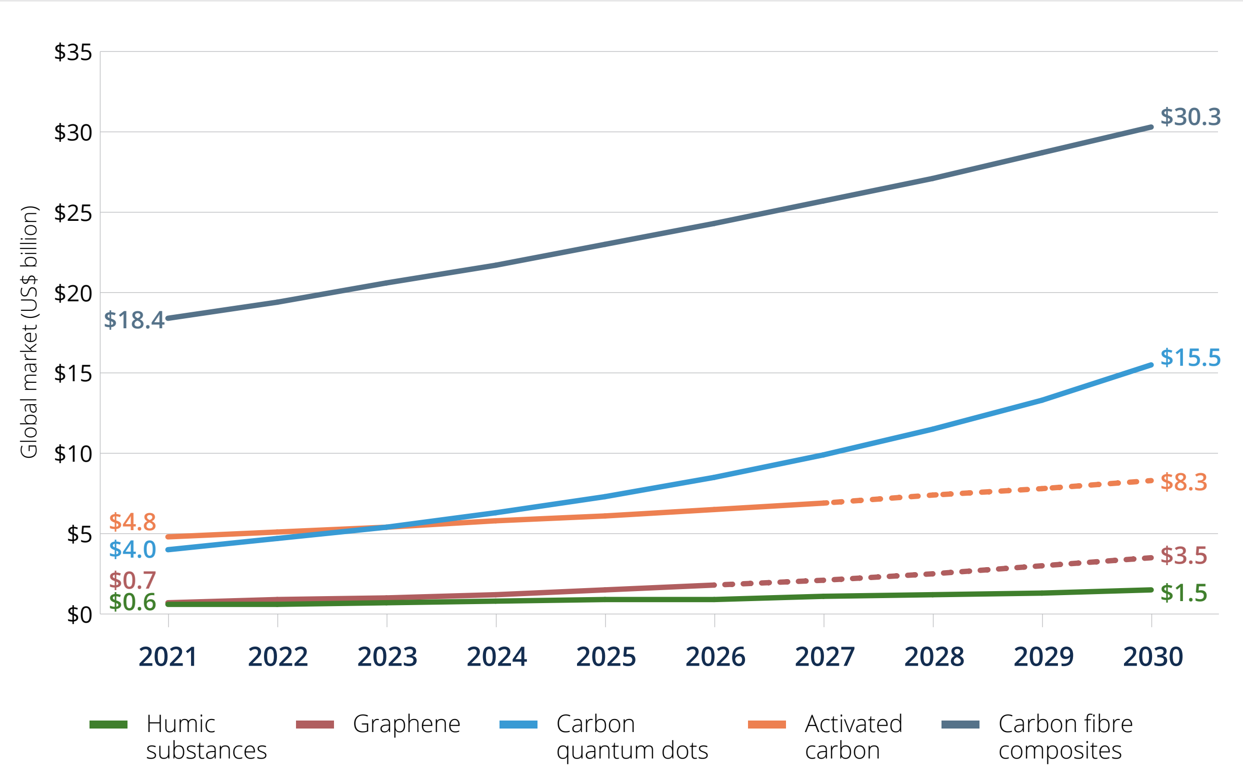
Activated carbon: increasing demand for clean air and water[17].

Carbon fibres: increased aircraft and vehicle production and increased demand for wind turbines[18].

Production technologies for some advanced carbon materials such as graphene and carbon monoliths are still in their infancy and large-scale commercial supply is still some way off. Victoria can leverage its lignite resource to secure its position and drive development of these emerging markets.

COMPOUND ANNUAL GROWTH RATE

12.0%	19.0%	16.0%	5.7%	6.3%
Humic substances	Graphene	Carbon quantum dots	Activated carbon	Carbon fibre composites



Action is needed to bring these opportunities to life

Building a clean lignite-based industry will require concerted and sustained effort from governments and industry

Commercially focussed research and development funding is urgently needed to realise the full economic potential of this important resource. Some applications are technically feasible, while others are in their infancy, and more research is required.

While it is possible to develop some lignite-based industries without a blue hydrogen industry, it would be challenging without the economies of scale in mining and feed preparation, that a blue hydrogen facility would bring.

CCUS is a necessary technology to maintain our current lifestyles and transition to a net zero economy. Essential industries will require storage for CO_2 captured from industrial processes or direct air capture (to offset unavoidable emissions). Studies have shown that the Gippsland Basin has extremely high potential storage capacity.

Many of these low carbon applications highlighted in the report (e.g., hydrogen for energy and blue urea) may not initially be able to compete with cheaper high emission alternatives without policies that would incentivise or mandate their use.

Local and foreign investment will need policy certainty and assurance that key inputs (lignite, carbon storage, renewable power, water and land) would be made available.

The Gippsland community has a long and proud history of energy production. Yet, community support for new industries must still be developed. Continued use of fossil fuel (lignite), and the need for CCS, will heighten the social licence challenges associated with a clean lignite industry.

Government, in coordination with the private sector, should start work on a net zero-compatible lignite industry strategy and plan, to actively encourage international and domestic investment in development of a world class resource. Actions under this plan should include:

- Provide funding, to support research and development of lignite processing technologies, and lignite-based applications.
- Establish a commercial-scale blue hydrogen industry which would catalyse development of clean lignite and CCS-using industries.
- Secure access to lignite and water resources for blue hydrogen production and other lignite-based industries.
- Secure access to land for industrial hubs and infrastructure to connect the production facilities to ports and demand centres.
- Introduce policy measures to support uptake of low emission alternatives to compete with cheaper emissions-intensive commodities, through a combination of mandates and incentives.
- Actively attract investment to those opportunities.
- Grow community benefits and support for blue hydrogen and CCS as well as alternative lignite industries. Actively engage the local community through education sessions and active consultations.
- Invest in training opportunities locally, including through TAFE and Gippsland and Federation University.

Endnotes

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