Australia's Bioenergy Roadmap

Appendix – Resource Availability

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Australian Government
Australian Renewable Energy Agency

ARENA

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1. Key findings

Australia’s potential bioenergy resources are significant:

- **Australia’s theoretical resource potential for bioenergy is estimated at over 2,600 PJ per year.** Though its whole potential is not accessible due to competing uses, accessibility and sustainability considerations, it represents more than ten times Australia’s current bioenergy supply.
- **Queensland and New South Wales offer the greatest resource potential,** with 30 and 21 per cent of Australia’s total resource potential respectively.
- **Organic wastes and residues are the largest resource opportunity** for developing the industry in the short term. They represent 37 per cent of Australia’s current potential. They are less expensive to produce than primary resources such as agricultural and forestry resources, have fewer competing uses and pose fewer socio-economic and environmental-sustainability obstacles.
- **Agricultural resources can complement the wastes and residues opportunity.** They have the largest potential at 41 per cent of Australia's resource potential, but they are more expensive to produce than wastes and have competing uses. Still, a more intensive, sustainable and value-add utilisation of these resources is possible. Some of Australia’s agricultural resources (such as canola and tallow) are currently exported to overseas markets with robust sustainability frameworks in place. Also, other agricultural resources are already used for bioenergy production in Australia, such as sorghum or sugarcane. These have scope to be more intensively used for bioenergy.
- **The forestry sector’s main contribution is likely to be through plantation forests,** most of which are certified sustainable, forestry residues and wood-processing wastes. Overall, forestry accounts for 22 per cent of total resource potential. Given the low community support for harvesting native forests, this resource is an unlikely contributor to the growth of Australia’s bioenergy industry.

The exact magnitude of Australia’s resource potential requires further assessment to account for supply constraints. The preliminary resource assessment in this Roadmap does not consider factors that would constrain supply such as resource quality, competing uses, accessibility and collection costs. A number of potential industry intiatives have been identified to address resource availability issues:

- **Australia’s resource potential could be further expanded through strategies that minimise competition for land from other uses.** These strategies include increasing crop yields (tonnes per hectare), integrating energy crops with other crops on agricultural land (intercropping), and using marginal lands for energy cropping.
- **A sustainability framework would ensure resources used for bioenergy in Australia are sustainably sourced.** To promote positive socio-economic and environmental outcomes, Australia’s bioenergy industry would benefit from a sustainability framework.
- **Bioenergy hubs (biohubs) may also provide a solution to multiple barriers for further development of bioenergy.** They could, for example, help aggregate the supply of bioenergy resources and provide other benefits. Bioenergy hubs can also allow for economies of scale that will ultimately result in bringing down the cost of producing bioenergy. A detailed resource assessment can be used to inform the establishment of bioenergy hubs, where projects are co-located with available resources, existing infrastructure and multiple utilisation options.

2. Appendix overview

This appendix provides a preliminary assessment of Australia's resource potential for bioenergy. It is based on information currently available and stakeholder input gathered as part of the consultation process.

Specifically, it:

- reviews available information for an accurate assessment of Australia's resource potential
- outlines Australia's bioenergy resources and current uses
- assesses Australia's theoretical resource potential[1]
- discusses factors such as resource quality, sustainability and supply chain aspects to derive an assessment of the current technical and economic potential
- identifies opportunities and constraints to expand this potential in the future.

3. Available data and limitations

This Roadmap has leveraged information from the ARENA-funded Australian Biomass for Bioenergy Assessment (ABBA) project for its resource assessment.

This was complemented with production information from the Australian Bureau of Agricultural and Resource Economics and Science (ABARES) for forestry and agricultural resources.

The ABBA project is collating data on biomass resources as Australia's first central and national source of information [2]. In addition to the ABBA project, other studies have looked at Australia's resource potential at a regional level or at a national level for specific bioenergy markets.

Image: MSM Milling's canola processing facility in Manildra, NSW

[1] The theoretical resource potential is the maximum amount of resources that can be considered available for bioenergy production, as defined by the IEA [1]. This Roadmap has estimated Australia's theoretical resource potential based on current levels of production. This does not, however, consider factors that act as a barrier or enabler to ensure consistent supply.

The Australian Biomass for Bioenergy Assessment (ABBA) project

The ABBA project, funded by ARENA, began in 2015. It collates data on the different types, volumes and locations of organic wastes and residues that may be used for bioenergy. The project is led by AgriFutures Australia (previously the Rural Industries Research and Development Corporation) in collaboration with state governments.

The purpose of the ABBA project is to enable better links between biomass suppliers and end users to help local businesses maximise the value of organic material that would otherwise be destined for landfill disposal or other low-value uses.

Information collected through the ABBA project is geospatially presented on the Australian Renewable Energy Mapping Infrastructure (AREMI) platform as a central information source. This enables bioenergy industry stakeholders to map resource data alongside existing network and transport infrastructure, land use capability and demographic data.

Notably, the ABBA project does not cover the technical, economic and sustainability assessments of Australia's biomass resources.

Although there have been efforts to ensure consistency, different reporting methodologies and resource types between states make it difficult to accurately assess Australia's resource potential. The ABBA project has applied some sustainability constraints, such as Queensland applying a 2 t/ha stubble retention for cropping residues to maintain soil cover. However, it does not provide information about additional factors that may limit supply, such as economic or technical feasibility.

Given the ABBA project scope did not extend to primary resources, this Roadmap has also used production data (10-year average from 2008–09 to 2017–18) of forestry and agricultural resources from ABARES [3].

Potential assessment scope expansion

Notwithstanding these limitations, the ABBA project can be considered a first step in providing an assessment of Australia's resource potential for bioenergy. Already providing a good foundation, its scope may be expanded to provide a more accurate and comprehensive view of Australia's resource potential.

Improvements to the information available through the ABBA project could include:

- **Covering more resource types:** Consideration could be given to expanding the resources to include primary feedstocks (forestry and agricultural resources) in coordination with industry associations such as the Australian Forest Products Association and the National Farmers' Federation.
- **More information about resources:** This could include information about the resource quality, competing uses, accessibility and costs of the resources. This could be further enhanced by considering Australia's sustainable resource potential that accounts for socio-economic and environmental considerations.
- **Consistency:** Harmonising assessment frameworks and methodologies across the states to ensure consistent reporting.

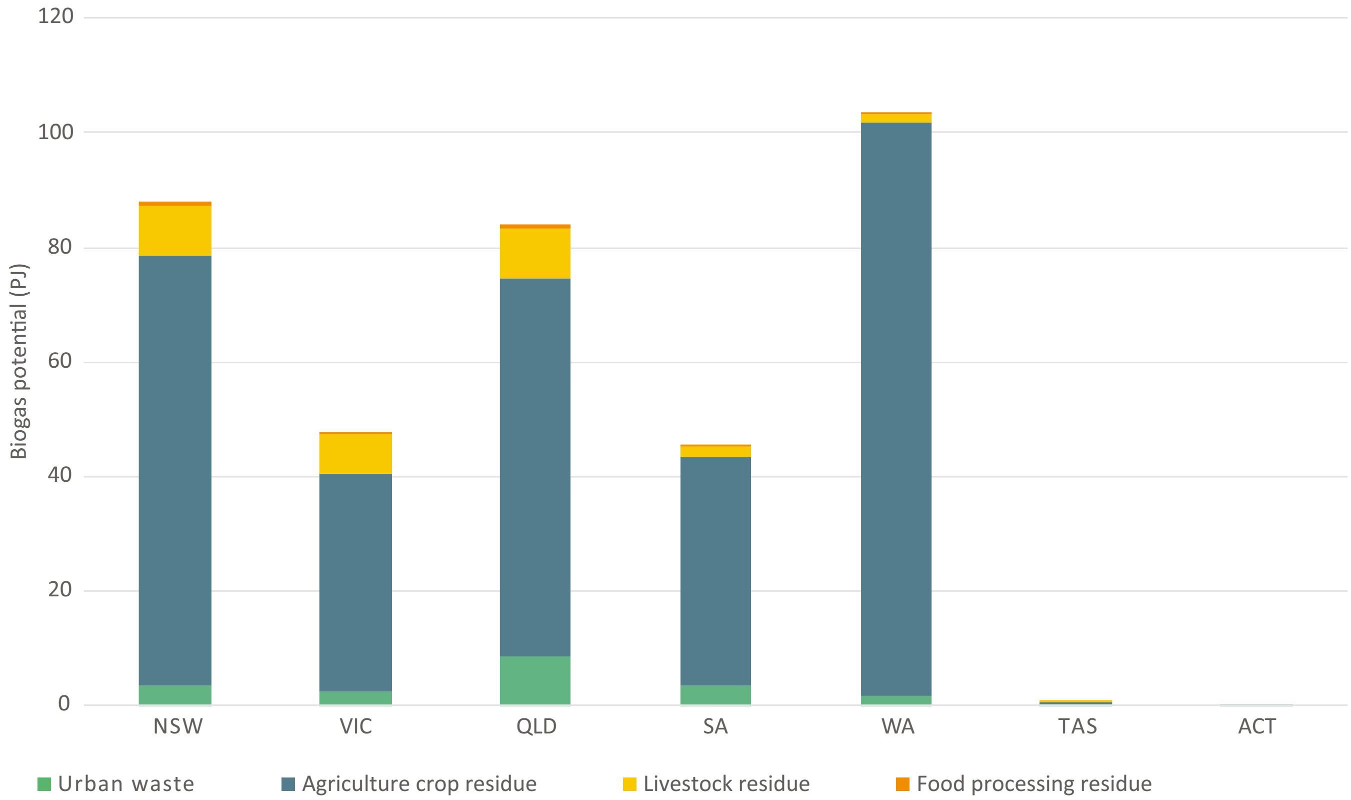
A detailed resource assessment including the above would assist project developers, investors and policy makers in understanding supply risks to support Australia's bioenergy industry.

In addition to the ABBA project, other studies have looked at Australia's resource potential at a regional level or at a national level for specific bioenergy markets.

Previous regional studies include the Victorian Government's Bioenergy for Agriculture report, published in 2010. This study aimed to improve the understanding of bioenergy opportunities for Victorian farmers and identify bioenergy resources that could be produced by Victorian farmers [6]. In 2015, A Bioenergy Roadmap for South Australia identified existing and potential sources of biomass on a geographic basis to identify potential bioenergy hubs across South Australia. However, this study did not consider environmental and social impacts nor the likelihood of landowners making these resources available [7].

A 2017 study by Deloitte, Decarbonising Australia's gas distribution networks, estimated Australia's biogas potential to be 371 PJ [8]. Agricultural crop residues are the most important biogas resources (86 per cent), followed by livestock residues (8 per cent) and urban waste (5.4 per cent). Feedstocks are mainly concentrated in Western Australia, New South Wales, and Queensland. These three states account for approximately 75 per cent of the biogas potential [8] (see Figure 1).

Figure 1 – Estimated biogas potential by feedstock and state



Source: Deloitte Touche Tohmatsu [8]

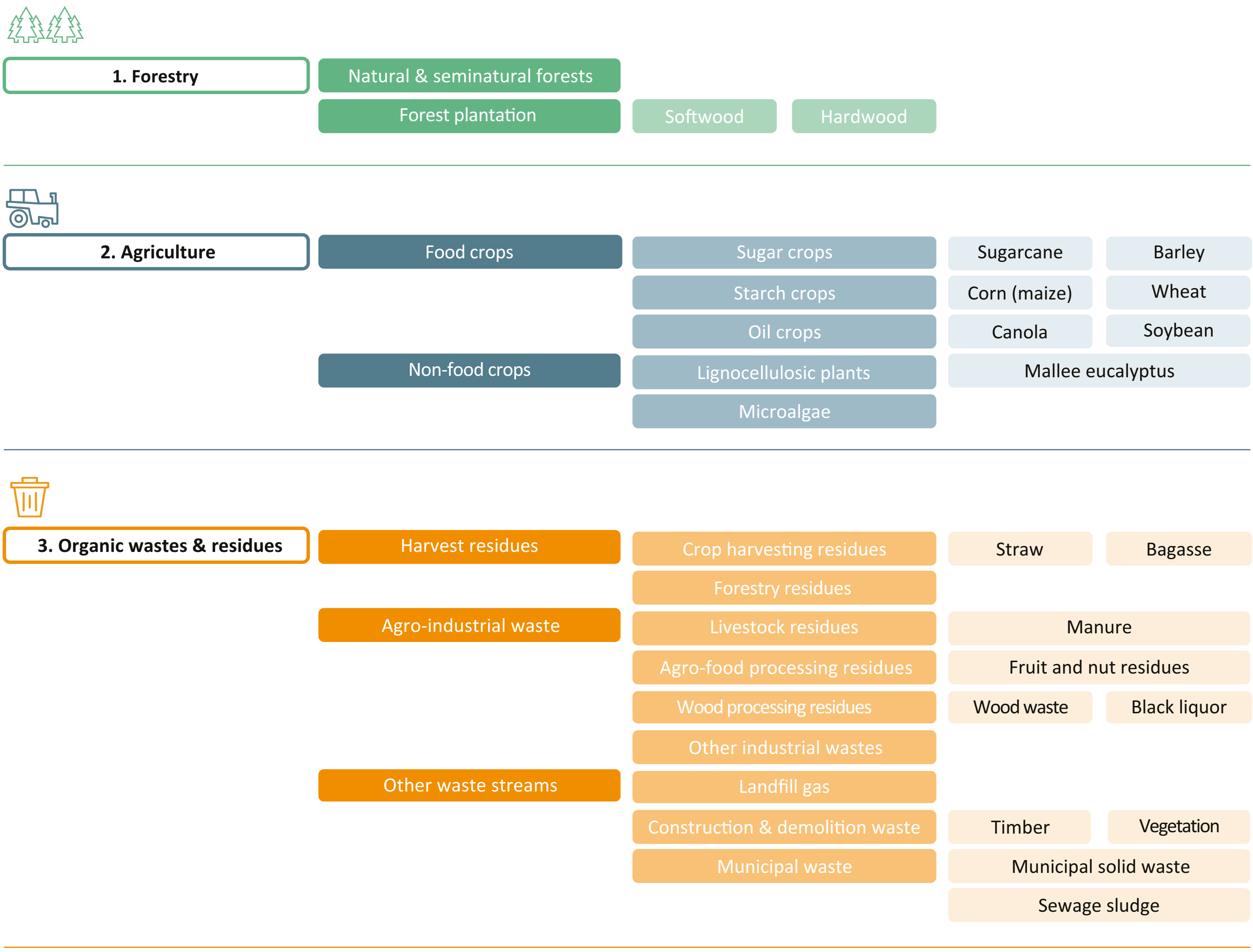
The *National Waste Report 2018* stated that Australia produced 30 million tonnes of organic waste in 2016-17. However, according to information collected through the ABBA project, around 82 million tonnes of waste and residues may be available for bioenergy production. This discrepancy may be due to the wider reporting scope of the ABBA project, which included more comprehensive assessment of the crop harvest and forestry residues.

4. Australia's resources and current uses

Bioenergy resources can be divided into three principal categories: forestry, agriculture and organic wastes and residues.

Australia has a variety of resources for bioenergy with established agricultural and forestry industries. Resources for bioenergy include biomass and combustible components of municipal solid wastes (MSW). These have been classified into three principal categories based on their origin (see Figure 2). Forestry and agricultural resources are considered primary resources, whereas organic wastes and residues are by-products from other processes.

Figure 2 – Bioenergy feedstock categories



Source: IEA [1]

Forestry

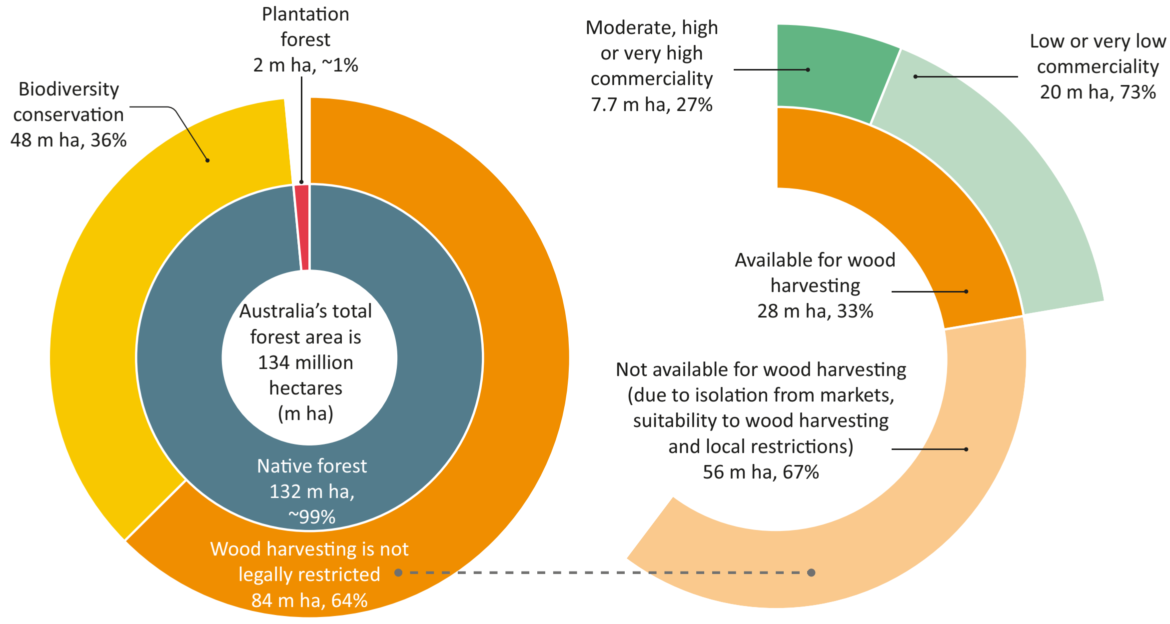
Forestry comprises wood harvested from native forests and plantations.

Globally, forestry is the oldest resource for energy production. Firewood has traditionally been used for residential heating and cooking and is a significant resource in developing countries.

Australia has 134 million hectares of forests, covering 17 per cent of Australia's land area. 132 million hectares of Australia's forest area are native, comprising mainly eucalypt and acacia species.

However, taking into account biodiversity conservation, local restrictions, climate, accessibility and proximity to timber and wood-processing industries, only 7.7 million hectares are considered to be moderately, highly or very highly commercially viable for harvesting (see Figure 3).

Figure 3 – Australia's forest area available for wood harvesting



Source: Commonwealth Government [9]

Despite native forests comprising a significantly larger share of Australia's harvestable area, the majority of wood comes from commercial plantations. Australia has close to two million hectares of commercial plantations, comprising hardwood and softwood species. In 2017-18, 88 per cent of Australia's log harvests were from commercial plantations [10].

In Australia, log harvests are mainly used for the provision of paper products, wood chips and sawn timber for construction, infrastructure and manufacturing [11].

Australia's current use of forestry resources for bioenergy

According to Australian Energy Statistics, firewood and industrial fuelwood are reported under 'wood and wood waste'. This accounted for 89.2 PJ of primary energy supply in 2017-18 (23% of total primary renewable energy supply and less than 2 per cent of total primary energy supply) [12].

Industrial fuelwood includes wood products and wood waste generated during wood processing. Examples of industries using industrial fuel wood include wood and wood products and pulp, paper and printing industries. Firewood is collected from native forests, plantations and agricultural land for residential heat generation. Permits are used to protect threatened species and ecological communities from the impacts of wood collection from native forests.

Between 2011-12 and 2015-16, the average consumption of wood for energy production was 5.6 million cubic meters per year. Firewood used for residential heating is an important segment of Australia's forestry sector, averaging 4.3 million cubic meters annually [9].

Agriculture

Agriculture can be divided into food crops, including sugar, starch and oil crops, and non-food crops, including lignocellulosic plants (woody biomass).

Australia's commercial crop production includes:

1. Sugar crops: sugarcane and barley
2. Starch crops: wheat, oats, corn and grain sorghum
3. Oil crops: canola, soybean and sunflower.

Nearly all of Australia's agricultural resources are used to produce food products for domestic consumption or are exported as raw products.

Crop industries make an important contribution to the Australian economy. The annual gross value of production of grains and oilseeds is around $9 to $13 billion and sugar is $1 billion [13].

Non-food crops include short rotation coppice, which are fast-growing trees such as Mallee eucalyptus. Woody biomass can be used for salinity control on agricultural land. This was the main motivation for planting Mallee eucalyptus in Western Australia. However, these crops are yet to be used commercially.

Australia's current use of forestry resources for bioenergy

There is limited use of agricultural resources for bioenergy in Australia. Despite this, Australia is already sustainably producing oil crops for bioenergy, although they are being used overseas where policies are driving demand.

Around half of Australia's canola production is sold to the European biofuels market (in 2017-18 Australia produced 3.9 million tonnes of canola [3]). This canola is certified as sustainable to comply with EU requirements [14].

The United Petroleum Dalby Biorefinery in Queensland uses locally sourced sorghum to produce ethanol (76 million litre capacity) and high-value animal feed [15]. Other biorefineries use agricultural and food-processing residues.

Organic wastes and residues

Organic wastes and residues include:

1. Harvest residues from agriculture and forestry
2. Wastes and residues from food and wood processing
3. Livestock residues such as manure
4. Landfill gas
5. Wastes from municipal solid waste (MSW), construction and demolition (C&D) and commercial and industrial (C&I) sectors.

In Australia, 22 per cent of organic wastes and residues are sent to landfill and only 7 per cent are used for energy recovery [16].

According to the National Waste Report 2018, in 2016-17, Australia produced 30 million tonnes of organic waste, of which 14 million tonnes were from MSW, C&D and C&I waste streams and the remainder was from agriculture and fisheries. 6.7 million tonnes of organic waste were sent to landfill and only 2 million tonnes were used for energy recovery [16].

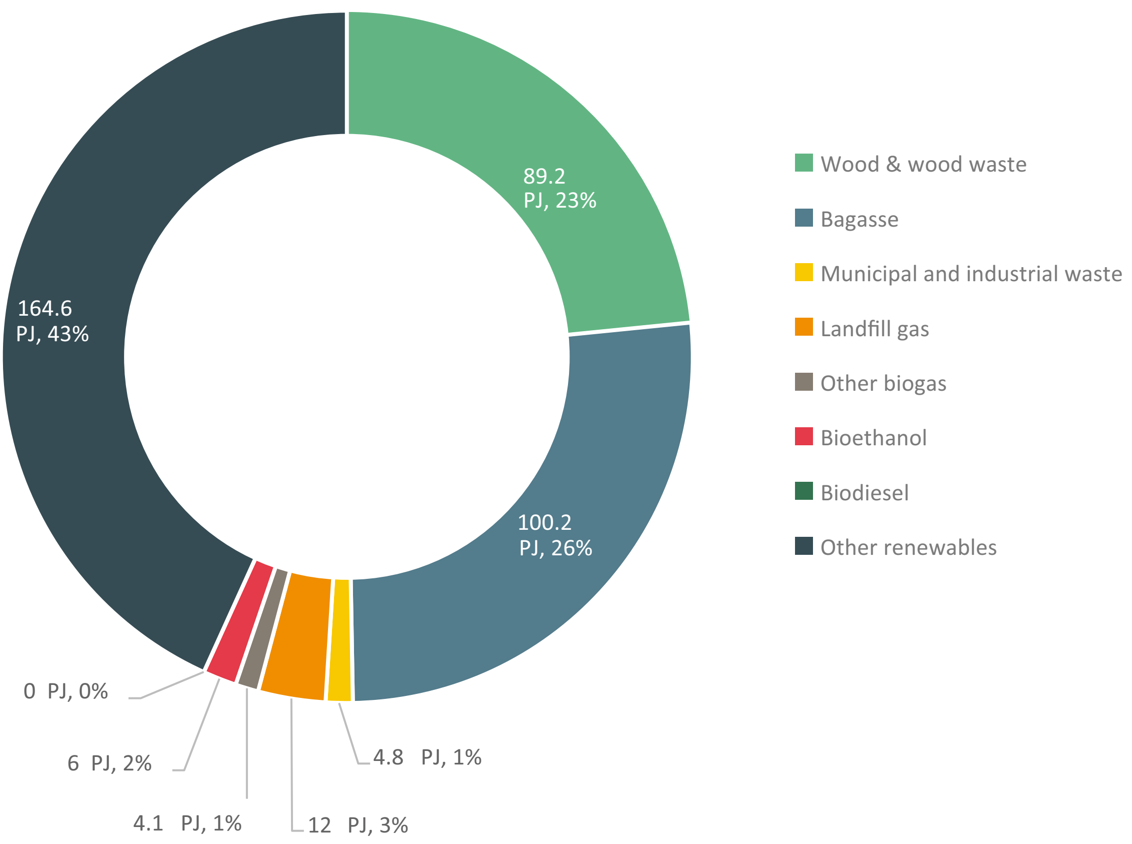
Organic wastes and residues can be recycled and composted to generate products to improve soil productivity and health. In 2016-17, 5.3 million tonnes of organic waste from MSW, C&D and C&I waste streams were recycled mainly for land rehabilitation, soil improvement and urban development. The National Waste Report 2018 did not report the fate of organic waste from agriculture and fisheries, which may have been used for animal feed or as soil cover or burnt without energy recovery [16].

Australia's current use of organic wastes and residues for bioenergy

Bagasse is the main biomass resource used for energy production. It amounts to 26 per cent or Australia's renewable energy supply. On the other hand, municipal and industrial waste only amounts to 1 per cent of Australia's renewable energy supply [12].

In 2017-18, 189 PJ of energy was generated from solid biomass (89 PJ from wood and wood waste and 100 PJ from bagasse), accounting for almost 50% of Australia's renewable energy generation (see Figure 4). Biogas (mainly captured at landfills) made up 16 PJ of energy generation [12].

Figure 4 – Renewable energy supply by fuel, 2017-18



Source: Commonwealth Government [12]

Queensland sugar mills generate 900,000 MWh of renewable electricity from bagasse, of which 425,000 MWh is exported to the national electricity grid. Organic wastes and residues are used in Australia's relatively small biofuel market. Manildra Ethanol Pty Ltd in New South Wales is Australia's largest ethanol producer (capacity of 300 million litres per year) and manufactures ethanol from waste starch, a by-product of wheat milling. The Wilmar Bioethanol plant in Queensland uses molasses and has an annual capacity of 60 million litres. Australia also has two renewable diesel plants that use cooking oils, tallow and industrial wastes [17]. Also, Australian tallow is exported overseas to be converted to renewable diesel for sale into the Californian biofuels market, where decarbonisation policies are driving demand [17].

5. Current theoretical resource potential for bioenergy

The purpose of this Roadmap's resource assessment is to indicate the magnitude of Australia's resources that could currently be available for bioenergy across the three principal resource categories.

This has been determined through looking at current production levels across these categories. In particular, for primary forestry and agricultural resources, current production levels of wood products and oil, sugar and starch crops have been factored into this assessment respectively, irrespective of their current uses (bioenergy, food or other).

Australia has a significant theoretical resource potential for bioenergy.

Australia's theoretical resource potential for bioenergy is estimated to be over 2,600 PJ per year. This represents 42 per cent of Australia's primary energy supply in 2017-18 and more than ten times Australia's current bioenergy supply.

Primary agricultural resources have the greatest theoretical potential at over 1,000 PJ per year (41 per cent of total resource potential), followed by organic wastes and residues with over 900 PJ per year (37 per cent) and lastly, forestry, with over 500 PJ per year (22 per cent).

This potential is consistent with the consultation undertaken as part of this Roadmap, where stakeholders highlighted Australia's significant resource potential for bioenergy.

Queensland and New South Wales hold the greatest resource potential, at 30 per cent and 21 per cent of Australia's theoretical resource potential, respectively.

In Queensland, this is supported by the large agricultural sector, especially sugarcane. Agriculture also shows the greatest potential in Western Australia, where most of Australia's starch and oil crops are produced.

Organic wastes and residues make up the majority of theoretical resource potential in New South Wales and South Australia.

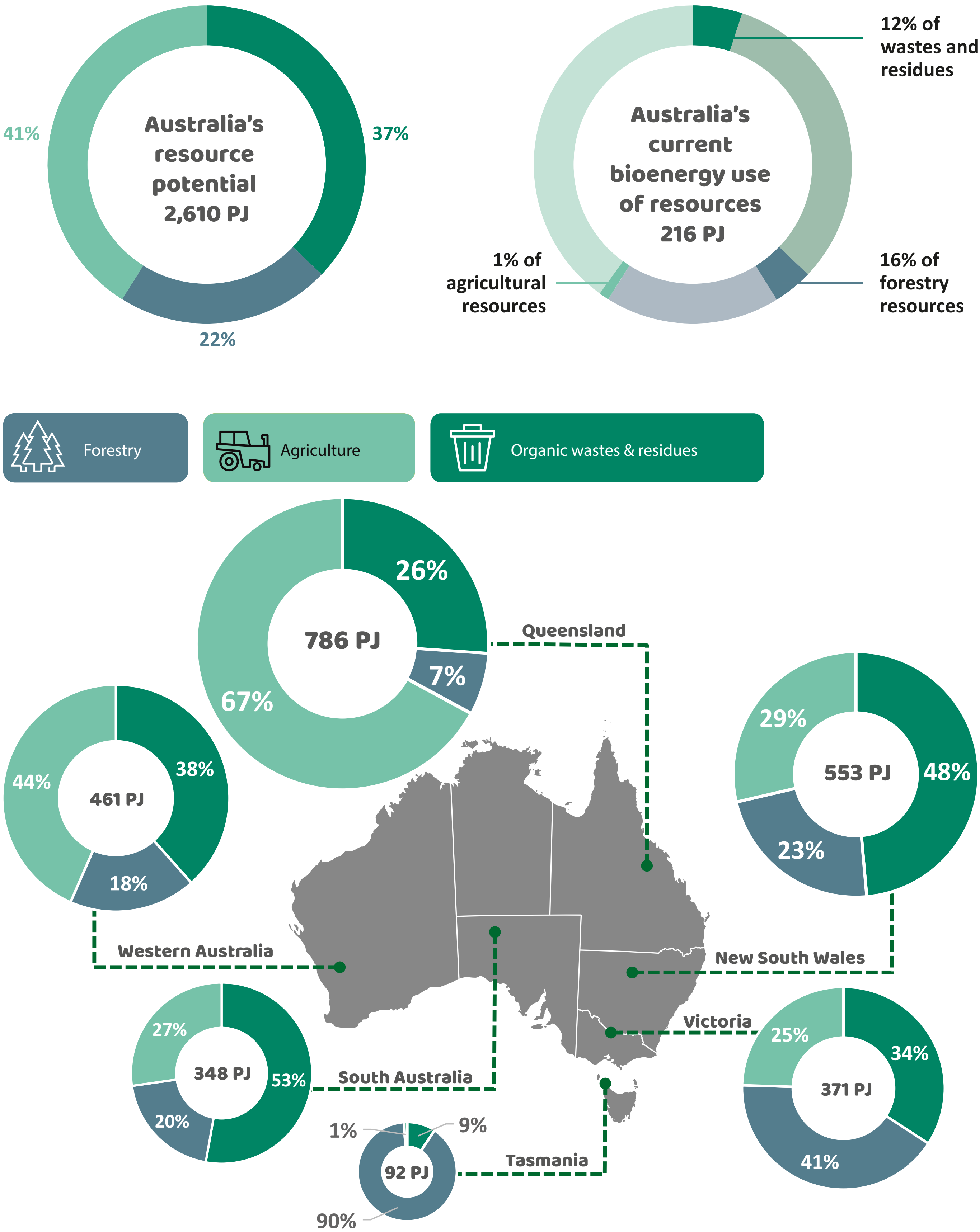
Tasmania and Victoria both have large forestry industries. This is reflected in the breakdown of their theoretical resource potential (see Figure 5).

Despite the significant theoretical potential, only a small portion of these resources are currently used for bioenergy production.

Australia's bioenergy supply was 216 PJ in 2017-2018, comprising wood and wood waste (89 PJ), bagasse (100 PJ), municipal and industrial waste (5 PJ), biogas (16 PJ) and bioethanol (6 PJ) [18]. However, organic wastes and residues currently used for energy recovery are marginal compared to the level of production.

In addition, bioenergy is a marginal use of forestry and agricultural resources. The majority of Australia's agricultural resources is used for domestic food production or exported overseas. Also, log harvests are mainly used for the provision of paper products, wood chips and sawn timber for construction, infrastructure and manufacturing.

Figure 5 – Breakdown of Australia's theoretical resource potential (PJ per year)



Source: Deloitte Touche Tohmatsu, Enea Consulting, based on ABBA project information and ABARES production data

6. Current technical and economic potential

This section outlines factors that influence the current potential of using resources for bioenergy, including resource quality, sustainability and supply chain. It then derives from the theoretical resource potential an estimate of the current economic potential.

Resource quality

The quality of resources can influence their suitability for bioenergy production. Quality and subsequent energy content varies by resource.

However, information about resource quality was not available in the literature. This creates uncertainty about the exact potential of each resource.

Nevertheless, as a general overview, the following three factors can influence resource quality:

- **Moisture content:** This is the quantity of water present in biomass and is expressed as a percentage of weight. A high level of moisture will lower the usable energy content of biomass. A high-moisture content can also increase the rate of decomposition, impacting storage durability.
- **Ash content:** This is the inorganic and incombustible component of biomass. The presence of ash affects combustion and gasification processes. Ash can cause corrosion of equipment and requires capture and disposal. Therefore, a lower ash content is considered more favourable for bioenergy use.
- **Energy density:** This refers to the energy value per unit of volume (MJ per m^3). Biomass is typically available in low-bulk densities and has lower energy content compared to fossil fuels. This means that bioenergy resources can have low-energy densities, meaning high volumes of biomass are required per unit of energy output. This can have material implications for supply, transport and storage [19].

Sustainability

Using resources for bioenergy presents both opportunities and challenges within each of the principal resource categories.

For example, producing resources for bioenergy can create competition with negative impacts primarily driven through land use change. On the other hand, sustainably produced resources and waste streams can offer opportunities such as decreased emissions, enhanced biodiversity and soil productivity, and reduction of waste sent to landfill.

Thus, developing a framework to ensure sustainable supply of resources is vital to Australia's bioenergy industry, particularly when considering future resource production.

Agricultural resources are the resource category facing the most significant sustainability challenges, including the food-versus-fuel debate.

Increasing demand for bioenergy could have a negative impact on food security. This may be due to diverting food crops for bioenergy or limiting available land for food production.

As such, potential impacts on domestic food prices and food security could be a focus when developing a sustainability framework to support Australia's bioenergy industry, building on examples from overseas.

In addition to those challenges, using agricultural resources for bioenergy poses several environmental sustainability challenges, particularly regarding land use.

Both direct and indirect land use change can impact the overall lifecycle emissions of using bioenergy. As trees, grasses and other plants grow, they capture CO_2 through photosynthesis. On the other hand, clearing land for cropping can disturb soil that has been absorbing carbon for many years, releasing emissions.

A prominent example is deforestation in South East Asia (particularly Indonesia and Malaysia) to support demand for palm oil, which is used for many products including biofuels. The EU has stated that of all biofuel sources, palm oil was associated with the highest levels of deforestation. Between 2008 and 2015, 45 per cent of palm oil expansion took place in high carbon stock areas [20].

Sustainability frameworks can ensure that the production of bioenergy resources does not cause deforestation through land use change and negatively impact carbon sinks.

In addition, other environmental sustainability considerations for agricultural resources include:

- **Water consumption:** Agricultural resources for bioenergy tend to be water-intensive, and irrigated crops can require high levels of water extractions. Even rain-fed crops can decrease water availability for downstream users [21].
- **Biodiversity:** Large-scale expansion of agricultural land can reduce biodiversity through habitat loss [21]. Also, monocultures based on a narrow selection of energy crops can reduce agricultural biodiversity. Conversely, energy cropping may promote biodiversity when multiple species are planted. Also, planting short rotation woody crops on degraded or marginal lands can restore habitats for biodiversity [19].
- **Soil productivity:** Overexploitation of harvest residues can prevent nutrients from returning to the soil, reducing soil quality. This is typically managed through high fertiliser inputs, which may increase nutrient runoff and contamination of water with excess nitrogen, phosphorous and other nutrients. Removal of residues may also increase erosion at the site. This means that using forestry and agricultural residues for bioenergy should consider sustainable removal rates. Retaining 1 to 1.5 tonnes of residues per hectare has been recommended to provide soil protection [22].

It is expected that sustainability considerations might limit the contribution of the forestry sector to Australia's bioenergy resource potential. It might be limited, for example, to only forestry plantations, forestry residues and wood waste.

Australia is a global leader in sustainable forestry. In line with this, harvesting of native forests is closely regulated to conserve natural resources. In addition, it faces strong objection from the broader community.

Organic wastes and residues offer an opportunity in terms of sustainability within the broader context of the circular economy.

Energy recovery from waste is one way to reduce the amount of organic waste sent to landfill and achieve Australia's waste management aspirations. This is an example of the circular economy. It refers to the use of material and resources in a closed loop where all input materials are locally treated and processed into new products.

The preliminary resource assessment undertaken by this Roadmap highlights the significant potential of organic wastes and residues.

Accessibility and supply chain

Given the low-energy densities and distributed nature of bioenergy resources, supply chain considerations will prioritise the most easily accessible resources.

Resource accessibility was identified by stakeholders as one of the largest barriers to the acceleration of the bioenergy industry in Australia (refer to the Technical Appendix 9 – Stakeholder Engagement for more detail).

The costs of collection, transport and storage can have a significant influence on the economic viability of bioenergy projects. Also, interannual variability due to climate and water availability along with seasonal variability will affect consistent supply. This means that ensuring consistent supply for bioenergy production may require access to multiple feedstocks.

Also, transporting raw resources over large distances to bioenergy plants is expensive. Typically, up to 100 km from farmgate or roadside to bioenergy plant is considered a maximum range [7]. Usually, solid, dense, dry and easily handled resources, such as wood products, are transported the furthest.

On the other hand, liquid resources, such as animal manure, tend to be used on-site, mitigating the need for transportation. Once transformed, some bioenergy commodities – such as wood pellets – can be transported much longer distances.

Transporting raw resources over large distances to bioenergy plants is expensive. Typically, up to 100 km from farmgate or roadside to bioenergy plant is considered a maximum range

Biohubs

The creation of bioenergy hubs (biohubs) based on analysis of resource catchment areas would ensure that projects are established in strategic locations to maximise available resources.

Co-locating bioenergy projects with resources and transport infrastructure will enable economies of scale, thus going some way in addressing supply chain constraints.

Previous projects have identified locations that could serve as biohubs. For example, the *Bioenergy Roadmap for South Australia* identified southeast South Australia as an ideal location for anaerobic digestion given its access to poultry, dairy, piggery and feedlot waste streams [7]. Identifying locations for biohubs was outside the scope of this Roadmap but could be incorporated into a future national assessment.

Establishing energy hubs could also allow for the unlocking other benefits, such as facilitating permitting processes, encouraging industry collaboration, competition, and research and development.

These benefits are not specific to bioenergy. As a consequence, energy hubs are an increasingly popular concept. For instance, hydrogen hubs are a key element of the Australia's National Hydrogen Strategy while Renewable Energy Zones are a central component of AEMO's Integrated System Plan.

A number of biohubs are already in various stages of development around Australia. For example, the G21 Geelong Region Alliance has been proposed in Victoria. The resource potential for this biohub is estimated to be 20,000 tonnes of organic waste per annum from industrial and municipal solid waste feedstocks [23].

Another proposed biohub is the Daintree Bio Precinct in Queensland. Potential feedstocks include sugarcane, bagasse, sugar and molasses. The Mossman Sugar Mill crushes 850,000 tonnes each season, which could be used for this biohub [24].

Biohubs could leverage the Special Economic Zones established by the NSW Government, where regional and rural areas receive taxation and financial incentives to promote economic growth, employment and investment. Providing incentives for bioenergy on a locational basis could help promote development in regions with the greatest potential.

Assessment of current economic resource potential

In the short term, the most cost-effective opportunity for bioenergy is likely to be residues and wastes.

This illustrates the supply curve of Australia's theoretical resource potential based on indicative costs, excluding transportation costs.

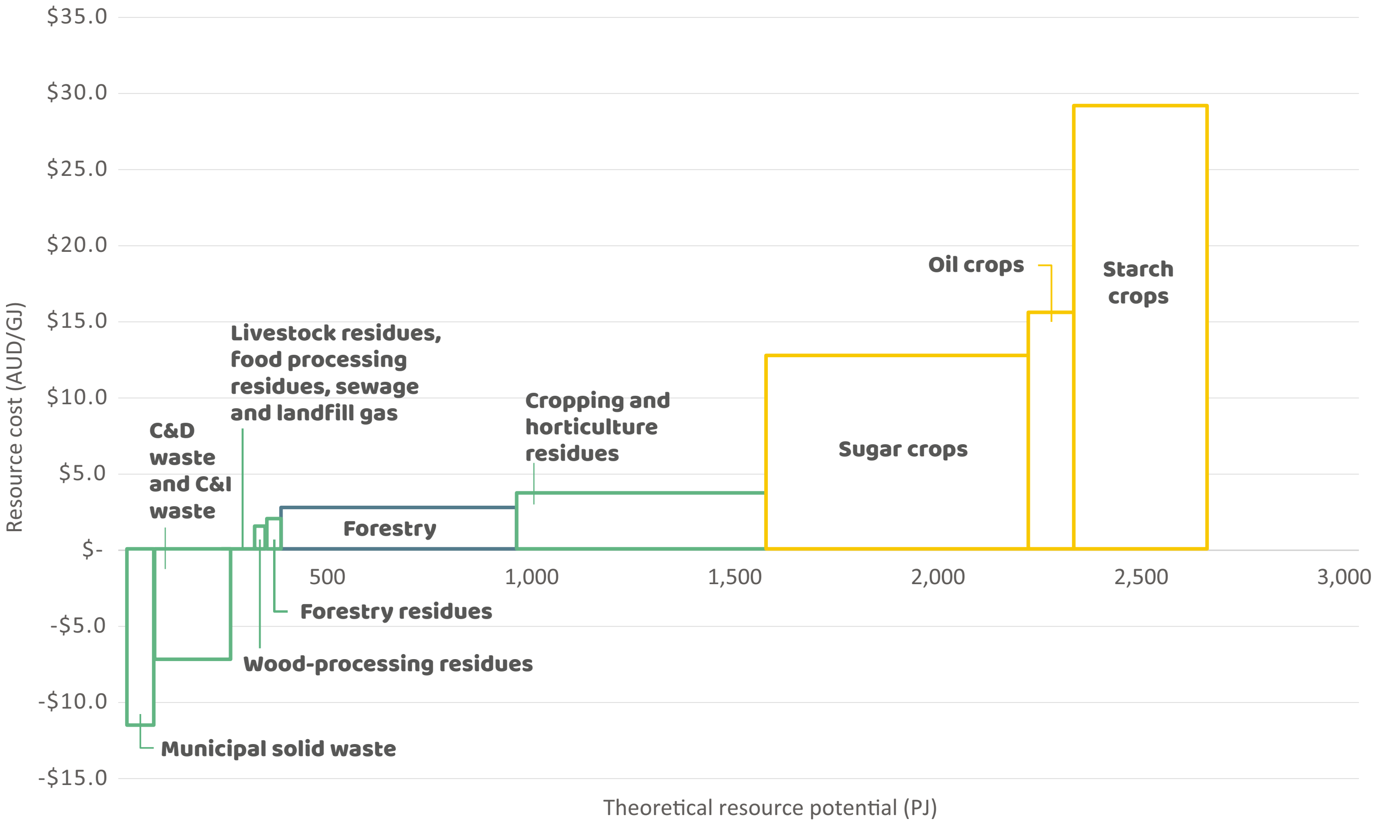
In some cases, using wastes and residues will avoid disposal costs, resulting in negative resource costs. Victoria, South Australia, Queensland, New South Wales and Western Australia currently have landfill levies and the Australian Capital Territory and Tasmania are considering the introduction of landfill levies in 2021.

Livestock residues, food processing residues and sewage generally have zero cost as they generally incur limited collection costs. On the other hand, harvest residues from cropping, horticulture and forestry incur collection costs.

Despite resources in the agricultural category showing the greatest theoretical resource potential, agricultural and forestry crops are more expensive than residues and wastes.

Thus, the opportunity cost of using agricultural land for food production will influence farmers' decisions to produce resources for bioenergy. This means that farmers would likely only divert current production for energy if the price they receive is higher than what they would have received for food [21].

Figure 6 – Cost curve of Australia's theoretical resource potential[1]



Source: ITP Thermal, Indufor Asia Pacific (Australia), NERA Economic Consulting

Note: For crop residues, horticulture residues, forestry residues, wood-processing residues, livestock residues and sewage, costs are derived from ITP Thermal 2019, Renewable Energy Options for Industrial Process Heat – Appendices (page 263) [25]; for forestry, costs are derived from the average harvest rates from Indufor Asia Pacific (Australia) and NERA Economic Consulting 2017, HFD Harvest and Haul Audit (page 48) [26]; for sugar crops, oil crops and starch crops, costs are derived from ABARES' gross unit of farm products (returns received from crops harvested) value tables; for food processing residues, it was assumed costs were zero; for MSW, C&D waste and C&I waste, prices are derived from a comparison of states' waste levies.

Assumptions

Due to competing uses, supply chain and sustainability considerations, the amount of bioenergy resources that are technically and economically available is less than the theoretical potential outlined previously outlined in this Roadmap.

The economic modelling undertaken as part of this Roadmap assumes that, on average, **45 per cent** of Australia's theoretical resource potential would be available for bioenergy.

However, this share varies across resource categories, assuming a higher share of wastes and residues would be available for bioenergy production compared to primary agricultural and forestry resources. This assumption has been informed by feedback collected through the stakeholder consultation process.

As previously highlighted, this is a preliminary resource estimate. A more detailed assessment considering the technical and economic constraints outlined in this section would provide a more accurate view of this potential.

7. Future resource potential

While organic wastes and residues are immediately available for growing Australia's bioenergy industry, under an adequate sustainability framework, agricultural and forestry resources can increase future supply.

Future supply will need to consider the impacts of climate change and options to sustainably expand current resources. In addition, there may be opportunities for new bioenergy resources to contribute to an increased potential in the future.

Consideration of climate change

Assessment of Australia's future supply of bioenergy resources should consider climate change impacts. These will impact sectors that are dependent on natural resources, such as agriculture and forestry.

Rising temperatures, decrease in rainfall, increasing intensity and frequency of severe weather events such as prolonged drought, and natural disasters such as bushfires and floods, all pose risks to Australia's agricultural and forestry production.

In particular, Australia's cropping industries may experience reduced predictability of seasons and rainfall, plant stress and crop losses and changes in regional suitability to certain production systems. These impacts will vary by crop, location and season.

Partnerships between industry and government are researching strategies for climate change adaptation [27].

Accordingly, consideration should be given to the impact of climate change on future supply of resources to ensure the industry is resilient in the face of environmental change.

Sustainable expansion of current agricultural resources

Australia's agricultural resource potential may be expanded in the future by:

- increasing current crop yields (tonnes per hectare)
- integrating energy crops with other crops on agricultural land (intercropping)
- using marginal and degraded lands for energy cropping.

Increasing crop yields of existing crops such as sugarcane and sorghum can increase future resource supply for bioenergy.

Improving land use efficiency through higher yielding systems will reduce, or even avoid, land use change for energy cropping. However, increasing crop yields can require increasing use of fertilisers, pesticides and irrigation water.

Intercropping energy crops within existing agricultural systems can increase bioenergy resources without clearing additional land or converting land previously dedicated to food production.

There is an increasing interest in intercropping in Australia. However, this is mainly driven by rotational benefits, risk management, soil improvement and reduced input costs. By comparison, improving yields is a secondary motivation. Further research on intercropping for bioenergy resources is required to identify options with the greatest potential for Australia.

However, a recent study by the Grain Research and Development Cooperation [28] found that growing two species can have potentially large yield benefits. The report identified several issues that would need to be overcome before intercropping can be widespread in Australia:

- sowing techniques when two crops require different sowing depths
- the combination of crops may limit the range of herbicides available
- techniques for separating harvested grain.

> **A recent study by the Grain Research and Development Cooperation found that growing two species can have potentially large yield benefits**

Also, using lignocellulosic resources on marginal and degraded lands can decrease future pressure on prime cropping land.

It can also mitigate land use change while also improving carbon sequestration in soils and biomass. Crops that may be suitable to marginal agricultural land include Agave tequilana (blue agave), sweet sorghum, energy grasses and short-rotation forestry crops [29].

However, further research on marginal lands available for energy cropping and suitable species is required. Also, it should be noted that truly marginal lands are not a true option for future supply given biomass yields would be low, increasing collection costs.

Opportunities for new bioenergy resources

Short-rotation coppice may present a medium-to-longer-term opportunity as a bioenergy resource.

A study published in 2015 estimated Australia's bioenergy resource potential for six feedstocks in 2010, 2030 and 2050. It was estimated that the increase of Australia's resource potential would largely be driven by short-rotation coppice, representing more than 70 and 80 per cent of this increase by 2030 and 2050 respectively [30].

Short-rotation coppice includes the fast-growing tree Mallee eucalyptus. Woody biomass can be used for salinity control on agricultural land. This was the main motivation for planting Mallee eucalyptus in Western Australia. However, these crops are yet to be used commercially.

Microalgae is another example of a resource that is not commercial yet but may be a prospective bioenergy resource in the longer term.

Microalgae are rapidly growing, photosynthetic micro-organisms that use sunlight, water and nutrients to produce biomass. Many species of microalgae produce lipids and carbohydrates that may be converted to biofuels and other bioproducts such as biochemicals.

The algae-based bioenergy market is still developing and there are no examples of industrial commercialisation of microalgae for such uses. Due to a lack of established industry and proven practices, microalgae are unlikely to be competitive as a resource for bioenergy in the short to medium term.

Image: Sydney Water's Malabar wastewater treatment plant. Image_ Sydney Water Corporation(3)

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