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Biogas opportunities for Australia

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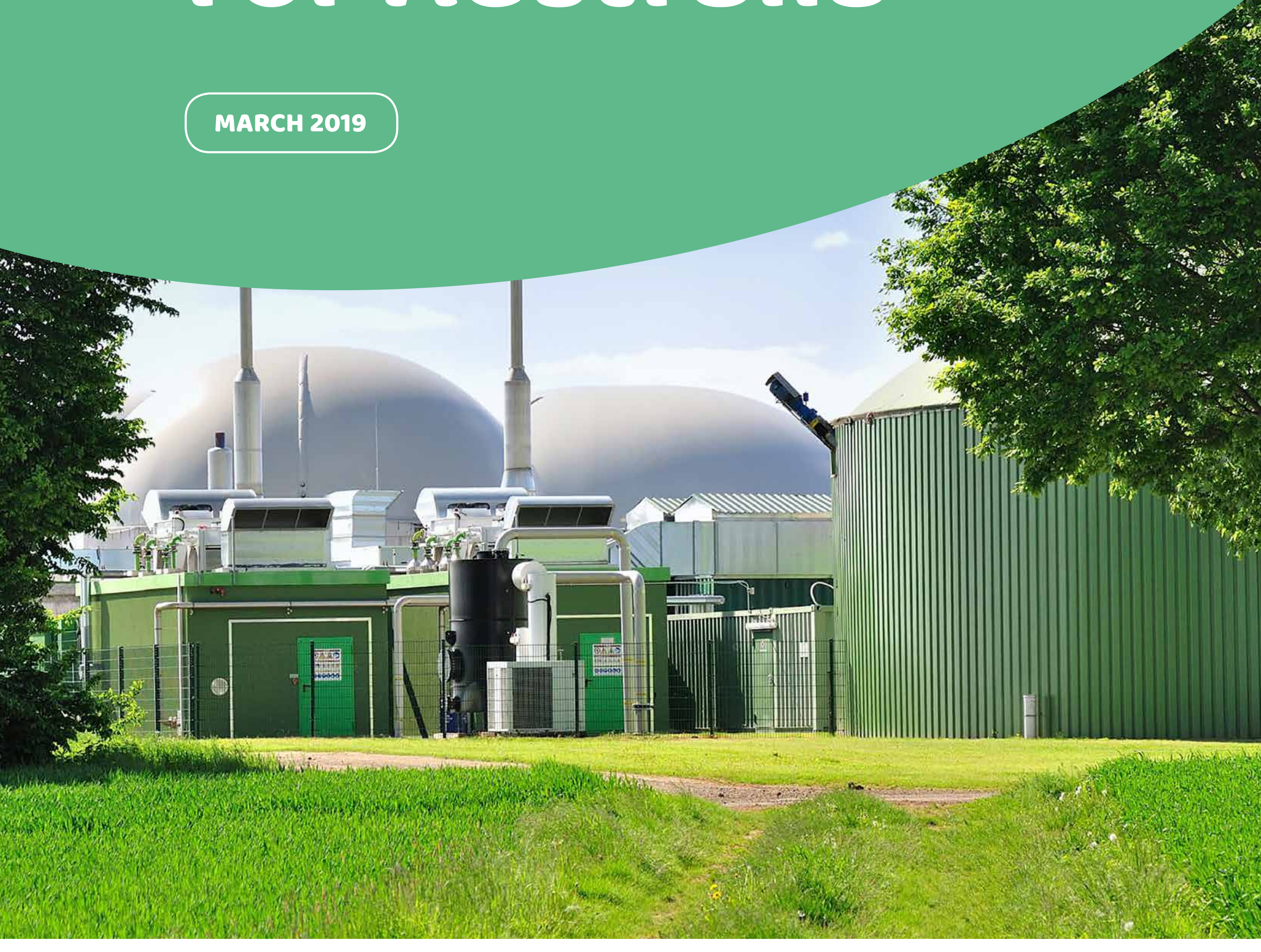

ARENA Australian Government Australian Renewable Energy Agency

CEFC CLEAN ENERGY FINANCE CORP

Energy Networks Australia

IEA Bioenergy

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The views in this report reflect those of the authors and industry stakeholders, not necessarily those of the partners.

Executive summary

Biogas is a renewable, reliable and local source of energy. The biogas industry provides an alternative route for waste treatment while contributing to the development of local economies.

The Australian biogas industry is emerging. In 2016-17, electricity generation from biogas was about 1,200 GWh[1] (4,320 TJ), or 0.5 per cent of the national electricity generation *Bib.1*.

In 2017, there were 242 biogas plants in the country, half of which were landfills collecting landfill gas *Bib.2*. Roughly half of this landfill gas was not used as an energy source and was flared.

The total estimated biogas potential in Australia is 103 TWh (371 PJ)[2] *Bib.3*, which is comparable with current biogas production in Germany. Australia's biogas potential is equivalent to almost 9 per cent of Australia's total energy consumption of 4,247 PJ in 2016-2017 *Bib.1*. Considering the current average size of biogas units in Australia, this could represent up to 90,000 biogas units[3].

Moreover, the investment opportunity for new bioenergy and energy from waste projects is estimated at $A3.5 to 5.0 billion, with the potential to avoid up to 9 million tonnes of CO_{2e} emissions each year *Bib.4*. As well as biogas projects, this investment opportunity includes other waste to energy technologies such as direct combustion of waste (biomass combustion or waste incineration).

In Australia, however, there are several barriers that need to be overcome in order to maximise the sector's potential. In this context, Bioenergy Australia commissioned ENEA Consulting to prepare this report to examine the benefits of biogas and the hurdles currently faced by the industry. The report also includes recommendations to advance Australia's biogas sector.

This report was made possible by the support and partnership of Australian Renewable Energy Agency, Clean Energy Finance Corporation, Energy Networks Australia and International Energy Agency's Bioenergy Task 37: Energy from Biogas.

Introduction to biogas

Biogas is produced from the anaerobic (oxygen free) digestion of organic matter. It can be made from a large variety of organic resources, including industrial waste, agricultural waste, energy crops, sludge from waste water treatment and biowaste (co-digestion or mono-digestion of food waste and other types of biowaste).

In addition to energy production, anaerobic digestion also produces digestate – the material remaining after anaerobic digestion of biodegradable feedstocks. Digestate is a nutrient-rich material that can be used as a fertiliser and applied on agricultural land instead of chemical fertilisers.

Biogas is a source of energy that can be converted into heat or electricity. Biogas can also be upgraded into biomethane: a gas with a chemical composition very similar to natural gas. Biomethane can be injected into the gas grid and serve several uses for consumers such as heating, industrial purposes or fuel for gas vehicles.

Global industry insights

Global biogas production represented 352 TWh (1.27 EJ) in 2014 *Bib.5*, which is about 1.5 per cent of the global renewable energy supply. It is driven by leading countries, such as Germany, the United Kingdom, the United States and China.

1 This figure captures all electricity generation in Australia, including behind-the-meter (on-site consumption).

2 Future work is required to assess the proportion of this potential that could be realised.

3 Based on the average annual biogas production per type of biogas unit.

The development of the biogas sector is driven by different objectives. This includes addressing landfill issues in the United Kingdom, supporting renewable energy in California, improving residential access to energy in China, promoting alternative transport fuel in Sweden or supporting the agriculture sector in France.

Significantly, the implementation of appropriate policy mechanisms has been a catalyst for biogas sectors' growth in various countries.

Opportunities offered by the Australian biogas industry

Biogas and its industry offer many benefits:

- Biogas is above all a renewable energy source that assists the decarbonisation of the economy.
- Biogas is a secure, continuous and dispatchable source of energy that can contribute to national energy supply.
- Biogas transformed into biomethane is a renewable gas that can replace natural gas, and can be used in homes for cooking, heating and hot-water, or as a fuel for gas vehicles. It can be injected into the gas grid or used directly on-site. This is an opportunity for the gas and transport sectors to further assist the energy transition.
- Biogas also provides an alternative route for waste treatment and, as such, can help divert waste from landfill.
- The biogas industry supports local economies and regional communities, creating jobs, and offering new income sources, particularly for farmers.

Challenges faced by the Australian biogas industry

Despite the many benefits, the biogas industry in Australia still faces a number of challenges that are slowing down the development of biogas projects. These challenges include:

- Financial viability of projects: although some financial incentives are available to improve projects' viability, the high level of investment required as well as the complexity of securing revenue sources for a project can be a barrier to overcome for project proponents. Nonetheless, some projects do stack-up financially. Based on feedback from project developers, projects for on-site consumption (behind-the-meter) usually demonstrate better financial viability.
- The need for more favourable policy conditions: although some support mechanisms are already available for the biogas sector, gaps still exist. Therefore, more favourable policy conditions could increase the uptake of project development. This could contribute to the growth of a mature and sustainable biogas industry in Australia.
- The complexity of project development and operation: project proponents regularly face several obstacles in developing and operating biogas plants, including:
  - Securing feedstock and revenue sources
  - Going through various approval processes
  - Accessing private funding
- Lack of widespread industry experience, given the infancy of the biogas industry in Australia.

Addressing these challenges means that Australia could help grow its biogas industry.

Recommendations

Several recommendations have emerged from this report for Australian Governments and industry stakeholders to consider, aiming to advance Australia's biogas sector.

RECOMMENDATIONS

1. Setting renewable gas target(s)
The Commonwealth and State Governments could consider setting targets to encourage renewable gas production and consumption.

- A national target could be similar to Australia's Renewable Energy Target, which currently only applies to electricity.
- Even non-binding targets, as seen overseas, can act as catalysts to spur industry growth.

2. Launching industry stakeholder consultation for policy design
The Commonwealth and State Governments could launch a detailed consultation with industry stakeholders to gather their insights on how existing policies could be adapted and how new ones could be designed to support the sector. This task should aim to deliver more harmonised and uniform national and state policies, which could provide greater policy direction.

Existing and new mechanisms include feed-in tariffs, contracts-for-difference, investment support (capital grants, soft loans), or tax rebates.

In particular, policies could be designed to promote the following outcomes:

- Development of biomethane as a renewable substitute to natural gas, with for example:
  - Support mechanisms targeting the injection of biomethane into the gas grid
  - The development of a 'green gas' retail product for gas users in Australia.
- Support for large-scale and small-scale pilot biogas projects.

3. Introducing waste management strategies to support feedstock quality and quantity

- State Governments could work together to introduce more uniform waste levies to avoid perverse outcomes, whereby waste is sent to states with lower levies. This waste could otherwise be diverted from landfills if there was a financial incentive to encourage this behaviour. A federal policy framework on waste levies could also be an option.
  International examples have shown that appropriately targeted landfill taxes have encouraged the adoption of anaerobic digestion.
- State Governments could also encourage source separation of organic municipal solid waste (e.g. food waste). This would make it easier to use household and community organic waste as feedstock for anaerobic digestion.
- Government and industry stakeholders could work together to examine concerns about the establishment of long-term feedstock supply contracts.

4. Encouraging plant operators, especially landfill operators, to maximise biogas use
The Commonwealth and State Governments could introduce financial mechanisms, taxes or financial incentives, to encourage landfill operators to maximise the use of landfill gas.

- As there are many landfills operating in Australia, it is critical to leverage the biogas produced.
- Similar measures could be designed for biogas made from industrial and wastewater treatment plants.

5. Exploring opportunities for the transport sector
The Commonwealth Government could explore greater support mechanisms targeting the transport sector. In particular, the use of biomethane as an alternative vehicle fuel, as in Sweden, is a good case in point. This is a combined opportunity to foster biogas development while encouraging the decarbonisation of Australia's transport sector.

- Compressed natural gas (CNG) and liquified natural gas (LNG) are currently taxed in the same way whether the gas is of fossil or renewable origin (bioCNG and bioLNG). Reducing or removing the excise duty on bioCNG and bioLNG made from biomethane could be explored.
- Exploring future opportunities in decarbonising Australia's heavy goods vehicles such as trucks and farm machinery (e.g. tractors) by using biomethane as a low carbon alternative to diesel.

6. Providing regulatory clarity for the digestate
The Commonwealth and State Governments could provide regulatory clarity for the digestate.

At the moment, there are uncertainties around digestate regulation, which prevents the industry from maximising its use. Specifically, the conditions for using it as a commercial product could be clarified, as well as the specifications of its composition.

7. Simplifying approval processes
Governments, project proponents, local authorities and electricity and gas network businesses should work together to address the complex and very long approval processes. This would involve reviewing current processes to propose simplified ones, as well as developing guidelines and information packs. If issues remain, regulatory reform could be considered.

8. Informing the community about biogas and its benefits
Government and industry stakeholders could continue to inform the community about biogas and the opportunities it represents for the Australian energy transition and society. This could be done by:

- Developers during their project development processes
- Proactive industry and government collaboration.

9. Exploring future work
This report highlights the key benefits and opportunities that can be offered by the biogas industry in Australia. Future research could quantify the industry's economic potential, such as:

- Refining the biogas resource potential, assessing feedstock availability and its productive utilisation. Some of this work is currently being undertaken as part of the Australian Biomass for Bioenergy Assessment (ABBA) project.
- While taking into account project costs, assessing the full range of revenue streams that can be unlocked should be considered. For example, this includes policy support, such as facilitating the market for digestate, and remuneration for collecting and treating waste.
- The contribution to GHG emission reductions
- The associated level of investment
- The creation of new jobs and the support of existing ones
- The impact on the national and regional economies.

In addition, other work could also assess the value proposition of the different options for decarbonising the gas grid: biomethane, hydrogen and/or electrification.

Acknowledgements

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- **Andrew Edney,** Manager Commercial Services, Yarra Valley Water.

Acronyms

A$ Australian dollar

ABBA Australian Biomass for Bioenergy Assessment

ACCU(s) Australian Carbon Credit Units

AD Anaerobic digestion

ADEME French Agency for Environment and Energy Management ('Agence de l'environnement et de la maîtrise de l'énergie')

AEMO Australian Energy Market Operator

ARENA Australian Renewable Energy Agency

CAPEX Capital expenditure

CEFC Clean Energy Finance Corporation

CH_4 Methane

CHP Combined heat and power

CNG Compressed natural gas

CO_2 Carbon dioxide

CO_{2e} Carbon dioxide equivalent

CPUC California Public Utilities Commission

EJ Exajoule,
1 EJ = 10^3 PJ (petajoule)
= 10^6 TJ (terajoule)
= 10^9 GJ (gigajoule)

1 EJ = 277.78 TWh (terawatt hour)

ERF Emission Reduction Fund

FiT(s) Feed-in tariff(s)

GHG Greenhouse gas

H_2O Water or water vapor

H_2S Hydrogen sulphide

IEA International Energy Agency

IRENA International Renewable Energy Agency

LGC(s) Large-scale generation certificate(s)

LNG Liquified natural gas

LRET Large-scale renewable energy target

MSQ Mandatory Supply Quantity

OPEX Operating expenditure

PPA(s) Power purchase agreement(s)

PSA Pressure swing adsorption

RET Renewable Energy Target

RHI Renewable Heat Incentive

RPS Renewable Portfolio Standard

SRES Small-scale renewable energy scheme

STC(s) Small-scale technology certificate(s)

WWTP Waste water treatment plant

TWh Terawatt hour,
1 TWh = 10^3 GWh (gigawatt hour)
= 10^6 MWh (megawatt hour)

1 TWh = 3.6 PJ (petajoule)

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Context

Biogas is a renewable, reliable and local source of energy. The biogas industry provides an alternative route for waste treatment while contributing to the development of local economies.

The Australian biogas industry is emerging. In 2016-17, electricity generation from biogas was about 1,200 GWh[4] (4,320 TJ), or 0.5 per cent of the national electricity generation *Bib.1*.

In 2017, there were 242 biogas plants in the country, half of which were landfills collecting landfill gas *Bib.2*. However, a significant amount of this biogas is not used as an energy source and is flared.

According to Deloitte in the report *Decarbonising Australia's gas networks* *Bib.3*, the total estimated biogas potential in Australia is 103 TWh (371 PJ)[5] which is comparable with current biogas production in Germany. Australia's biogas potential is equivalent to almost 9 per cent of the Australian final energy consumption of 4,247 PJ in 2016-2017 *Bib.1*. Considering the current average size of biogas units in Australia, this could represent up to 90,000 biogas units[6].

Moreover, according to CEFC's 2015 report *The Australian bioenergy and energy from waste market*, the investment opportunity to 2020 for new bio-energy and energy from waste projects is estimated at $A3.5 to 5.0 billion, with the potential to avoid up to 9 million tonnes of CO_{2e} emissions eachyear *Bib.4*. As well as biogas projects, this investment opportunity includes other waste to energy technologies such as direct combustion of waste (biomass combustion or waste incineration).

In Australia, however, there are several barriers that need to be overcome in order to maximise the sector's potential. In this context, Bioenergy Australia commissioned ENEA Consulting to prepare this report to examine the benefits of biogas and the hurdles currently faced by the industry. The report also includes recommendations to advance Australia's biogas sector.

This report was made possible by the support and partnership of Australian Renewable Energy Agency, Clean Energy Finance Corporation, Energy Networks Australia and International Energy Agency's Bioenergy Task 37: Energy from Biogas.

This report complements another report commissioned by Bioenergy Australia that was recently published, *Bioenergy state of the nation report* *Bib.6*, as well as other initiatives launched by Energy Networks Australia: *Gas Vision 2050, Decarbonising Australia's gas distribution networks* and *Renewable gas for the future* *Bib.7. 3. 8*.

The preparation of this report employed a variety of approaches, including:

- Consultation with the Australian biogas industry and government stakeholders: to gather insights on the state of the industry and to provide examples of successful Australian projects where biogas technologies and their benefits have been demonstrated
- Literature review: to leverage previous studies by major industry organisations and consulting firms
- Global market research: to compile key learnings from the world's leading biogas countries.

Recommendations to Australian Governments and the industry have been designed based on this report's findings.

4 This figure captures all electricity generation in Australia, including behind-the-meter (on-site consumption).

5 Future work is required to assess the proportion of this potential that could be realised.

6 Based on the average annual biogas production per type of biogas unit.

1

Introduction to biogas

This chapter provides an introduction to biogas through the following sections:

1.1. What is biogas?
1.2. How is biogas produced and used?
1.2.1. Feedstock selection, collection and processing
1.2.2. Anaerobic digestion process
1.2.3. Use of products from anaerobic digestion.

1.1. What is biogas?

Biogas is produced from the anaerobic (oxygen-free) digestion of organic matter. It is typically composed of 50-70 per cent methane (CH_4), 25-45 per cent carbon dioxide (CO_2), and other gases in small quantities such as hydrogen sulphide (H_2S), water vapor (H_2O), oxygen (O_2), ammonia (NH_3) and other trace gases *Bib.9*.

From biogas, biomethane can be produced via an upgrading and purification process to separate methane from other gases[7], such as CO_2 and H_2S (refer to section 1.2.3).

In addition to energy production, anaerobic digestion also produces digestate – the material remaining after anaerobic digestion of biodegradable feedstocks. Digestate is a nutrient-rich material that can be used as a fertiliser and applied on agricultural land instead of chemical fertilisers (refer to section 1.2.3).

1.2. How is biogas produced and used?

The process of producing and using biogas is outlined in **Figure 1**. There are three main steps in this process. They are discussed in the following sections:

1.2.1 Feedstock selection, collection and processing

The first phase in the biogas value chain is related to the selection, collection and processing of suitable feedstocks. Various organic feedstocks can be used as inputs for the anaerobic digestion process. The feedstock can be either in solid, slurry or liquid (both diluted or concentrated) form, including:

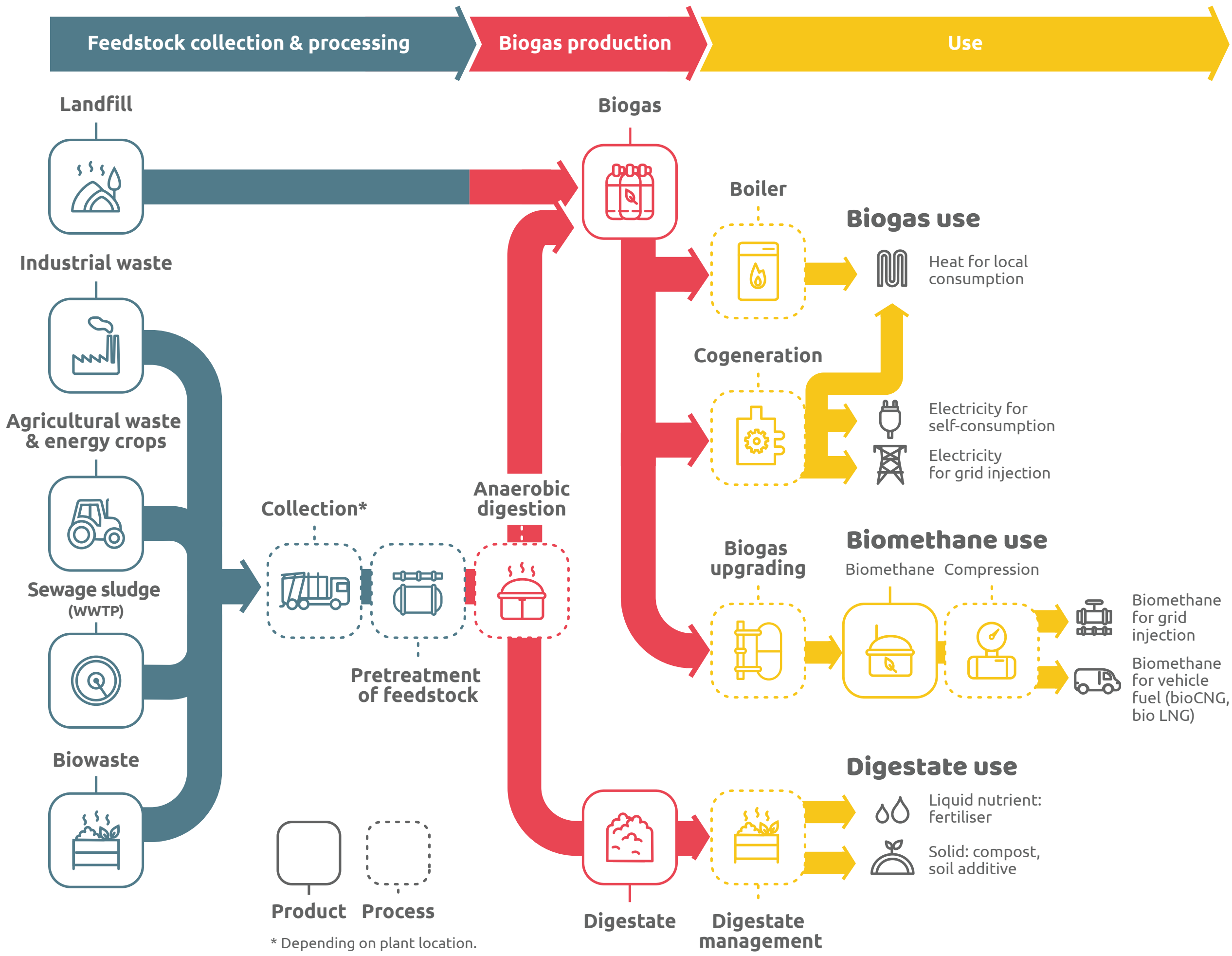
- Industrial waste such as waste from food and beverage processing, and dairy, sugar, meat, pulp and paper industries
- Agricultural waste as animal by-products and crop residues
- Energy crops[8] as maize, silage, grass, sorghum, cereals and sugar beet
- Sludge from waste water treatment plant (WWTP)
- Biowaste from households, communities or small-scale commercial and industrial activities.

Anaerobic digestion of organic materials also occurs naturally in landfill sites releasing landfill gas. The composition of the landfill gas is quite close to biogas from anaerobic digestion. Landfill gas, however, has a lower methane (CH_4) content and a higher presence of trace gases, especially oxygen and nitrogen from air as well as impurities[9] *Bib.11*.

7 Gases with no calorific value or pollutants.
8 The use of energy crops as a feedstock can be restricted by regulations due to the potential competition with food supply and land use.
9 Biogas from landfill can be a good option to treat unsorted waste containing organic matter. However, considering the issues associated with landfilling and the presence of impurities in the landfill gas which can impact generators, anaerobic digestion remains a better option when possible. To be able to digest biowaste from households, communities or small-scale commercial and industrial activities, a separate collection of organic waste is required.

Figure 1

Biogas value chain *Bib.10*



Feedstock selection has a major impact on the amount and quality of biogas that will be produced by the anaerobic digestion process. It also impacts digestate production. This is elaborated further in **Box 1**.

Biogas projects differ depending on the main type of feedstock used. The five biogas categories are:

1. Industrial biogas
2. Agricultural biogas
3. Sewage sludge biogas
4. Household/community biogas (from biowaste)
5. Landfill (bio)gas.

It is also possible to have projects mixing feedstocks from these different categories. These are referred to as co-digestion. Co-digestion can increase the biogas production capacity by increasing the quantity of feedstock used and increasing the methane yield potential. Thus, co-digestion is usually seen in large-scale biogas plants *Bib.13.14*. Co-digestion also provides the right ratios of carbon and nitrogen which are essential to reduce inhibition of the anaerobic digestion process *Bib.15*.

For co-digestion plants especially, it is usually required to collect the different feedstocks from various locations as they are not always located at the anaerobic digestion plant's premises.

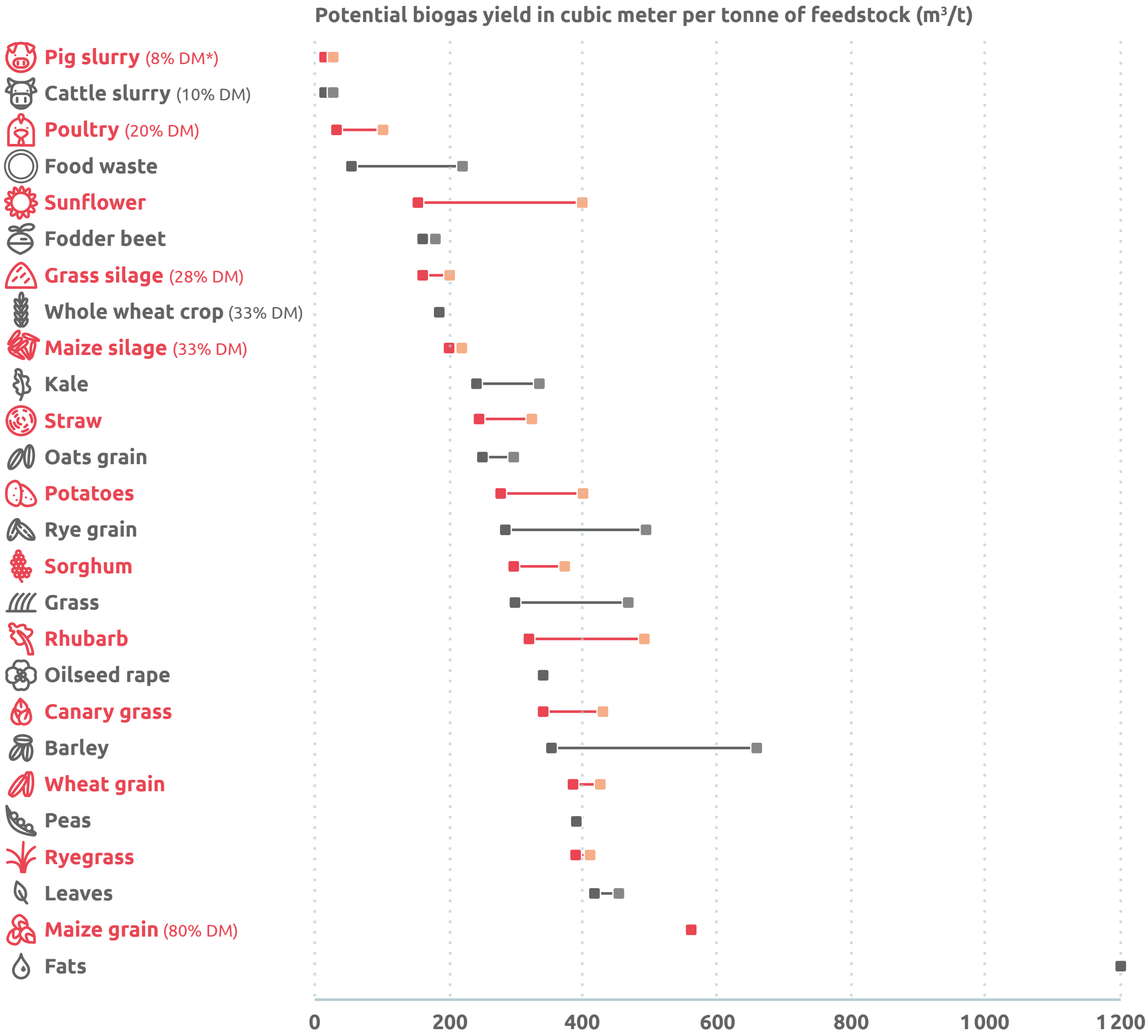
BOX 1 - FEEDSTOCK CHARACTERISTICS

The amount of biodegradable organic matter available varies according to the type of feedstock. This results in highly variable biogas production and methane content for a same amount of fresh feedstock.

Figure 2 provides the biogas yield of several feedstocks.

Figure 2

Biogas yield of different feedstocks and energy crops *Bib.12*



* DM = Dry Matter

It should be noted that these figures are only indicative as for a given type of feedstock, the biogas yield can also vary considerably based on other factors (dry matter content, storage and handling conditions, reaction with other feedstocks). Feedstock testing is required prior to the establishment of any project to confirm the actual methane content.

Before being loaded into the production process, the feedstock must be properly sorted and pre-treated to maximise the amount of biogas yield and the digestion process efficiency.

- An initial pre-treatment of most feedstock may be necessary to remove inert and plastic waste, and ensure the organic materials are available in homogeneous particle size (< 10 mm). These are essential for microorganisms to breakdown the feedstock *Bib.16. 17.*
- Some feedstocks require specific pre-treatment. For example, the pasteurisation of livestock manure for destroying pathogens can be usually needed to be compliant with local sanitary standards *Bib.18.*

1.2.2 Anaerobic digestion process

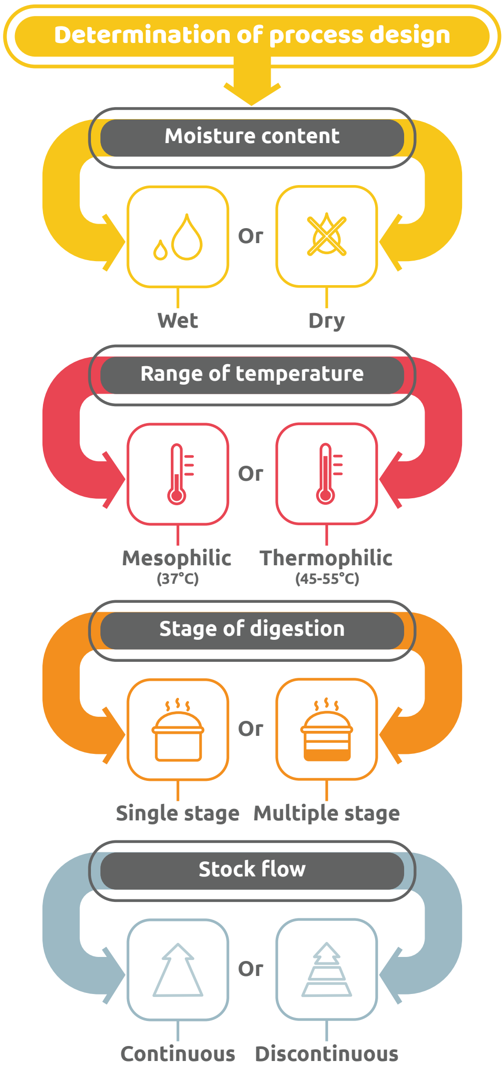
The second part of the biogas value chain is the anaerobic digestion process, which converts the feedstock into biogas. In this process, the organic material is biochemically digested into CO_2 and CH_4 by the anaerobic microorganisms.

The complete feedstock decomposition process comprises of four different phases (hydrolysis, acidogenesis, acetogenesis, methanogenesis) taking place simultaneously. Each phase is facilitated by a specific type of microorganisms.

Anaerobic digestion typically occurs simultaneously in one or multiple digesters. The digester configuration and technologies used are primarily determined by the feedstock characteristics (such as its moisture content) and the stock flow *Bib.16. 19.* The main differentiating parameters of the anaerobic digestion processes are presented in **Figure 3** and typical anaerobic digestion technologies are in **Box 2**.

Figure 3

Determination of anaerobic digestion process design *Bib.20*



BOX 2 - ANAEROBIC DIGESTION TECHNOLOGIES

Three main types of anaerobic digestion technologies currently exist:

1. Wet process: technologically mature and widely used globally
2. Continuous dry process: technologically mature, however, it is currently used less than the wet process as it is more recent
3. Batch dry process: technologically mature but recently emerged from research and development.

The main characteristics of these different processes are presented in Table 1.

Table 1

Main characteristics of different anaerobic digestion processes *Bib.20, 9*

	Wet process	Continuous dry process	Batch dry process
Dry matter content of the feedstocks	Low dry matter content < 15-20 per cent	Medium to high dry matter content 15-20 to 40-45 per cent	High dry matter content > 30 per cent
Feedstock form Examples of feedstocks	Liquid Manure, catering waste, sewage sludge etc.	Slurry/solid Kitchen food waste, green waste* (grass, leaves), grains, etc.	Slurry/solid Green waste* (grass, leaves), grains, etc.
Digester design	Vertical round vessels with fully mixed agitation	Horizontal (or vertical) vessels with slow- rotating agitator e.g. Plug-flow processes	Rectangular concrete boxes e.g. percolation systems
Digester height	Medium	Low for vertical vessels High for horizontal vessels	Medium
Feedstock agitation	Motor agitators, mixers	Horizontal shaft with paddles	None
Operating temperature range	37°C (mesophilic digestion) or, 45 to 55°C (thermophilic digestion)	37°C (mesophilic digestion) or, 45 to 55°C (thermophilic digestion)	37°C (mesophilic digestion)
Problem caused by contaminants	High	Low	Low

*Composting is an alternative for treating the green waste component of food and garden organic waste.

1.2.3 Use of products from anaerobic digestion

The last part of the value chain is the use of the products from anaerobic digestion. As illustrated in **Figure 1**, there are two products from the anaerobic digestion process: the biogas and the digestate. Both are valuable, and their possible uses are discussed in this section.

Biogas use

Once produced, the biogas is a source of energy that can be used in several ways:

- **Direct use for heat and/or electricity generation:** the biogas can be used directly onsite for local heat production via a boiler. This is a typical use for biogas plants located at WWTP, meat processing plants or piggeries.

  The biogas can also be converted into electricity and heat by a combined heat and power (CHP) unit, where the removal of water vapour and varying levels of H_2S is needed to avoid equipment damages. The electricity produced can be used onsite or exported to the electricity grid. The heat can be used in local industrial processes or by specific customers (e.g. greenhouses) if they are close to the plant *Bib.9*.

- **Upgrading to biomethane for grid injection or vehicle fuel use:** biogas can further be converted into biomethane via upgrading technologies (refer to **Box3**), where the separation of methane from CO_2 and other gases takes place. The product of the upgrading process, called biomethane, has a CH_4 content of up to 97-98 vol. per cent.

  Because biomethane's chemical composition is very close to natural gas, it can be fed directly into the natural gas grid for storage and distribution to gas end-users. Biomethane that is blended into the natural gas grid can be retrieved from the grid for industrial and residential uses such as heating, cooking, or for vehicle fuel at petrol stations.

  Subsequently, biomethane can be converted into compressed natural gas (bioCNG) or liquefied natural gas (bioLNG), to be transported in bottles or to be used in gas vehicles. Refuelling stations can either be located directly on the site of the biomethane facility (or very close by) or connected to the gas grid. The gas grid provides a way to transport the biomethane between the production facility and the refuelling station.

Digestate use

As illustrated in **Figure 1**, anaerobic digestion also produces digestate – the material remaining after anaerobic digestion of biodegradable feedstocks. Digestate is a nutrient-rich material that can be used as a fertiliser and applied on agricultural land instead of chemical fertilisers. It is usually rich in nitrogen (or ammonia) and phosphorus.

The digestate can be spread directly on land as a fertiliser. This is restricted in some countries, especially when nutrient uptake is controlled. In Australia, there is no clear regulation on the use of the raw digestate before treatment (refer to section 4.2.2).

Alternatively, the digestate can also be treated and separated into liquid and solid digestate:

- Liquid digestate can be sprayed directly on soil in replacement of conventional fertilisers
- Solid digestate can be converted into compost or soil amendments and then be commercialised.

Finally, in the absence of other options, the digestate is sent to landfill.

BOX 3 - UPGRADING TECHNOLOGIES

Four main technology families have been developed to upgrade biogas into biomethane (see **Table 2**). The choice of a technology is based on the properties of the biogas to be purified (e.g. chemical composition, gas flow) and the requirements for the output biomethane.

Technologies for upgrading biogas are now widely available globally with a strong presence in Europe, where 342 upgrading units were in use in 2016 *Bib.21*.

Although there is currently no biogas upgrading plant in Australia, some international providers are already present, such as Greenlane Biogas (New-Zealand company) or Hitachi Zosen Inova (Swiss company with an Australian office).

Table 2

Number of upgrading plants by technology in Europe in 2016 *Bib.21* and technology descriptions

Upgrading technology and number of plants by technology type in Europe in 2016	Description
Absorption or scrubbing **115** water scrubbers out of 342 plants **87** chemical absorption plants **27** physical absorption plants	▪ Separation of the impurities from the biogas based on the different solubilities of gas components in the solvent (e.g. CO_2 and the other impurities dissolves much better in water than CH_4). ▪ Three different types of solvents can be used: pressurised water, amines (chemical absorption) and organic solvent (physical absorption). ▪ Similar process regardless of the solvent used: - Impurities absorbed by the solvent in a first column - Regeneration of the solvent in a second column. Production of a lean gas, which must be treated before its release to the atmosphere. Absorption/scrubbing technologies for biogas upgrading are mature and widely used.
Pressure swing adsorption (PSA) **70** out of 342 plants	▪ Batch process, in which the biogas passes through an adsorbent medium (molecular sieve, activated carbon, zeolites) at high pressure. The adsorbent medium acts as a filter by preferentially fixing impurities such as H_2O, CO_2 or H_2S. ▪ In the regeneration phase, release of the impurities from the saturated medium with the pressure drop. Production of a lean gas, which must be treated before its release to the atmosphere. ▪ Process made continuous by the operation in parallel of several adsorption/desorption columns. PSA for biogas upgrading is technologically mature.
Membrane separation **43** out of 342 plants	▪ Principle based on the selectivity of the membranes for certain molecules: - Membranes are highly permeable to smaller molecules, allowing the diffusion of impurities such as H_2O, CO_2 or H_2S. - Larger molecules, like methane, remain preferentially in the main gas stream. - The process is continuous and generates a poor gas flow that needs to be treated. ▪ Removal of hydrogen sulphide and water vapor in the inlet gas stream required prior to the membrane separation to protect the membranes. Substantial improvements in power requirement, methane loss and membrane service life have been achieved in the past ten years, encouraging the uptake of the technology. Membrane technology for biogas upgrading is now mature.
Cryogenics	▪ Process based on the difference in gas liquefaction conditions (pressure and temperature). ▪ Compression followed by a strong cooling of the raw biogas (up to -160°C) ▪ CO_2 recovered in in liquid form by crystallisation and condensation. The technology is being demonstrated in a few pilot plants and commercial plants. Cryogenic treatment is a promising technology as a cost-effective solution for producing high methane purity, especially well-suited for landfill gas treatment.

2

Global industry insights

This chapter provides insights on global biogas industries. Several countries in Europe, North America and Asia were analysed in more detail as they are representative of the global industry and can provide learnings for Australia. For these countries, the following aspects were examined:

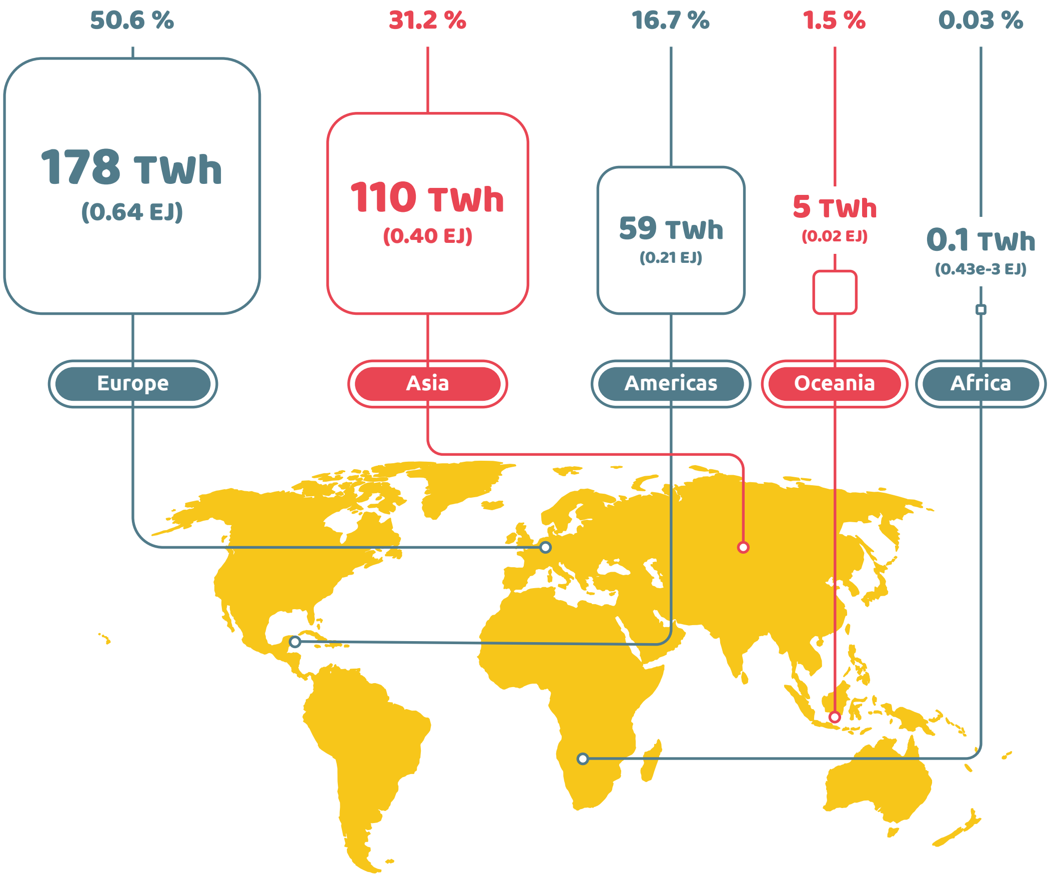
- **Overview of their biogas industries**
- **Key objectives and drivers to develop their biogas industries**
- **Main policy mechanisms**
- **Assessment of the effectiveness of these policies.**

This analysis is provided in sections:
2.1. Snapshot of the global biogas industry
2.2. Key learnings for Australia.

2.1. Snapshot of the global biogas industry

Global production of biogas accumulated to 352 TWh (1.27 EJ)[10] in 2014 *Bib.5*, representing about 1.5 per cent of the global renewable energy supply *Bib.22*. As exhibited in Figure 4, Europe is the leader in terms of production, contributing to more than 50 per cent of the global production, followed by Asia and North America *Bib.23*.

Figure 4
Global and regional biogas production in 2014 *Bib.5*



10 All biogas production figures are given in gross energy. This refers to the energy produced, not the end energy that is converted, transmitted or distributed to consumers (businesses or households).

2.1.1 Europe

In 2015, biogas production in Europe reached 182 TWh (654 PJ), increasing from 99 TWh (357 PJ) in 2010 *Bib.24*. As illustrated in **Figure 5**, the biogas market in Europe has experienced a strong growth. Between 2009 and 2015, the number of installations almost tripled (~6,200 in 2009 to 17,400 plants in 2015). This is particularly thanks to the strong will of some countries to develop their sectors and the establishment of appropriate support mechanisms and policies *Bib.21*.

Since 2015, the sector's growth in Europe has been stabilising. This is mainly due to changes in the national legal frameworks of leading countries like Germany, as discussed subsequently in this section and in section 2.2.

Germany, the United Kingdom (UK) and France are among the leaders in terms of European biogas production, with respectively around 100 TWh (~360 PJ), 23 TWh (82.8 PJ) and 5.5 TWh (19.8 PJ) *Bib.13*, see **Figure 6**. In these countries, different objectives have driven the development of their sectors, which is illustrated by the characteristics of the biogas industry for each of them, particularly in terms of the feedstock used. Thus, the analysis of the key drivers and associated support mechanisms for those countries can illuminate lessons for the development of the Australian biogas industry.

Similarly, **Sweden** is an interesting case study for Australia. Although it is a more moderate biogas producer with 1.9 TWh (7,000 TJ) *Bib.13*, the country's desire to develop the biogas sector for vehicle fuel use deserves attention.

These four countries are studied in more depth.

Germany

Out of the 17,662 biogas plants in Europe, Germany is home to 10,431 plants, accounting for more than 50 per cent of the biogas production in the region *Bib.13*. From the late 1990s, the desire to increase the production of electricity from renewable sources was a key driver for the development of the

Figure 5

Evolution of the number of biogas plants in Europe *Bib.21*

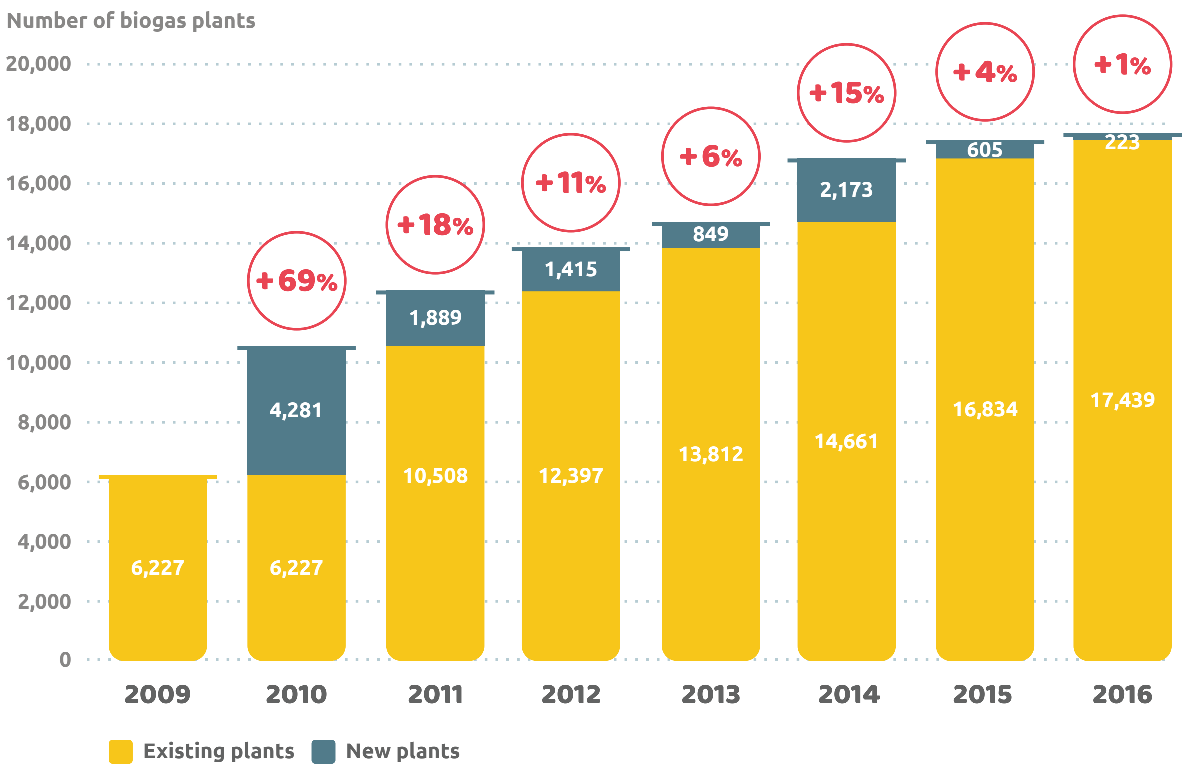
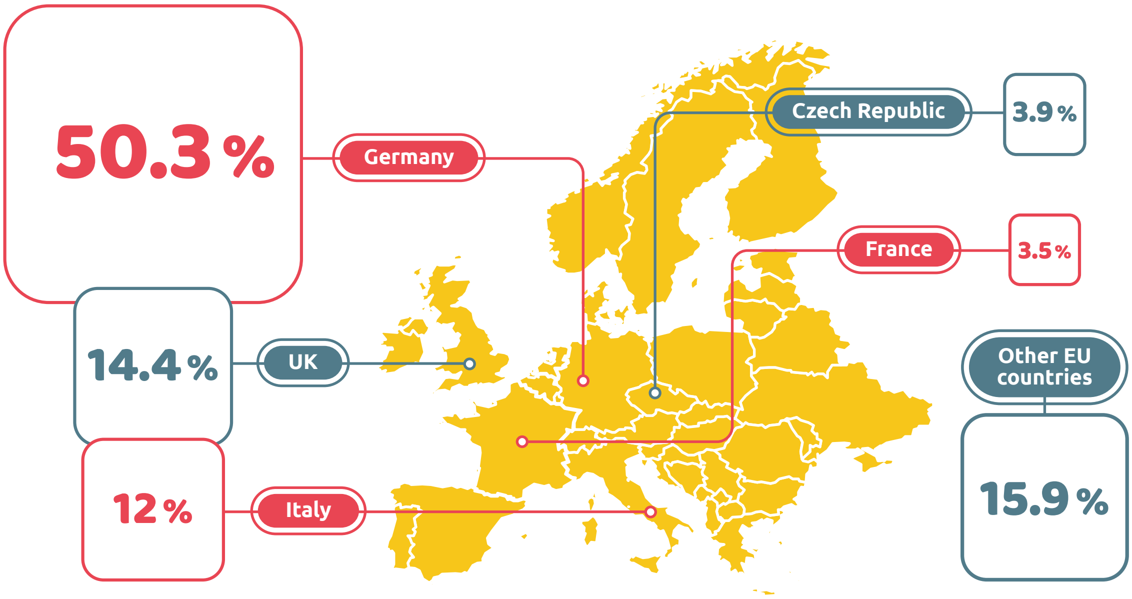


Figure 6

Percentage contribution by countries to EU biogas production in 2015 *Bib.24*



biogas industry in Germany. This was amplified in 2011 with the decision to leave nuclear energy *Bib.25*.

Several mechanisms have been implemented in Germany to support biogas development, in particular:

- The introduction of feed-in-tariffs (FiTs) under the Renewable Energy Act 2000, providing biogas producers with a purchase guarantee at a fixed price for 20 years. The FiTs were considered sufficient to allow biogas plants to be viable and, as such, no additional support for investment was offered. FiTs have been revised several times. Since 2014, they have been gradually replaced by direct sales on the electricity market for units larger than 100 kW. A contract-for-difference scheme is used to facilitate the transition.
- The introduction of a specific bonus in the FiTs for the use of energy crops, primarily maize, between 2004 and 2012, to take advantage of the high methane yield of such feedstock. This has been replaced by a bonus encouraging the use of biowaste.
- Various investment support for biomethane plants, including certificates ensuring the traceability of biomethane exchange *Bib.26*.
- The prohibition of landfilling for waste with an organic matter content of more than 5 per cent since 2002, which has forced the development of alternative routes for waste treatment.

Such mechanisms have resulted into a “biogas boom” between 2000 and 2015. However, the gradual replacement of FiTs by direct sales on the electricity market has led to a stagnation of the industry over the recent years *Bib.25*. This has been emphasised by the restriction on the amount of energy crops used in biogas plants, as a result of the strong opposition faced *Bib.27*. A similar slowdown has been experienced for biomethane production as a result of the cancellation of the FiT for electricity generation from biomethane.

United Kingdom

The biogas sector in the UK has experienced strong growth over the recent years, from 275 units in 2010 *Bib.21* to 987 in 2016 *Bib.13*. This has been boosted by several mechanisms, in particular:

- The establishment of a FiT scheme in 2010 for electricity production and export to the grid *Bib.24. 25*. A contract-for-difference scheme within this FiT scheme is applicable to large generators.

- The obligation for landfill gas to be collected, which, when combined with the above FiT scheme, has considerably encouraged the development of biogas production from landfill *Bib.28*.
- Additional support scheme in the form of Renewables Obligation Certificates (ROCs)[11] for electricity generation and export. Similar certificates for the production and injection of biomethane are available, especially for transportation use *Bib.24. 25. 10*.
- The Renewable Heat Incentive (RHI), which provides complementary support for heat generation from biogas and especially for biomethane injection into the gas grid *Bib.25. 10*. The RHI has boosted the biomethane development between 2013 and 2016. The reduction of Government support in 2017 has resulted in a slowdown of the number of plants built every year *Bib.13*.
- The introduction of a landfill tax from 1996 also contributed to the biogas sector's development. Initially at £7 per tonne of active waste[12] (A$12.3[13]), it reached almost £99 per tonne in 2018 (A$174.5) *Bib.25. 29*.

These different mechanisms have contributed to the biogas sector's development in the UK, which is now the second highest European producer, as illustrated in **Figure 6**. Despite the existence of a landfill tax that intends to encourage the development of anaerobic digestion plants as opposed to landfill gas recovery plants, the latter still contributed nearly 70 per cent of the total electric installed capacity from biogas in 2016 *Bib.21*. The country therefore tends to encourage both the production of biogas by anaerobic digestion and the use and valuation of landfill gas.

Finally, as in Germany, it is worth noting that the recent reduction of Government support for biomethane has slowed down the sector's growth.

France

In France, the total number of biogas plants rose from 498 units in 2010 *Bib.2* to 687 in 2016 *Bib.13*, and from 1 biomethane plant in 2011 *Bib.26* to 47 in 2017 *Bib.13*. The development of the French biogas sector is associated with a desire to involve the agricultural sector, by providing farmers with an additional activity and source of income. Such as Germany and the UK, France has implemented several support mechanisms:

- FiT schemes for electricity export and biomethane injection into electricity and gas grids. To support the agricultural sector, biomethane FiTs include a premium for units using a minimum quantity of agricultural residues as feedstocks. The FiTs are also higher for small-scale units, encouraging on-farm project development.
- Various support for investment, such as capital grants and soft loans from the national energy agency (ADEME) and local councils.
- Different targets for biogas and biomethane, in particular the objective to develop 1,000 on-farm biogas units by 2020 *Bib.30* and to have 10 per cent of renewable gas in the country's total consumption by 2030.
- Certificates ensuring the traceability of biomethane exchange between producers, retailers and consumers (Guaranties of Origin) and providing complementary revenues for the purchase of biomethane *Bib.31*.

In addition to these support mechanisms, some obligations on waste have also encouraged the production of biogas and biomethane:

- Landfilling is regulated and taxed. Landfills must collect the landfill gas naturally produced and at minimum flare it. In addition, when the landfill gas is recovered to produce energy, the level of tax is reduced.
- In addition, any large biowaste producer[14] has the obligation to sort its biowaste and to recover it through composting or anaerobic digestion.

Thus, the French sector has grown considerably in recent years, particularly driven by the enthusiasm for biomethane production and the different mechanisms in place. While historically landfill gas represented a large part of the production, this trend is evolving towards more biogas from agricultural waste, as a result of the different objectives and incentives.

11 FiTs and ROCs cannot be used together.

12 Inactive waste includes most material used in the building industry. Active waste covers all other form of waste, including organic waste that can be used for anaerobic digestion.

13 Conversion rate (28/11/2018): £1=1.76A$.

14 Producing more than 10 tonnes of biowaste annually.

Sweden

Compared with the previous countries, Sweden is a moderate biogas producer, with 279 plants in 2016 *Bib.13*. However, the country is characterised by its proactive policy for the development of natural gas vehicles, in particular from biomethane. In this regard, Sweden has set the ambition for a fossil independent transport sector by 2030.

Several support mechanisms are in place to encourage the use of biomethane as a vehicle fuel, such as:

- Tax exemptions for the use of biomethane as a vehicle fuel instead of diesel or petrol
- Capital grants to support investment in new technologies for biogas and biomethane
- Until 2017, tax rebates for companies using natural gas vehicles *Bib.25*.

In addition to the desire to develop biogas for gas vehicle use, landfilling of organic waste is banned since 2005, which has also driven the biogas sector development.

As a result, Sweden is one of those few countries that has achieved well-developed infrastructure for gas vehicles. Out of its 62 biogas upgrading plants, 47 are supplying biomethane in fuel form, making the country a world leader in biomethane for automotive use *Bib.32*. Despite these developments, the achievement of the 2030 target seems difficult *Bib.25*.

2.1.2 United States

The **United States** (US) is another major biogas producer. The US biogas market saw 2,200 biogas units in 2017, of which about 70 per cent are anaerobic digestors at WWTP. The remaining are landfill gas recovery plants and a very small number of farm-based anaerobic digesters *Bib.17*. According to the American Biogas Council, the construction and operation of biogas plants in 2016 may have supported around 7,000 jobs *Bib.33*.

The US biogas sector differs considerably state by state. **California** ranks first in terms of biogas production, with 276 operational biogas plants in 2015 and up to 1,187 potential projects to be developed in coming years. The willingness to increase renewable energy production and to reduce the state's methane emissions have been key drivers for the development of the Californian biogas industry. The high cost of energy in California is another key driver (the cost of energy varies considerably between different states in the US).

Several mechanisms currently encourage the biogas sector's growth in California, in particular:

- California has pushed for one of the US's most ambitious renewable energy targets under its Renewable Portfolio Standard (RPS). The RPS enforces the procurement of renewable energy sources making up 50 per cent of utilities'[15] total procurement portfolio by 2030 *Bib.34*. Under the RPS, the Bioenergy Feed-in Tariff program was launched in 2015 by California's three largest investor-owned utilities. Small bioenergy generators of less than 3MW are eligible to apply.
- In 2016, state legislation (Senate Bill 1383) included a 40 per cent methane emission reduction target by 2030. As part of this target, landfill disposal of organic waste was also mandated. The objective is to reduce it by 50 per cent by 2020 and by 75 per cent by 2025, from 2014 levels *Bib.35*.
    - This has boosted the biogas and biomethane industries, as producers of organic waste had to identify other ways of treating their waste.
    - Furthermore, in California, emissions from livestock by-products are responsible for more than half of the state's methane emissions. In this context, and in response to the target, California Public Utilities Commission (CPUC) has requested natural gas utilities to implement at least five dairy biomethane pilot projects. In addition to showcasing emission reduction possibilities, these projects shall also demonstrate reasonable cost recovery of connecting to the gas grid *Bib.36*.
    - The state legislation also imposes the development of a pilot financial mechanism to support the production of low-carbon transportation fuels, including bio-CNG from dairy biogas *Bib.35*.

15 The requirements are applied to investor-owned utilities (IOUs), publicly owned utilities, electric service providers, and community choice aggregators.

- The Assembly Bill 1826, which came into effect in 2016, requires all commercial producers of at least 200 tonnes of biowaste per year to recover their waste, either through composting or anaerobic digestion *Bib.37*.

Until recently, biogas was mostly used for heat and electricity generation. California is now looking to accelerate the growth of the biomethane industry via two new bills, which are subject to approval.

- This first bill (Assembly Bill 3187) would require the CPUC to reconsider existing finance program to offer 100 per cent coverage of interconnections costs.
- The second bill (Senate Bill 1440) would establish a biomethane procurement mandate for private, investor-owned gas utilities to secure 32 billion cubic feet (900 million cubic meters) of biomethane by 2030 for injection into the state's gas grid *Bib.38*.

2.1.3 Asia

In developing Asian countries, the production of biogas is dominated by small-scale digesters as a household alternative energy source for cooking and lighting.

China is among the leading countries in the region with the largest number of units of 100,000 modern biogas plants and 43 million residential-scale digesters in 2014, producing about 90 GWh (324 TJ). China has set a national target of 80 million household plants by 2020 *Bib.39*.

Nepal and Vietnam are examples of countries where governments have set national diffusion targets[16] for promoting domestic biogas via financing schemes and local workforce training campaigns *Bib.40*. Specifically, Nepal's Biogas Support Program enabled the installation of 300,000 domestic biogas units over the last 20 years with an average of 1,040 units per month. Vietnam constructed 183,000 commercial plants under the nation's Biogas Program for the Animal Husbandry Sector between 2003-2014 *Bib.39*.

In developed Asian countries, biogas production contributes to the country's electricity generation in the same way as other renewable energies.

For example, in **South Korea**, the biogas production was equivalent to about 2,798 GWh (10,073 TJ) with 110 biogas plants in 2016 *Bib.41*. For the past decade, the majority of biogas production in South Korea came from landfill gas plants. Since 2010, however, biogas plants from sewage sludge and biowaste have started to take up and contributed to 44 per cent and 25.3 per cent of the nation's biogas production in 2016. In the same year, there were 10 biogas upgrading plants supplying biomethane as a vehicle fuel to 0.2 per cent of the total number of buses in the country *Bib.41*.

In South Korea, the main mechanism in place to support the sector's growth is the Mandatory Supply Quantity (MSQ), which has been implemented as part of the Renewable Portfolio Standard (RPS) in 2012. The MSQ requires power plants larger than 500 MW_e to supply 2 per cent of their total power generation "using an appropriate kind of renewable energy" *Bib.13*. The MSQ is supposed to increase up to 10 per cent by 2022. Renewable energy certificates enable transactions under the RPS, replacing the FiTs that were in place until 2011.

16 A targeted amount of biogas units that should be built within a specified time frame.

2.2. Key learnings for Australia

The different examples discussed above provide valuable learnings that could encourage Australia's biogas sector.

1. They illustrate the considerable importance of targets as well as support mechanisms for the development of the biogas sector, such as feed-in tariffs, contracts-for-difference, supports for investment (capital grants, soft loans), or tax rebates. Indeed, the introduction of such policies has resulted in strong sector growth in the countries studied. On the other hand, their withdrawal, or their replacement by less attractive mechanisms, has led to a slowdown in the sector, as experienced in Germany and the UK. In these countries, costs for biogas production are expected to be reduced through innovation, optimisation of technologies and operational practices and sectoral standardisation. Combined with the rising cost of electricity produced from fossil fuels and natural gas, biogas projects could become financially viable without support mechanisms.

The importance of sustainable biogas solutions, including from an economic perspective, has been highlighted in the IEA Bioenergy report, *Integrated biogas systems: Local applications of anaerobic digestion towards integrated sustainable solutions Bib.91*.

Based on these examples, it therefore seems reasonable for Australia to set renewable gas targets and to adopt more systematic support mechanisms, making it possible to supplement existing mechanisms to improve project viability (refer to section 4.1). The establishment of the right level of support must be clearly studied and developed in line with the country's overall strategy to allow for a continuous and sustainable development.

2. To respond to a country's ambition, the use of specific feedstocks is encouraged by certain countries: energy crops then biowaste in Germany, agricultural residues in France, and to a lesser extent, use of landfill gas in the UK. This is done through bonuses (or penalties) or additional incentives for specific feedstock types. The same applies to encouraging the development of small-scale units such as France encouraging small-scale on-farm units through higher FiTs.

In the same way as these countries, the introduction of supports targeting specific feedstock and promoting small-scale units can be a way for Australia to offer new opportunities in targeted industries such as agriculture or WWTP.

As illustrated by the German case, the question of using energy crops is controversial and must be carefully considered. In particular, the plantation of maize for energy has faced strong opposition in Germany considering potential adverse impacts of monocultures on soil, water and biodiversity. Another lively discourse around this problem concerns the increased competition over farm lands causing surging land prices.

3. The implementation of strong landfill constraints, such as the prohibition or restriction of organic waste (Germany, Sweden and California) or at least sufficient waste levies (UK and France) can also considerably encourage the sector's development. The question of waste levies in Australia is further developed in sections 3.5 and 4.2.2.

4. Support mechanisms can also target the use of biogas, as opposed to only its production, and in particular the use of biomethane as an alternative fuel for vehicle, as in Sweden. Encouraging such use may represent a new opportunity to decarbonise Australia's transport sector. This is further explored in section 3.4. Furthermore, biomethane can be easily substituted for natural gas in distribution networks. This can help to decarbonise the use of gas for end-users.

These lessons and their applicability to Australia's industry are elaborated in the following chapters:
3. Opportunities offered by the Australian biogas industry
4. Challenges faced by the Australian biogas industry.

3

Opportunities offered by the Australian biogas industry

The biogas industry brings multiple opportunities, whether from an energy, environmental, social or economic point of view. These opportunities are discussed in this chapter and detailed in the following sections:

- 3.1. Snapshot of Australia's biogas industry
- 3.2. Contribution to greenhouse gas emission reductions
- 3.3. Reliable source of energy
- 3.4. New opportunities for the gas and transport industries
- 3.5. Leveraging Australia's vast bioresources
- 3.6. Alternative route for waste treatment
- 3.7. Economic development opportunities.

3.1. Snapshot of Australia's biogas industry

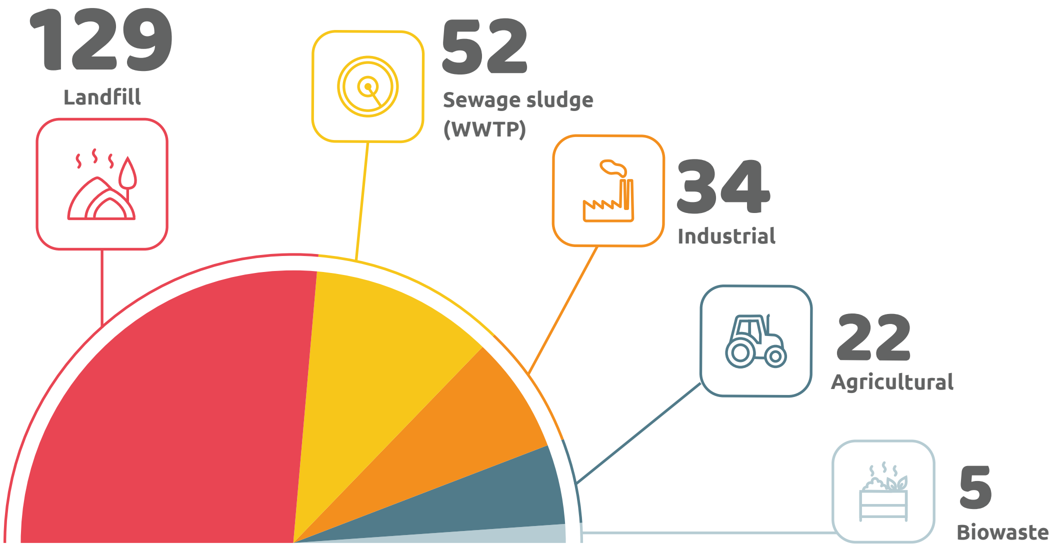
The Australian biogas industry is emerging. In 2016-17, electricity generation from biogas was about 1,200 GWh[17] (4,320 TJ), representing about 0.5 per cent of the national electricity generation *Bib.1*.

In 2017, there were 242 biogas plants in the country, half of which were landfills collecting landfill gas *Bib.2*. Roughly half of this landfill gas was not used as an energy source and was flared. This can be explained by the insufficient infrastructure to use it and, in the case of landfill gas, by the rather poor landfill gas quality.

Figure 7 provides the breakdown of Australian biogas plants.

Figure 7

Estimated number of biogas plants in Australia by feedstock type *Bib.13*



17 This figure captures all electricity generation in Australia, including behind-the-meter (on-site consumption).

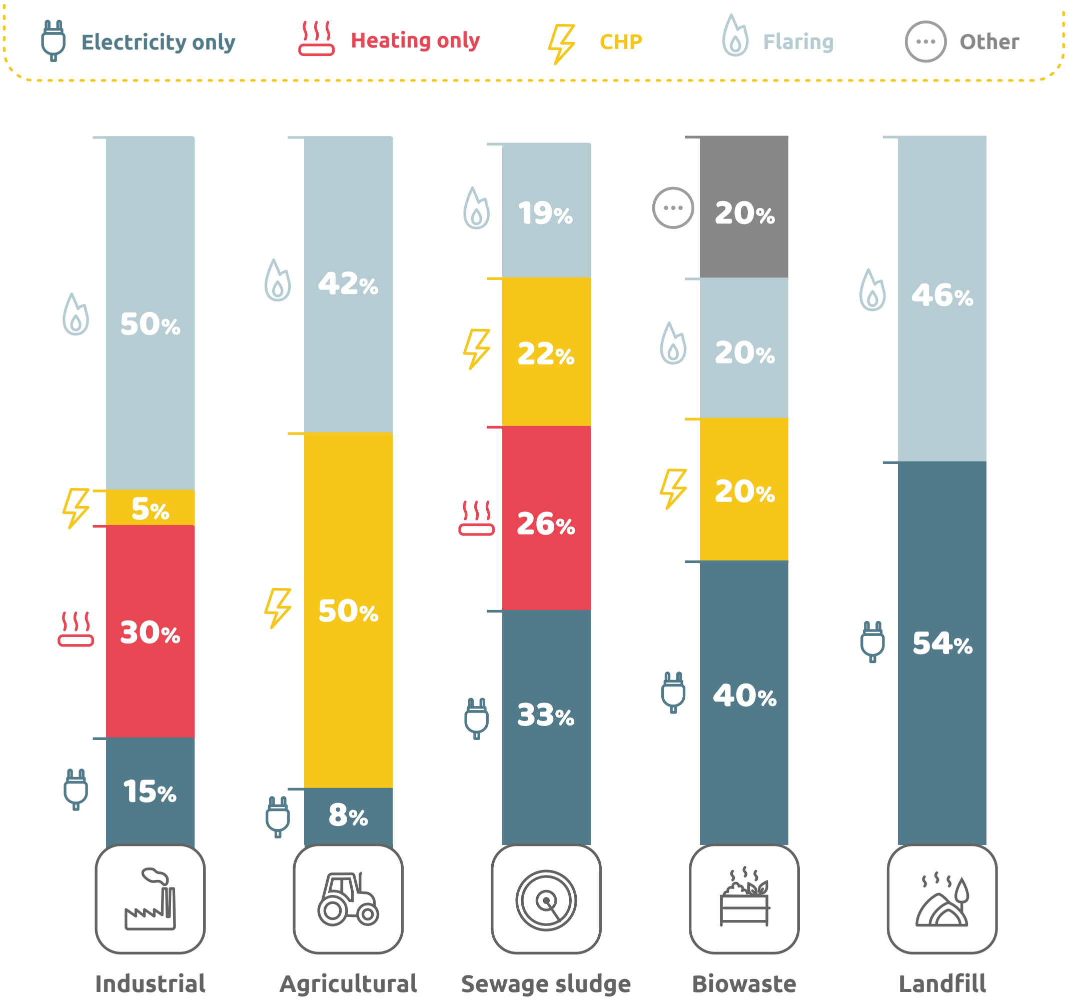
A survey by IEA Bioenergy Task 37 explored 122 out of 242 biogas plants available in Australia. According to this survey:

- Most of the biogas production in Australia is used for heat and electricity generation or is being flared (refer to Figure 8) *Bib.13.*
- Almost half of the landfill gas collected is currently flared. This can be explained by several reasons, including the absence of infrastructure for converting landfill gas into electricity and the lower CH_4 content of the landfill gas (refer to section 1.2.1)
- More than half of the 122 plants rely on biogas production to self-sustain their heat and electricity demand, or to generate revenues from the heat and electricity sales
- There is currently no biogas upgrading plant for biomethane production operating in Australia.

Two recent Australian successful biogas projects are the Jandakot Bioenergy Plant in Western Australia, as detailed in Box 4, and the ReWaste facility at Yarra Valley Water discussed in Box 5. These projects use commercial and industrial biowaste as the main feedstock sources and are among the first projects of their kind in Australia.

Figure 8

Utilisation of biogas in Australia* *Bib.13*



* Data from survey at end of 2017 with 122 respondents.

BOX 4 - PROJECT EXAMPLE 1 – RICHGRO JANDAKOT BIOENERGY PLANT, JANDAKOT, WESTERN AUSTRALIA

Figure 9

Jandakot Bioenergy Plant *Bib.42*

The Jandakot Bioenergy Plant was commissioned in 2015 by Biogass Renewables for Richgro.

- Biogass Renewables is an Australian company established in 2011. It provides anaerobic digestion systems and services including development, design, finance, planning approval support, grid connection, building, commissioning and operational support.
- Richgro is an Australian supplier of premium garden products since 1916.

Plant capacity

- The facility handles an annual volume of 30,000 to 50,000 tonnes of commercial and industrial biowaste.
- The plant has an installed capacity of 2MW for electricity and 2.2 MW for heat generation *Bib.42*.

Capital investment

A$8-10 million *Bib.43*.

Government support and funding

- The project received a A$2.2 million loan from CEFC in 2013.
- The project also received A$1.6 million in grants from the Clean Technology Investment Program[18] and the Western Australian State Government.

Revenues

- Richgro benefits from more than A$400,000 of annual electricity bill.
- By diverting waste from landfill, Richgro also earns additional income for its treatment.
- The bio-fertiliser product of biogas plant is blended with existing Richgro products, improving nutritional characteristics and value of their products.
- The payback period of the plant is estimated at less than four years before grants.

GHG savings

The facility has the potential to help save 142,772 tonnes of CO_{2e} over its lifespan of 20 years *Bib.44*.

18 The Clean Technology Investment Program is the Australian Government's A$800 million competitive, merit-based grants program that is applicable to low-pollution technologies, processes and products. The program was available between 2011 and 2018.

BOX 5 - PROJECT EXAMPLE 2 – REWASTE PLANT AT YARRA VALLEY WATER, WOLLERT, VICTORIA

Figure 10

Rewaste Plant at Yarra Valley Water

The Waste to Energy Plant, known as ReWaste, was built by Yarra Valley Water and located next to its existing Aurora sewage treatment plant. The plant came into commercial operation in 2017 *Bib.45*.

- Aquatec Maxcon is an Australian company that manufactures and provides water and wastewater treatment technologies, as well as waste-to-energy technology via a partnership with Weltec Bio Power. Aquatec Maxcon is the technology provider for the ReWaste facility and in charge of the engineering, procurement and construction (EPC) *Bib.46*.
- Yarra Valley Water is Victoria's largest water utility.

Plant capacity

- The facility handles an annual volume of 33,000 tonnes of commercial and industrial biowaste *Bib.47*.
- The installed electric capacity of the plant is 1MW *Bib.46*.

Capital investment

A$27 million *Bib.48*.

Grant funding

The project is eligible for the Emission Reduction Fund (see section 4.2.1).

Revenues

- Around 30 per cent of the overall electricity generation by the ReWaste plant can sufficiently supply the total electricity demand of the Aurora sewage treatment plant. The remaining electricity production is exported to the grid *Bib.45*.
- The plant can potentially produce digestate for agricultural use *Bib.46*.

3.2. Contribution to greenhouse gas emission reductions

Biogas production and utilisation can contribute to Australia's national greenhouse gas (GHG) emission reduction target by providing a renewable energy source and capturing emissions from animal waste storage and landfill sites. These emissions would otherwise be released into the atmosphere *Bib.49*.

In 2015 under the Paris Agreement, the Australian Government committed to reduce emissions by 26-28 per cent from 2005[19] levels by 2030. According to CEFC's 2015 report *The Australian bioenergy and energy from waste market,* the investment opportunity to 2020 for new bioenergy and energy from waste projects[20] was estimated to avoid more than 9 million tonnes of CO_{2e} emission Australia-wide, each year between 2015 and 2020 *Bib.4*.

The biogas sector's contribution to the reduction of GHG emissions is made through three main pathways:

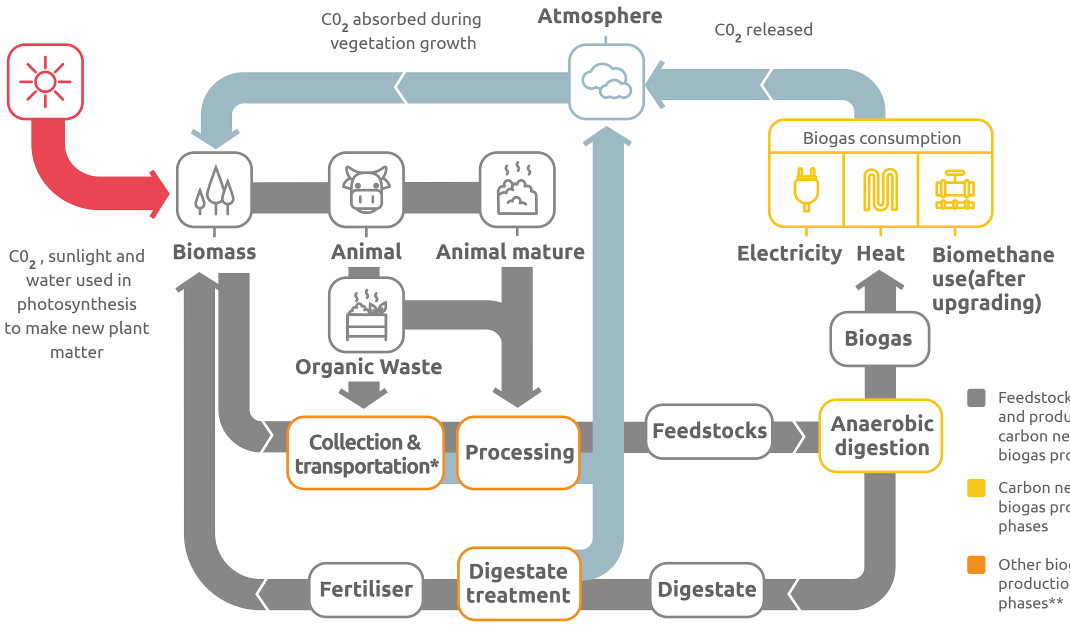
1. Replacement of fossil fuels: the reduction of carbon dioxide emissions is realised when biogas replaces fossil fuels for energy purpose. The combustion of fossil fuels releases carbon accumulated over millions of years. In contrast, the combustion of biogas is considered as carbon neutral (see Figure 11), due to the shorter lifecycle of the biomass used.

In Australia, the consumption of natural gas from the gas grid accounts for the emission factor of 51.53 gCO2e per MJ, while the emission factors for the combustion of sludge biogas or landfill gas are 4.83 gCO2e per MJ *Bib.92*.

In a study conducted by ENEA Consulting and Quantis in 2015, the replacement of natural gas by biomethane in France resulted in the reduction of GHG emissions by 54 gCO_{2e} for each MJ that was produced[21], injected into the gas grid and consumed *Bib.50*. This amount translates to more than 85 per cent emissions reduction from the consumption of natural gas, which has the emission factor of approximately 63.1 gCO_{2e} per MJ (LHV) in France *Bib.93*.

Figure 11

Representation of carbon neutral biogas combustion *Bib.51*



*This phase can be avoided for facilities, typically abattoirs, food manufacturers or wastewater treatment, where an anaerobic digester is located on-site.
**The biogas consumption (combustion) phase is considered to be carbon neutral. However, other biogas process phases, such as harvesting, transportation and processing of feedstock and digestate treatment, release additional GHGs (incl. methane) into the atmosphere. These must be taken into account in the overall biogas life cycle evaluation.

19 Australia's total GHG emissions in 2005 equalled about 503 MtCO2e, estimated by the Climate Action Tracker. National emissions are projected to reach 533 MtCO2e by 2020 and 548 MtCO2e by 2030, equivalent to a 6 per cent and 9 per cent increase compared to 2005 levels,respectively *Bib. 89*.

20 As well as biogas projects, this investment opportunity includes other waste to energy technologies such as direct combustion of waste (biomass combustion or waste incineration).

21 Based on a representative mix of the French biomethane production, including biomethane from agricultural and industrial waste (81%), from WWTP (9%), from household biowaste (6%) and from landfill gas (4%).

It is important to consider the entire lifecycle of the biogas production and use. Indeed, although the combustion phase is considered carbon neutral, the other phases of the process (transport, feedstock and digestate treatment etc.) release GHGs in the atmosphere.

2. Capture of methane emissions from landfills: new landfill sites start to release methane[22] after five years, reaching a peak emission in about 20 years, and continue to discharge gas over the course of following decades. Thus, capturing exiting methane from landfills to utilise for energy production contributes to GHG emission reduction.

3. Capture of methane emissions from animal waste and meat processing waste water storage lagoons: open storage of slurry and lack of manure treatment results in methane emissions being released into the atmosphere. By using them as a feedstock for biogas production, methane emissions are avoided or at least reduced.

3.3. Reliable source of energy

In addition to offering a renewable energy source, energy produced from biogas provides a secure, continuous and dispatchable source of energy that can contribute to the national energy supply.

This is especially relevant when the biogas is converted into power for exporting to the grid. Considering the increasing penetration of variable renewable energies in the electricity generation mix, such as solar and wind, biogas can support the reliability and predictability of the energy system with a continuous source of supply.

In the case of biomethane injection, the gas grid offers a way of storing energy from biogas.

3.4. New opportunities for the gas and transport industries

The development of the biogas sector, and in particular the biomethane sector, represents new opportunities for the gas industry and the transport sector:

- **Biomethane for grid injection:** as biomethane has similar characteristics to natural gas, its injection into the gas grid does not require any adaptation of the existing infrastructure (neither the gas grid nor customer equipment connected to it). The *Gas Vision 2050* report[23] reflects the ambitions of the key organisations representing Australia's gas sector on accelerating the decarbonisation of the gas sector beyond 2050. Biogas production is identified as one of the primary technologies for achieving this using existing infrastructure *Bib.52*.
- **Biomethane for vehicle fuel:** biomethane produced from biogas upgrading plants can be further compressed or liquefied to be used as fuel for vehicles, mostly cars, buses and trucks of various sizes (see **Box 6**). It therefore offers a new opportunity to decarbonise the transport sector while promoting new uses for gas.

BOX 6 - BIOMETHANE FOR MOBILITY: LEVERAGING THE SWEDISH EXPERIENCE

Only a few countries have achieved a well-developed infrastructure for vehicle gas. For example, Sweden has set the ambition for a fossil-fuel free transport sector by 2030. Biomethane is a key way of achieving this ambition *Bib.53* (see section 2.1).

This opportunity has already been recognised by a number of pioneering providers of commercial vehicles developing alternative solutions for vehicle fuels.

- Scania, a Swedish manufacturer of commercial heavy vehicles, has offered 95 biomethane buses to the Kalmar county public transport in 2017, as part of a longer-term service contract targeting the distribution of more than 500 vehicles *Bib.54*. In Australia, Scania has signed memoranda of understanding with different biofuel providers as well as the NGV Group *Bib.55*. This has the potential of opening up future opportunities for fuelling its current fleet of gas buses and future gas vehicles with biomethane in Australia.
- Iveco is another major provider of natural gas-powered commercial vehicles, headquartered in Italy, with a long-term presence in Australia *Bib.56*. The company has supplied five units of biomethane-fuelled trucks to Verbio Logistik GmbH, a German biofuel provider, representing representing Germany's first CO_2 neutral fleet. These trucks will be run on biomethane produced from Verbio's own plant in Schwedt *Bib.57*.

22 A very potent GHG with a global warming potential more than 25 times that of CO2 *Bib.4*

23 An initiative created by The Australian Pipelines and Gas Association, the Australian Petroleum Production & Exploration Association, Energy Network Australia, the Gas Appliance Manufacturers Association of Australia, and Gas Energy Australia.

3.5. Leveraging Australia's vast bioresources

As discussed in section 1.2.1, various feedstock types can be used for biogas production. Australia has many of these resources at its disposal, especially:

- Industrial waste from food industries such as dairy and meat industries
- Agricultural waste such as pig slurry and crop residues
- Sludge from WWTP
- Biowaste, or organic waste, from households, communities or small-scale commercial and industrial activities.

A number of studies have estimated the biogas potential in Australia. In the report *Decarbonising Australia's gas networks* *Bib.3*, Deloitte estimated[24] the total biogas potential in Australia at 371 PJ (103 TWh), representing 102 per cent of the gas consumption from the distribution network.

This would represent up to about 90,000 biogas units, considering the current average size of biogas units in Australia[25]. However, future work is required to assess the proportion of this potential that could be realised. Moreover, the estimated biogas potential is highly variable state by state. For instance, the estimated biogas potential in Victoria represents only 27 per cent of the state's gas consumption from the distribution network.

As the distance between the feedstock and the chosen location of a project is critical, detailed mapping of resource availability is necessary to facilitate project development. This is the objective of the ABBA project. As part of this project, a national database of biomass resources for bio-energy across Australia will be delivered *Bib.58*. This work should considerably facilitate the access to the relevant feedstocks for biogas projects and address Australia's 'tyranny of distance' (refer to section 4.3).

3.6. Alternative route for waste treatment

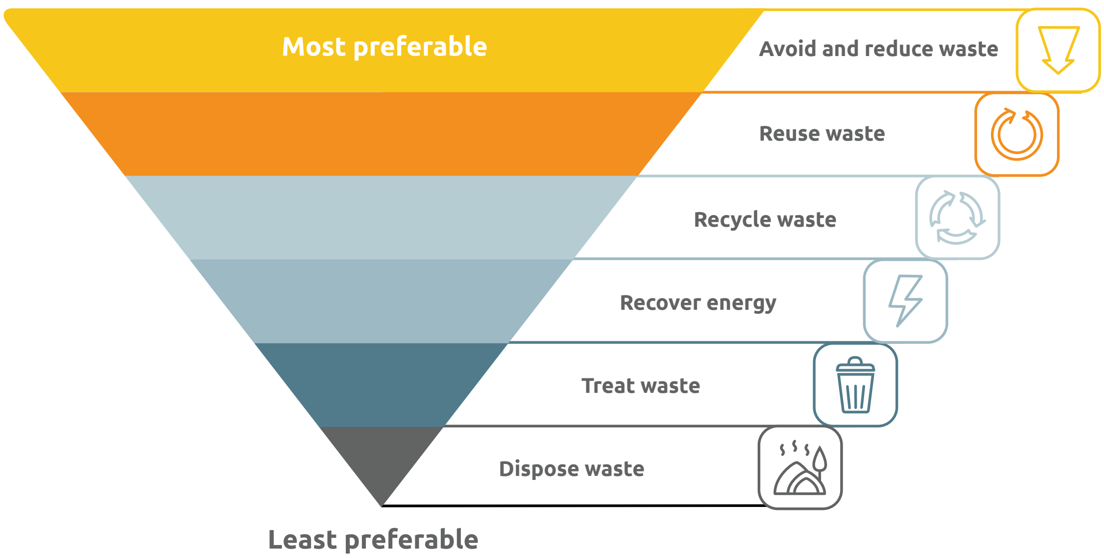
Another positive attribute of biogas is the opportunity for a more sustainable waste management route.

Following the waste hierarchy (see Figure 12), the most preferable waste management option is avoiding and reducing waste. Accordingly, Australia has set a national goal of halving food waste by 2030 *Bib.59*. Subsequently, recovering energy from waste, which includes biogas production, is more preferable than landfill disposal. Disposing waste into landfills is the least preferred option.

According to the *National Waste Report 2018*, Australia generated about 14.2 megatons (Mt) of non-hazardous organic waste in 2016-2017 *Bib.61*:

Figure 12

Waste hierarchy *Bib.60*



24 Estimation based on literature review.

25 Based on the average annual biogas production per type of biogas unit.

- More than 50 per cent of the total amount of waste generation is recycled, predominantly via composting
- About 10 per cent is used for energy recovery, predominantly through the collection of landfill gas and use for electricity generation
- The remaining waste volume (less than 40 per cent) is being sent to landfills with gas collection systems. The gas, however, is not being recovered for electricity and is instead flared *Bib.61*.

The significant cost of landfilling is another element to consider when assessing the different options, as detailed in Box 7.

Beside the treatment of organic waste, biogas technology can also be implemented for wastewater treatment. Anaerobic digestion is applicable for treating organic matter in wastewater into biogas, especially for industrial wastewater with high organic matter content and warm temperatures. High strength wastewaters such as the ones from meat industries require an adequate removal of solids *Bib.15*.

In municipal WWTP, anaerobic digestion can be incorporated prior to the aerobic treatment to reduce the amount of sludge and improve the efficiencies of energy and chemical use of the plant *Bib.68*.

BOX 7 - WASTE LEVIES IN AUSTRALIAN STATES

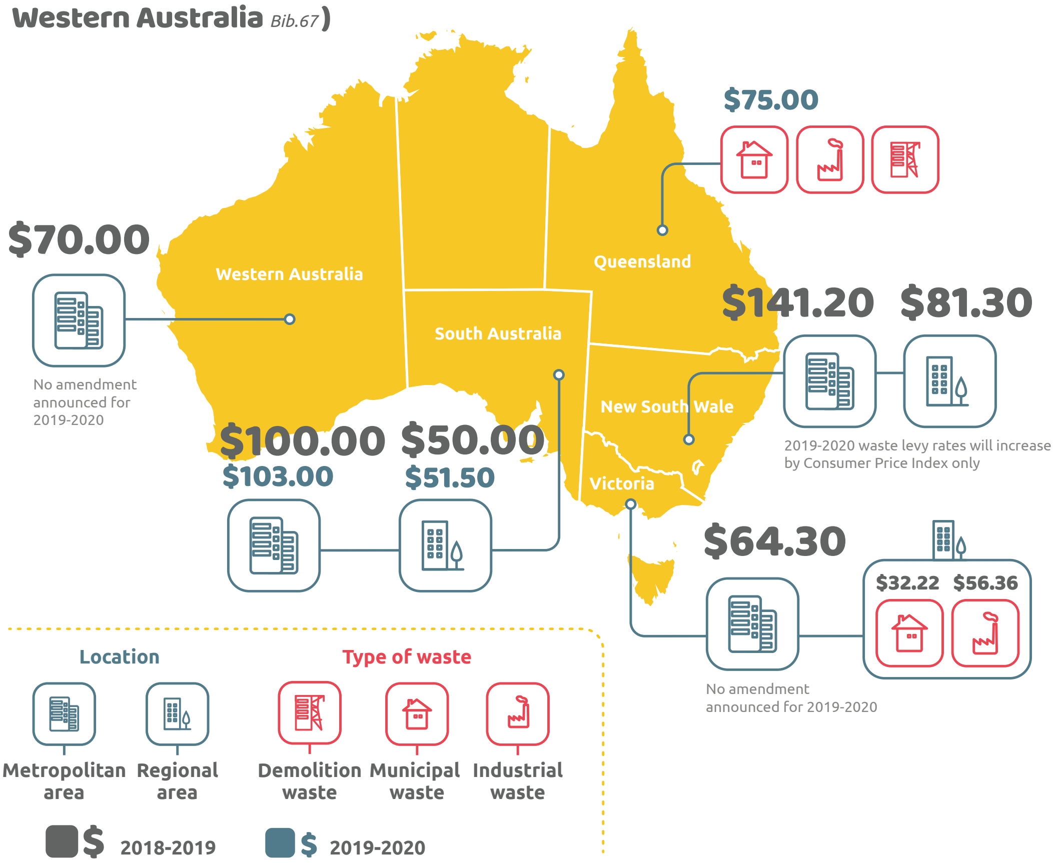
Waste levies

Landfilling comes at a cost. This cost has been valued at approximately A$120/tonne of waste after taking into account post-closure remediation and replacement costs *Bib.4*. Landfill sites also incur environmental and social costs of GHG emissions and odour release. As a consequence, several states have put in place waste levies to recover landfill costs as outlined in Figure 13.

For the states where waste levies are available, they act as an imperative economic driver providing an additional source of income and enhancing the viability of biogas projects. The development of the biogas sector could benefit from more uniform levies between the states. This point is elaborated in the section 4.2.2.

Figure 13

Waste levies by state (A$/tonne) for 2018-2019 in Australia (Queensland *Bib.62, 63* **New South Wales** *Bib.64* **Victoria** *Bib.65* **South Australia** *Bib.66* **Western Australia** *Bib.67***)**

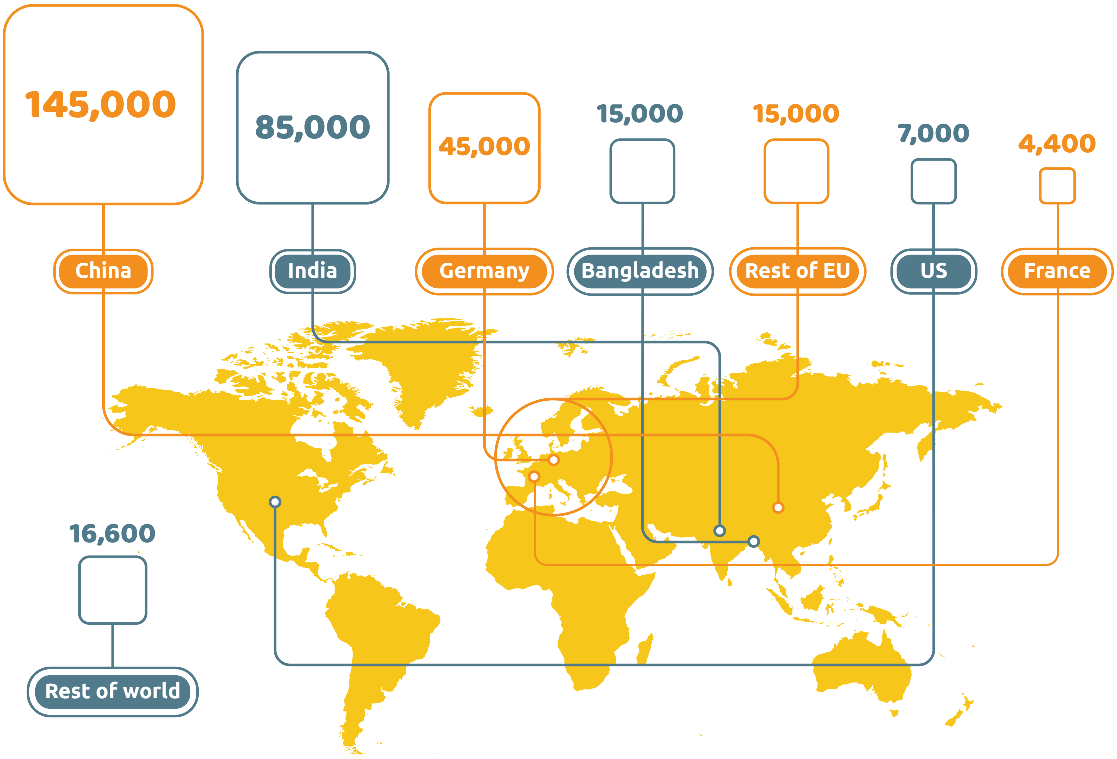


3.7. Economic development opportunities

Developing the biogas sector contributes to the development of local economies via several ways:

- **Investment opportunity:** According to CEFC's 2015 report *The Australian bioenergy and energy from waste market*, the investment opportunity to 2020 for new bioenergy and energy from waste projects is estimated at $A3.5 to 5.0 billion *Bib.49*. As well as biogas projects, this investment opportunity includes other waste to energy technologies such as direct combustion of waste (biomass combustion or waste incineration).
- **Job creation:** the development, construction and operation of biogas units result in direct and indirect job creation. According to the International Renewable Energy Agency (IRENA), the biogas sector represented about 333,000 jobs globally in 2016 (see Figure 14). China accounted for slightly less than half of these jobs, with 145,000 estimated direct and indirect jobs in the biogas industry. In the United States, the construction and operation of biogas plants in 2016 may have supported around 7,000 jobs according to the American Biogas Council *Bib.33*.
- **Local circular economies:** by using waste locally produced as inputs and generating biogas and digestate as outputs, the overall biogas value chain is representative of the circular economy concept[26]. Biogas and digestate can be used locally, as an energy source and an alternative fertiliser for agriculture, respectively. This has been demonstrated in a number of international case studies as discussed in the report by IEA Bioenergy Task 37, *The role of anaerobic digestion and biogas in the circular economy Bib.69*. A local example of a piggery in NSW, which has effectively treated and turned the animal by-products into biogas, is provided in Box 8.
- **New source of income for farmers:** the development of anaerobic digestion plants directly on farms offers new business opportunities and therefore potentially new sources of income for farmers. This was one of the drivers for the development of the biogas sector in France (see section 2.1).

Figure 14
Estimated direct and indirect jobs in biogas industries worldwide in 2016 *Bib.33*



26 Circular economy refers to the use of materials and resources in a closed loop, where all the input materials are locally treated and processed into new products.

BOX 8 - PROJECT EXAMPLE 3 – RIVALEA BIOGAS GENERATOR PROJECT, COROWA, NSW

Figure 15
Rivalea biogas installation *Bib.71*

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The Rivalea biogas generator project was commissioned in 2017 by Evo Energy for Rivalea Australia.

- Evo Energy is an Australian company that has been offering heat pump, cogeneration and heat recovery solutions for over 11 years *Bib.70*. Evo Energy partners with 2G Energietechnik – a German provider of combined heat and power technologies – for Rivalea's biogas cogeneration system.
- Rivalea is among the leading Australian integrated agri-food companies. After the successful installation of the first covered anaerobic lagoon at another site in NSW in 2010, the company was looking to further reduce its energy consumption and environmental impact. This was the main driver for Rivalea's biogas project at its Corowa farm, incorporating a covered lagoon for biogas collection and the cogeneration system *Bib.71*.

Plant capacity
Rivalea biogas generator deploys a custom-built 500 kW combined heat and power unit. The system involves a pre-treatment of biogas prior to the combustion of high-quality biogas. The plant can also provide heat for the lagoon and piggery sheds during winter *Bib.71*.

Capital investment
No public information available.

Grant funding
No public information available.

Revenues
The CHP unit contributes to significant energy cost savings by supplying about 25 per cent of the site's power demand.

GHG savings
The plant is estimated to help avoid 28,000 tonnes of CO_{2e} emission per year *Bib.72*.

4

Challenges faced by the Australian biogas industry

A number of challenges are currently faced by the biogas industry in Australia, slowing down the development of biogas projects. These challenges are detailed in the following sections:

- **4.1. Financial viability**
- **4.2. Further policy support**
- **4.3. Issue of distance in Australia**
- **4.4. Project development and operation obstacles.**

4.1. Financial viability

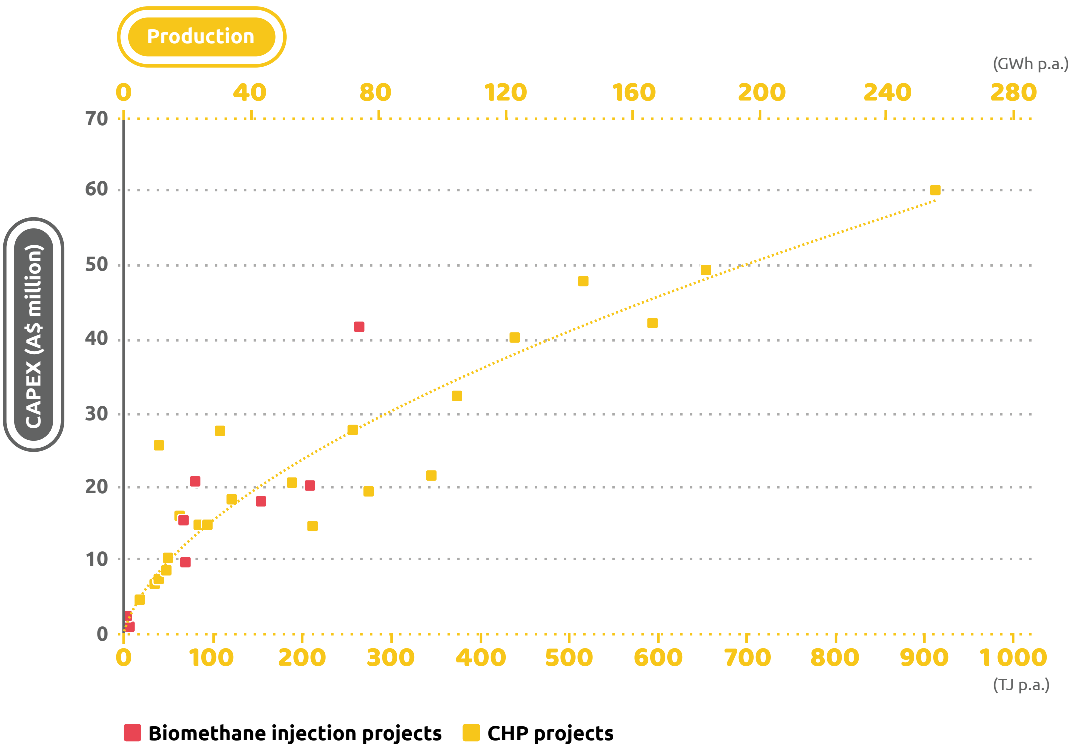
To ensure strong and sustainable development of the sector, biogas projects need to be financially viable. To achieve this, the cost of producing energy from biogas, encompassing both capital (CAPEX) and operating expenditures (OPEX), must be compensated by the sources of incomes from the operation of a biogas unit, in addition to any financial support received.

Whatever the selected use for the biogas (heat, electricity, and/or biomethane), biogas plants require relatively substantial CAPEX, constituting a first barrier for project development. As an illustration, Figure 16 below provides typical CAPEX for biogas projects in Europe (Denmark, France, Germany, Holland and UK) and the US.

Typical CAPEX can range from approximately A$5 million for a small plant (less than 5 GWh or 18 TJ

Figure 16

Typical CAPEX for biogas projects in Europe (Denmark *Bib.10* **France** *Bib.10* **Germany** *Bib.73* **Holland** *Bib.10* **and UK** *Bib.74, 75* **) and the US** *Bib.76, 77, 78*



per annum) up to A$50 million for a large one (around 200 GWh or 720 TJ per annum). Small to medium scale projects, typically less than 30 GWh per annum (108 TJ), are particularly disadvantaged. They do not benefit from economies of scale and project proponents may have limited resources.

The overall cost of producing and injecting biomethane into the grid is illustrated in Box 9 with German and French examples.

On top of CAPEX and OPEX, sources of incomes throughout the project lifetime must also be

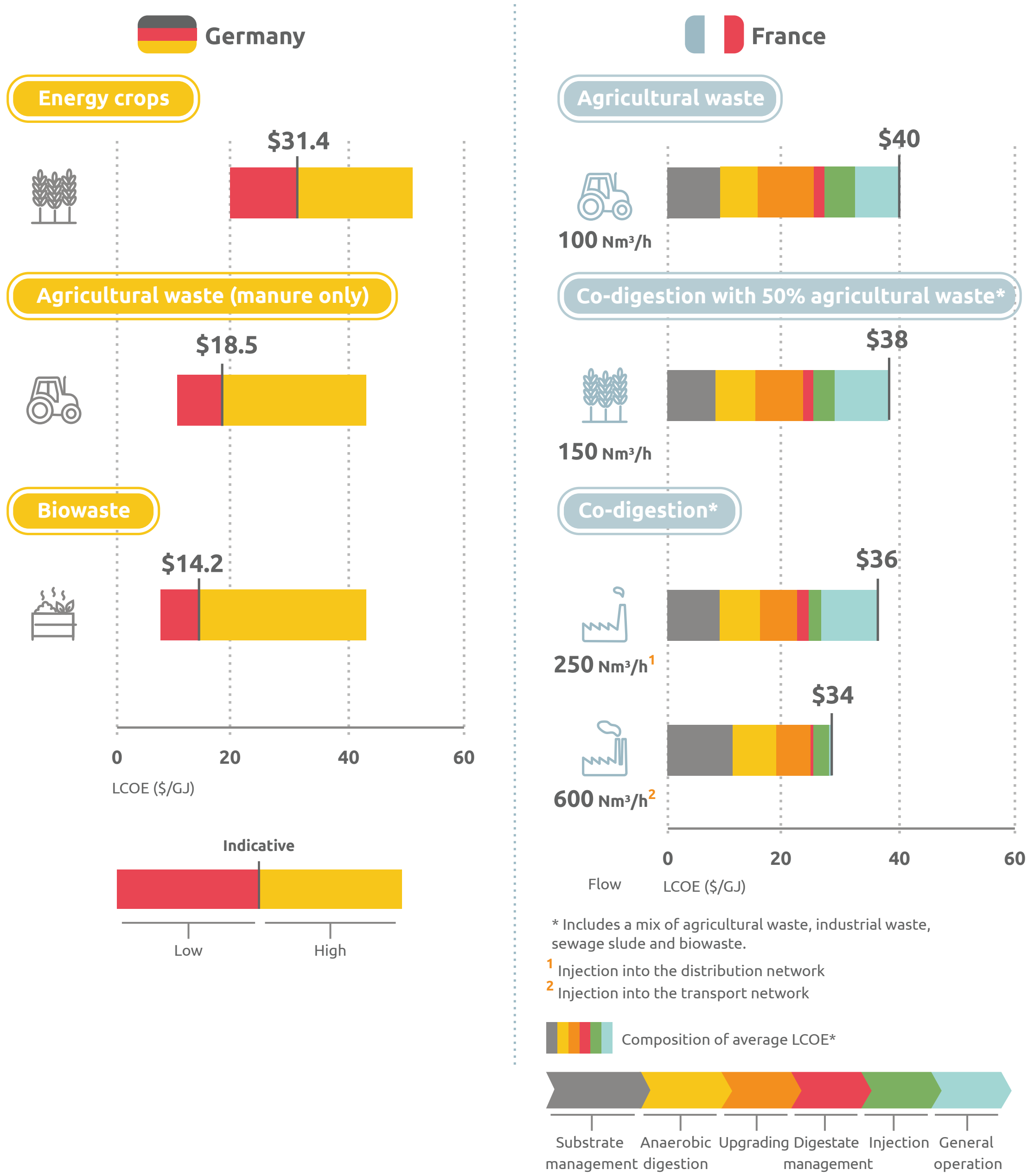
BOX 9 - BIOMETHANE PRODUCTION AND INJECTION COSTS

To facilitate the emergence of biogas upgrading and injection plants in Australia, lessons can be learned from some of the leading countries in terms of biomethane development.

Based on German and French examples, the cost of producing and injecting biomethane into the gas grid ranges from about A$7.4/GJ to A$51/GJ, mainly depending on the type of feedstock used and the size of the unit, as illustrated in Figure 17.

Figure 17

Cost of producing and injecting biomethane into the German and French grids (Germany) *Bib.3* **and (France)** *Bib.31*



* Includes a mix of agricultural waste, industrial waste, sewage slude and biowaste.

[1] Injection into the distribution network

[2] Injection into the transport network

carefully considered to assess the overall financial viability of a project.

Typical sources of income include:

- Revenues from waste treatment, where applicable (see section 3.5)
- Revenues (or savings) from the sale or self-consumption of the energy produced
- Revenues from the sale of digestate.

At the moment, such income sources are not always sufficient to compensate project costs and they can be hard to secure throughout the lifetime of a project. This point is further elaborated in section 4.4.

Some financial incentives are available to improve projects' viability (refer to section 4.2.1). However, the high level of investment required as well as the complexity of securing revenue sources for a project still represent a barrier to overcome for project proponents. It makes it all the more difficult to find and secure private financing.

Nonetheless, currently in Australia, some projects do stack-up financially. Based on feedback from project proponents, projects for on-site consumption (behind-the-meter) usually demonstrate better financial viability.

4.2. Further policy support

Several incentives schemes are available for the Australian biogas sector. This section provides an overview of such schemes (see section 4.2.1), before detailing the main gaps in the current regulatory framework (see section 4.2.2), which are:

- Absence of national targets for biogas production
- Absence of a regulatory framework and a national target for biomethane production
- Financial uncertainties associated with power exported to the grid
- Gaseous fuel tax
- Lack of consistent national digestate regulations
- Lack of uniform landfill waste levies
- Lack of uniform and concurrent directions from national and state governments.

4.2.1 Existing support mechanisms for the Australian biogas sector

National support
Several national support mechanisms are available for the development of biogas in Australia, in particular:

- **The Emission Reduction Fund (ERF)**[27] aims to incentivise the adoption of new practices and technologies that reduce GHG emissions among Australian businesses, farmers, land holders and others. The ERF is a voluntary scheme, where Australian Carbon Credit Units (ACCUs) in the unit of tonne of CO_2e stored or abated can be sold to the Government or in the secondary market[28].
- **The Renewable Energy Target (RET) scheme** aims to generate 23.5 per cent of Australia's electricity or 33,000 GWh generation from renewable sources by 2020 – operating in two distinct parts *Bib.80*:
  - Small-scale renewable energy scheme (SRES) provides financial incentives for small-scale production (<100 kW) of renewable electricity by households, small businesses and community groups that is offered in form of small-scale technology certificates (STCs). Due to the 100 kW limit, few biogas plants qualify as they are usually larger.
  - Large-scale renewable energy target (LRET) encourages large energy users to adopt renewable sources to support their electricity use through purchasing large-scale generation certificates (LGCs) from renewable energy power stations (>100 kW).
- **Australian Renewable Energy Agency (ARENA)** offers a number of funding opportunities for renewable energy projects. As an example, the Goulburn Bioenergy project led by ReNu Energy (see Box 10) has received a A$2.10 million funding from ARENA in 2017 and is benefitting from LGCs and ACCUs.

27 With A$2.55 billion funding from the Australian Government.

28 The secondary market refers to transactions of ACCUs outside a contract with the Clean Energy Regulator.

BOX 10 - PROJECT EXAMPLE 4 – GOULBURN BIOENERGY PROJECT

Figure 18

Anaerobic digester and flare of the Goulburn Bioenergy Project *Bib.83*

The Goulburn Bioenergy Project at the Southern Meats abattoir commenced operation in February 2018.

- ReNu Energy is an Australian independent power producer (IPP) offering clean energy solutions. ReNu Energy has provided a build, own, operate and maintain (BOOM) model for the Goulburn Bioenergy Project.
- Southern Meats abattoir purchases the electricity via a 20-year power purchase agreement (PPA).

Plant capacity

The bioenergy plant includes a covered anaerobic lagoon for the treatment of wastewater from the abattoir, followed by a biogas treatment process. Produced biogas is then fed into 2 x 800 kW dual fuel Caterpillar generators that can run on dual fuel, blending biogas and natural gas.

Capital investment

A$5.75 million *Bib.81*

Government support and funding

- The project has received a A$2.1 million grant funding from ARENA.
- The project is eligible to obtain approximately 2,500 Large-Scale Renewable Energy Certificates (LGCs) per year.
- The project will also benefit from about 8,000 ACCUs per year via a contract with the Clean Energy Regulator *Bib.82*.

Revenues

The facility supplies approximately 4,200 MWh of energy for the abattoir during peak and shoulder periods, which help to significantly reduce the facility's electricity bill by over 50 per cent per year *Bib.82. 83*.

GHG savings

The plant is estimated to contribute to approximately 18,000 tonnes CO_{2e} emission savings *Bib.82*.

This assistance has most likely contributed to the project's viability. Other biogas-related initiatives funded by ARENA include feasibility studies and enabling projects:

- Unitywater sewage waste-to-energy feasibility study
- Feasibility study for the integrated community waste-to-energy project for Mt Alexander Shire
- Participation in the IEA's Bioenergy program
- ABBA project (see section 3.5).

CEFC is working with Foresight Group to identify and develop opportunities to invest equity in a range of bioenergy and energy from waste projects in the Australian market. These can include landfill gas capture and destruction, anaerobic digestion, biomass to energy, and the production of biofuels such as processed engineered fuel (PEF) and refuse derived fuel (RDF) which can be used as an alternative to gas or coal-fired generation. Internationally, the Foresight Group has financed waste projects with an annual waste processing capacity of 1.9 million tonnes.

State support

In addition to national support, several grants and specific policies are available at the state level, as listed in Table 3. They are further elaborated in the report *Bioenergy state of the nation report* Bib.6.

Table 3

Policies applicable for biogas development in the different Australian states

Northern Territory, Tasmania, Western Australia

- No specific grants or incentives for the biogas sector were identified in these States according to Bioenergy state of the nation report [6].

Queensland

- Planning Act 2016
- Waste Reduction and Recycling Act 2011
- Resource Recovery Industry Development Program with A$100m funding over three years.

South Australia

- A$150m Regional Growth Fund
- A$150m Renewable Technology Fund.

New South Wales

- Protection of the Environment Operations Act 1997
- Waste Avoidance and Resource Recovery Act 2001
- Environmental Planning and Assessment Amendment Act 2017
- Climate Change Fund with A$1.4 billion investment between 2017 and 2022 administered by the Office of Environment & Heritage Bib.84
- Regional Community Energy funding program supporting community renewable energy projects Bib.85.

Victoria

- Victorian Waste and Resource Recovery Policy under the Environment Protection Act 1970
- Landfill guidelines by Environmental Protection Agency (EPA) Victoria
- Sustainability Fund re-distributing landfill levies to funding programs
- Waste to Energy Infrastructure Fund (closed)
- The Renewable Energy (Jobs and Investment) Act 2017 and especially the Climate Change Act 2017 setting a net-zero emission target by 2050
- New Energy Technologies - Sector Strategy realising the need to support the bioenergy sector growth.

Australian Capital Territory

- Waste Management Strategy 2011-2025
- Sustainable Energy Policy setting the state's 100 per cent renewable generation goal by 2020.

4.2.2 Policy challenges and gaps

Despite the above-mentioned support mechanisms for the biogas sector, a certain number of gaps and challenges have been identified. These include:

- **Absence of national targets for biogas production:** there are currently no targets for biogas production. Clean Energy Council's suggested targets for electricity generation from bioenergy (including biogas and other forms of energy from biomass), are *Bib.51*:

  - 2,413 GWh by 2020
  - 55,815 GWh by 2050.

- **Absence of a regulatory framework and a national target for biomethane production:** some mechanisms presented in section 4.2.1 are currently not applicable to biomethane production, grid injection and use as a vehicle fuel. This is the case with the ERF and the RET. The extension of the ERF mechanism to a wider market such as biomethane injection has been recommended by Energetics in the report *Renewable gas for the future Bib.8* for Energy Networks Australia.

  It would be applicable to biomethane and hydrogen produced from renewable sources.

  More generally, Australia has a target for renewable electricity production and for electricity generated from bioenergy, as mentioned in 4.2.1. However, there is currently no similar objective for the generation of renewable gas and its injection into the gas grid. Such a target has also been recommended in the report *Renewable gas for the future Bib.8*.

  The development of a 'green gas' retail product for gas users in Australia is another option to encourage biomethane production and use. This would be undertaken in conjunction with retailers and may enable greater injection of biogas into networks as energy users could voluntarily choose to pay a premium for accessing 'green gas'.

- **Financial uncertainties associated with power exported to the grid:** as 2020 approaches, there is uncertainty around the price of LGCs, which could drop if the 2020 target is met. This uncertainty combined with the complexity of signing strong PPAs, tend to encourage the consumption of power onsite as opposed to its export to the grid. This is also reflected in the high percentage of biogas captured and flared without being converted into power *Bib.15. 86*.

- **Gaseous fuel tax:** Compressed natural gas (CNG) and liquified natural gas (LNG) are taxed by the Australian Taxation Office, regardless if they are from renewable (bioCNG and bioLNG) or fossil sources. To the extent that one of the possible uses of biomethane is as a fuel for gas vehicle in the form of bioCNG and bioLNG, the excise duty on bioCNG and bioLNG can be a barrier.

- **Digestate regulations:** there is a lack of consistent national regulation for the digestate, which can be classified as a waste, a biosolid or a compost depending on the states and on the level of treatment done on the digestate. The absence of clear regulation and guidelines makes the valuation of the digestate more complex for project proponents *Bib.86. 13*.

- **Landfill waste levies:** as detailed in section 3.5, state-based waste levies act as an imperative economic driver for biogas development, providing additional income and enhancing the viability of biogas projects. However, the lack of uniform waste levies among the states can discourage the investment in landfilling alternatives such as biogas technologies. Indeed, this lack of uniformity results in perverse outcomes, whereby waste is sent to states with lower levies.

- **Lack of uniform and concurrent directions from national and state governments:** although there are support policies at both national and state levels, as discussed in section 4.2.1, the absence of uniform policy direction represents a significant barrier for project proponents *Bib.87*.

Thus, although some support mechanisms are already available for the biogas sector, more favourable policy conditions would increase the uptake of project development. This could contribute to the growth of a mature and sustainable biogas industry in Australia.

4.3. The issue of distance in Australia

As discussed in section 3.5, Australia has many resources that can be used as feedstocks for biogas production. However, distances between these resources and the preferred location of a project might be considerable, reducing the feasibility of a project. Indeed, the greater the distance, the higher the cost of feedstocks.

Therefore, the optimal size of a plant needs to be determined based on the feedstock availability within a reasonable distance as well as the local demand for the energy from biogas. Co-location with WWTP is a good option for feedstock availability.

Since small to medium size projects are generally more difficult to set up, particularly for economic reasons such as achieving economies of scale (refer to section 4.1). Support mechanisms specifically targeting these types of projects can be a way to encourage them.

4.4. Project development and operation obstacles

In addition to the economic and regulatory challenges discussed above, various obstacles are regularly faced in the development and operation of biogas projects. These include:

- **Access to a secure source of feedstocks:** one of the fundamentals when developing a biogas project, in particular in the case of a co-digestion unit, is to secure a strong supply plan for the feedstocks. Securing feedstock suppliers, feedstock quality and quantity, as well as their cost or potential revenues[29], represent key success factors, as this impacts the financial viability of a project over its lifetime.
Identifying and securing the relevant feedstocks and securing their price for the development of a biogas project is a particularly complicated exercise for several reasons:

  - Feedstock suppliers can be reluctant in signing long-term agreements as they do not want to bear the risk of supply shortage
  - The absence of uniform state levies complicates the possibility of fixing revenues from waste treatment (refer to sections 3.5 and 4.2.2)
  - The potentially long distances between the location of a biogas unit and the targeted feedstocks can considerably increase its cost (refer to section 4.3).

  As a result, the development of co-digestion projects can be challenging. Encouraging feedstock suppliers and project proponents in locking long-term contracts for the feedstock supply is hence critical to ensure the development of such projects.

29 When a biogas unit is remunerated for the treat- ment of waste (in replacement of land lling for example), feedstocks represent a source of revenue. In some cases, however, the feedstock acquisition can come at a cost, in particularly due to its transport over long distance.

In addition, feedstock suppliers can be incentivised to remove inorganic contaminants, in order to supply clean feedstock, which is easier to digest and reduce the need for pre-treatment. This can be done through a higher rate for clean feedstock. In Denmark, for example, feedstock suppliers get paid more by project proponents if the feedstock is of higher quality and is consistently supplied *Bib.15*.

- **Approval process complexity:** project developers and plant operators in Australia have highlighted the complexity and long duration of the different approval processes for setting up a biogas plant, such as:
  - Local authorities' approvals
  - Access to support mechanisms
  - Grid connection processes with electricity and gas network operators.

  The duration of these processes can be excessive with sometimes several years necessary for the acquisition of the required approvals. Such complexity is hence a strong barrier for the sector's development, as it can demotivate biogas adopters.

  For example, the process to access ACCUs is particularly complex and time-consuming. This limits the ability of small project proponents, especially small farmers, to access them *Bib.87*.

- **Private financing finding:** because of the financial viability question (see section 4.1) and the relative newness of the anaerobic digestion sector in Australia, searching and securing financing sources, especially private sources, can be challenging for project proponents.

- **Lack of industry experience:** the Australian biogas industry is still emerging. The lack of industrial experience, reliable data and guidelines result in higher risks for biogas project development and operation *Bib.15*. This is especially the case in terms of sizing generators (over/under capacity) and during the construction of the plant.
  In particular, the management and control of the anaerobic digestion process as well as the close monitoring of the plants are critical to maximise the profitability of an anaerobic digestion plant. Ideally, this requires an experienced and dedicated operator, which is particularly resource constraining for small-scale units.

- **Social license:** to the extent that most of the existing biogas projects in Australia are located outside of populated areas, few social acceptance issues have been faced by project developers *Bib.15*. Nonetheless, according to feedback from project developers, proactive community engagement is a critical first step for the success of a project *Bib.88*. Therefore, rigorous stakeholder engagement plans should be implemented throughout projects' development. Failure to do so could result in considerable difficulties in project development as local populations may oppose it.

  Accordingly, it is essential to continue to inform the community about biogas and the opportunities it represents for the Australian energy transition and society. This could be done by:

  - Developers during their project development processes
  - Proactive industry and government collaboration.

5

Recommendations

This report provided an overview of current global and Australian biogas industries, highlighted the opportunities for Australia and the barriers that need to be addressed.

From this analysis, several recommendations have emerged for Australian Governments and industry stakeholders, aiming to advance Australia's biogas sector.

1. Setting renewable gas target(s)
The Commonwealth and State Governments could consider setting targets to encourage renewable gas production and consumption.

- A national target could be similar to Australia's Renewable Energy Target, which currently only applies to electricity.
- Even non-binding targets, as seen overseas, can act as catalysts to spur industry growth.

2. Launching industry stakeholder consultation for policy design
The Commonwealth and State Governments could launch a detailed consultation with industry stakeholders to gather their insights on how existing policies could be adapted and how new ones could be designed to support the sector. This task should aim to deliver more harmonised and uniform national and state policies, which could provide greater policy direction.

Existing and new mechanisms include feed-in tariffs, contracts-for-difference, investment support (capital grants, soft loans), or tax rebates.

In particular, policies could be designed to promote the following outcomes:

- Development of biomethane as a renewable substitute to natural gas: the electricity sector has been a major focus in Australia for many years. Biomethane now represents an opportunity for the gas sector to have a greater role in the energy transition.
  - At present, there are no biomethane production and injection facilities in Australia. Unlike the export of electricity into the electricity grid, there is no mechanism for the injection of biomethane into the gas grid.
  - The development of a 'green gas' retail product for gas users in Australia is one of the options to encourage the use of biomethane and thus its production and injection into the gas grid.
- Support for large-scale and small-scale pilot biogas projects:
  - Reference large-scale plants can boost the sector's profile. And, financially supporting large pilot projects is a good first step. However, since large-scale projects can benefit from economies of scale, they are not the most critical projects in terms of overcoming the difficult financial viability faced by many projects.
  - In contrast, small and medium-scale projects generally have more financial difficulties and would benefit from more targeted financial support.

3. Introducing waste management strategies to support feedstock quality and quantity

- State Governments could work together to introduce more uniform waste levies to avoid perverse outcomes, whereby waste is sent to states with lower levies. This waste could otherwise be diverted from landfills if there was a financial incentive to encourage this behaviour. A federal policy framework on waste levies could also be an option. International examples have shown that appropriately targeted landfill taxes have encouraged the adoption of anaerobic digestion.

- State Governments also could encourage source separation of organic municipal solid waste (e.g. food waste). This would make it easier to use household and community organic waste as feedstock for anaerobic digestion.
- Government and industry stakeholders could work together to examine concerns about the establishment of long-term feedstock supply contracts.

4. Encouraging plant operators, especially landfill operators, to maximise biogas use

The Commonwealth and State Governments could introduce financial mechanisms, taxes or financial incentives, to encourage landfill operators to maximise the use of landfill gas.

- As there are many landfills operating in Australia, it is critical to leverage the biogas produced.
- Similar measures could be designed for biogas made from industrial and waste water treatment plants.

5. Exploring opportunities for the transport sector

The Commonwealth Government could explore greater support mechanisms targeting the transport sector. In particular, the use of biomethane as an alternative vehicle fuel, as in Sweden, is a good case in point. This is a combined opportunity to foster biogas development while encouraging the decarbonisation of Australia's transport sector.

- Compressed natural gas (CNG) and liquified natural gas (LNG) are currently taxed in the same way whether the gas is of fossil or renewable origin (bioCNG and bioLNG). Reducing or removing the excise duty on bioCNG and bioLNG made from biomethane could be explored.
- Exploring future opportunities in decarbonising Australia's heavy goods vehicles such as trucks and farm machinery (e.g. tractors) by using biomethane as a low carbon alternative to diesel.

6. Providing regulatory clarity for the digestate

The Commonwealth and State Governments could provide regulatory clarity for the digestate.

At the moment, there are uncertainties on digestate regulation, which prevents the industry from maximising its use. Specifically, the conditions for using it as a commercial product could be clarified, as well as the specifications of its composition.

7. Simplifying approval processes

Governments, project proponents, local authorities and electricity and gas network businesses should work together to address the complex and very long approval processes. This would involve reviewing current processes to propose simplified ones, as well as developing guidelines and information packs. If issues remain, regulatory reform could be considered.

8. Informing the community about biogas and its benefits

Government and industry stakeholders could continue to inform the community about biogas and the opportunities it represents for the Australian energy transition and society. This could be done by:

- Developers during their project development processes
- Proactive industry and government collaboration.

9. Exploring future work

This report highlights the key benefits and opportunities that can be offered by the biogas industry in Australia. Future research could quantify the industry's economic potential, such as:

- Refining the biogas resource potential, assessing feedstock availability and its productive utilisation. Some of this work is currently being undertaken as part of the ABBA project
- While taking into account project costs, assessing the full range of revenue streams that can be unlocked should be considered. For example, this includes policy support, such as facilitating the market for digestate, and remuneration for collecting and treating waste
- The contribution to GHG emission reductions
- The associated level of investment
- The creation of new jobs and the support of existing ones
- The impact on the national and regional economies.

In addition, other work could also assess the value proposition of the different options for decarbonising the gas grid: biomethane, hydrogen and/or electrification.

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