Where are the most viable locations for bioenergy hubs across Australia?

A summary of the FFCRC RP1.2-04 Viable Case Studies Report

June 2022

RP1.2-04

Integrated model for bio-methane injection in gas networks

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PROJECT INFORMATION	
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Description	A national scale assessment of viable bio-methane locations in Australia
Research Provider	University of Adelaide (ECMS)
Project Leader and Team	Project Leader: Holger Maier Project Team: Holger Maier, Peter Ashman, Aaron Zecchin, Tara Hosseini, Sam Culley, Sandra Kentish
Industry Proponent and Advisor Team	Proponent: Alistair Wardrope (Jemena) Advisor Teams: Jemena: Joshua Moran, Mike Davis, Brent Davis Australian Gas Infrastructure Group: Patrick Lowry Energy Networks Australia: Dennis R Van Puyvelde GHD Group: Craig Clarke Worley: Andre Lopes APA: Bart Calvert DMIRS: Mohammed Hammad, RSHQ: Tony O'Connor
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EXECUTIVE SUMMARY

The conversion of waste to bioenergy is regarded as an emerging opportunity to decarbonise energy systems in Australia, potentially capable of meeting up to 20% of Australia's energy requirements by 2050 (Carlu et al., 2019; ENEA and Deloitte, 2021). Despite the opportunity and the significant commercial success in Europe, the production of bio-methane and its injection into existing gas networks is currently almost non-existent in Australia. As part of the Future Fuels CRC, and in support of waste to bioenergy initiatives in Australia, our project (RP1.2-04) has performed an assessment to identify the most viable locations for large scale bio-methane hubs in Australia. This report is a summary of the full assessment, available for members of the Future Fuels CRC (Culley et al., 2022).

The two main components of this assessment are (i) an analysis of the relative suitability of different regions in Australia for locating a biogas plant, and (ii) the generation of bio-methane viability heatmaps, displaying the spatially distributed estimated levelised cost of energy (LCOE), if all available feedstock were used for bio-methane production (Figure i). Both assessments use a set of spatial data at the national scale, including factors relevant to bio-methane production such as feedstock availability, proximity to infrastructure (e.g. transmission and distribution pipelines), costs of utilities, and current land use surveys. The LCOE was estimated by sizing a plant at each location given the feedstock available, calculating the operational costs using the proto-type viability assessment model developed as part of project RP1.2-04. This analysis suggests that the LCOE of bio-methane plants mostly ranges from \$10/GJ to \$25/GJ[1]. The most commercially viable locations are within close proximity to major cities in each state, and near sugarcane production along north-eastern Queensland.

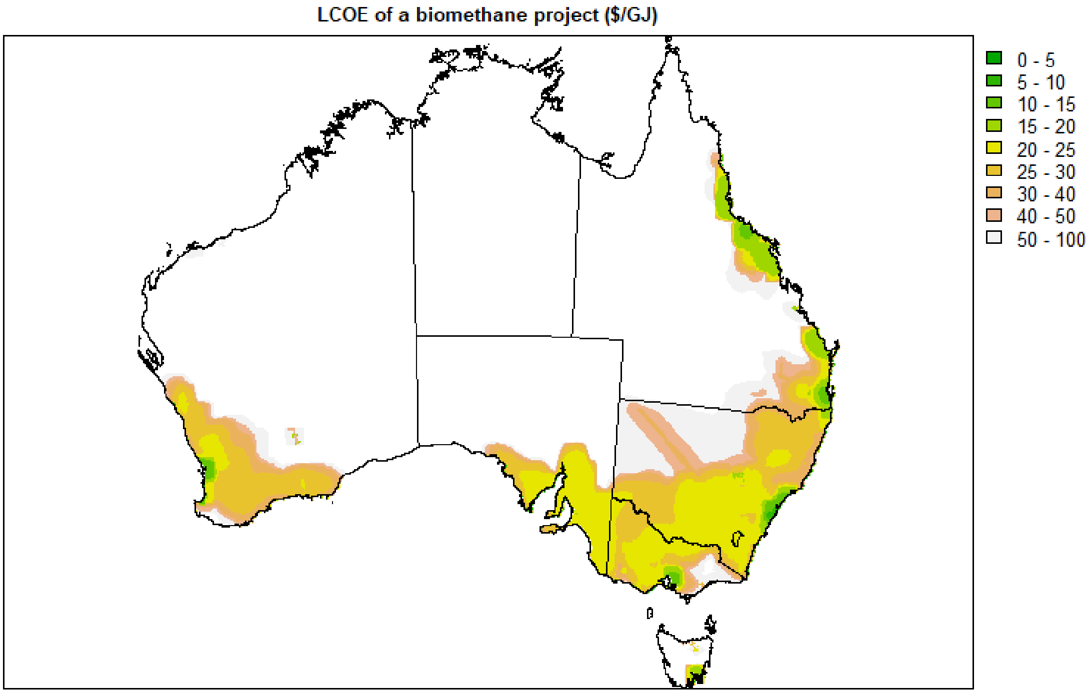

Figure i: Heatmap of LCOE, where colours indicate the cost per gigajoule. This is estimated for plants considering up to two months storage for agricultural feedstock sources, beyond their harvesting period.

The purpose of the suitability analysis was to determine locations of viable sites in Australia, based on the identified relevant factors, which include the feedstock available, distances to critical infrastructure and land use. Within this assessment, it is important to outline that there are key assumptions for the relevant factors (e.g. maximum transport distances, collection ranges of a plant and storage of feedstock) used that heavily affect the sites selected. Consequently, these results should be taken as broadly indicative of some of the most viable sites in each state,

[1] Note that to offset some production costs, revenue streams from selling digestate at a \$50/tonne profit, and a \$40/tonne gate fee for feedstock are included in this assessment

and by no means an exhaustive list. The results of the suitability and heatmap analysis are summarised in Table i, showing the feedstock available, distance from pipeline infrastructure (unless the plant connects to a distribution line), estimated GJ/year output and LCOE for the bio-methane projects identified by the suitability analysis. This shows that the locations of Perth (WA), Boonah (QLD) and Toowoomba (QLD) are the sites with the lowest LCOE. However, even though the sites in Table 1 have some of the largest potential bio-methane outputs in Australia, the LCOE is significantly higher than the price of gas (~$10/GJ), ranging from $15/GJ-$25/GJ, despite having two revenue streams to offset costs.

Table i: Sites identified from suitability analysis, and the resulting feedstock, distance from transmission line, and estimated PJ/year output. An estimate of LCOE is also provided, with a range showing the assumption that all feedstock is available evenly through the whole year (lower value) and the assumption that the agricultural feedstock is only available during the period of harvest (higher value).

State	Location	Feedstock available (wet T/year)	Averaged distance from transmission pipeline (km)	Estimated biomethane available (PJ/year)	Estimated LCOE ($/GJ)
SA	**Adelaide**	2.7M	25	7.6	20.8 (11.7 – 23.6)
	Lucindale	2.3M	38	5.5	23.4 (12.3 – 27.4)
	Berri	2.4M	14	6.2	23.1 (11.8 – 26.8)
Victoria	**Echuca**	0.7M	43	4.2	22.3 (9.8 – 30.8)
	Shepparton	0.7M	7	3.3	22.4 (10.0 – 30.5)
	Wodonga	1.0M	20	1.0	21.7 (10.2 – 29.5)
NSW	**Griffith**	0.8M	5	4.6	21.6 (8.9 – 30.3)
	Tamworth	0.5M	0	2.8	21.7 (9.2 – 30.3)
	Bathurst	0.3M	7	1.8	21.8 (10.3 – 29.8)
	Wagga Wagga	0.8M	0	4.5	21.4 (8.9 – 30.0)
QLD	**Toowoomba**	1.3M	5	1.4	20.7 (13.4 – 25.7)
	Boonah	1.4M	35	2.5	17.1 (15.4 – 18.0)
WA	**Perth**	1.1M	5	4.7	11.6 (10.3 – 12.34)
	Esperance	0.1M	0	1.1	22.8 (10.1 – 31.7)
	Geraldton	0.2M	0	0.9	22.1 (10.1 – 30.4)

The primary reason for this high LCOE is that the suitability analysis determines the locations that have the largest quantity of potential bio-methane, regardless of when it is available throughout the year. When the LCOE is estimated, it accounts for feedstock only being available around the time of harvest. This means that in the case of cereal straws (which has the largest volume of annual residues), the plant needs to be three times larger than if the feedstock were available steadily through the year, if it is to process all the available bioenergy. This is why the locations with the lowest LCOE (Figure i) are not the sites in Australia that have the most feedstock, but those that have more constant supplies like sugarcane production (a six-month window) or heavy municipal solid waste supplies (available throughout the year). For these locations, a plant designed around a more consistent supply of feedstock (either through energy crops, improved storage of feedstock, or a reduced capacity) will provide a much more commercially viable plant, as the capacity will be better utilised through the year. This is demonstrated in Figure ii, which shows different heatmaps assuming no storage of feedstock (Figure ii, top) and full storage of feedstock, and hence full utilization of the constructed plant (Figure ii, bottom). The LCOE values in the case of many plants that use agricultural feedstock with no storage range from $25-$35/GJ, whereas the values for plants assumed to store all available feedstock are $5-$15/GJ. This highlights the need for an easy and consistent approach to estimating the techno-economic viability of a proposed project, to understand the opportunities and barriers present.

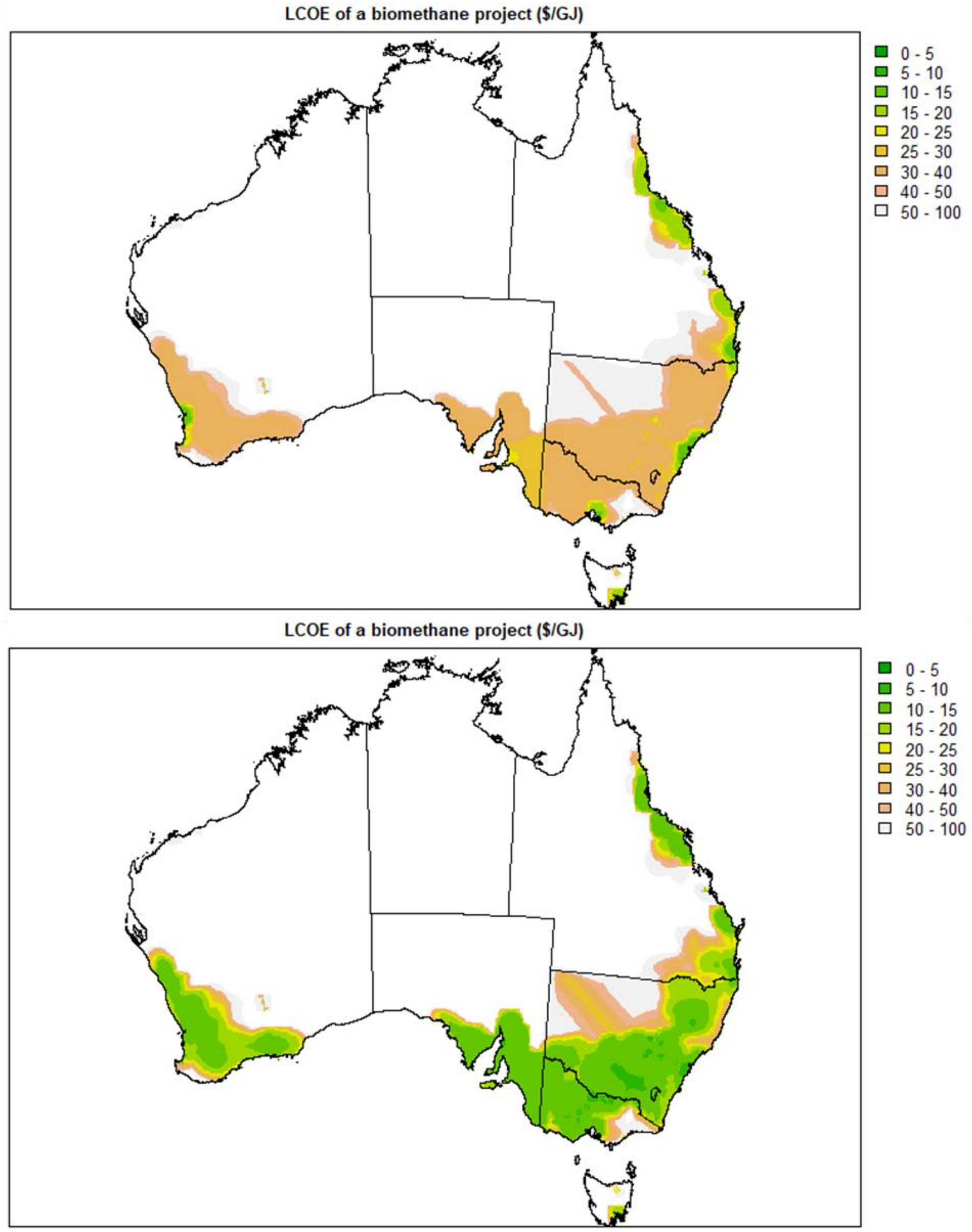

Figure ii: Heatmaps of LCOE when the plants are sized to produce the maximum available bio-methane considering i) no storage of agricultural feedstock (top), and ii) even availability of all feedstock types throughout the year (bottom)

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1. INTRODUCTION

The conversion of waste to bioenergy is regarded as an emerging opportunity to decarbonise energy systems in Australia, potentially capable of meeting up to 20% of Australia's energy requirements by 2050 (Carlu et al., 2019; ENEA and Deloitte, 2021). Despite the opportunity and the significant commercial success in Europe, the production of bio-methane and its injection into existing gas networks is currently almost non-existent in Australia. As part of the Future Fuels CRC, and in support of waste to bioenergy initiatives in Australia, our project (RP1.2-04) has performed an assessment to identify the most viable locations for large scale bio-methane hubs in Australia (Culley et al., 2022).

This document is a summary of an assessment for viable bio-methane sites across Australia. The two main sections of this assessment are the suitability analysis, and the generation of bio-methane viability heatmaps. The purpose of the suitability analysis is to determine locations of viable sites in Australia, based on relevant factors such as the feedstock available, distances to critical infrastructure and land use. The purpose of the heatmap is to estimate the available bio-methane, and the levelised cost of energy (LCOE) of running a bio-methane plant across Australia. Both assessments use a set of spatial data at the national scale, including factors relevant to bio-methane production such as feedstock availability, proximity to infrastructure (e.g. transmission and distribution pipelines), costs of utilities, and current land use surveys. This summary report is organised as follows:

- The spatial data used in this assessment is detailed in Section 2;
- The suitability analysis performed to identify the locations of viable bio-methane projects, given a set of contributing factors, is outlined in Section 3, and;
- Heatmaps of bio-methane availability and LCOE generated using the assessment framework embedded in the proto-type viability assessment tool are presented in Section 4.

2. DATA

This section of the report presents the spatial data set that was built for use in both the suitability analysis and the generation of heatmaps. The categories of data used in this assessment are formed by both the previous data needs identified by project RP1.2-03 (e.g. feedstock availability, costs, distances from infrastructure), and consultation with end-users. The categories of data considered are:

- Feedstock supply (Section 2.1);
- Proximity to infrastructure (Section 2.2);
- Market/economic factors (Section 2.3); and
- Prohibitive factors (Section 2.4).

Data comes from many different sources: statistical mapping over large areas (SA4, SA2), smaller local government areas (LGA), data applied at a state-wide level, or simpler line or point data across Australia. However, for consistency, all spatial information is converted into rasters that span Australia, at a 5 x 5 km scale. This means that no matter the form in which the data is available originally (e.g. point data, satellite data, or pipeline network shape files), it can be collated and used to provide information at a resolution of 25 km^2. The following sections provide details of where the data has come from, and how it was transformed into a 5 x 5 km raster[2].

2.1 Feedstock supply

Feedstock data maps were developed to indicate the annual wet tonnes of major organic residues available across Australia (listed below). Feedstock data for this analysis is taken from the ABBA data set (ARENA, 2020) in order to align with other publications, such as the bioenergy roadmap for Australia (ENEA and Deloitte, 2021). This means that the same assumptions and uncertainty present in the ABBA data also applies here; namely, this data should not be used specifically to design a biogas plant, as it is an approximation based on farmland locations and typical harvest residues. It also does not account for the fact that the residues may have an existing use (e.g. composting). This information is, however, broadly indicative of where the feedstock is likely to be located, and the

[2] All rasters have been projected to EPSG 3577, using the GDA 94 datum.

orders of magnitude of the available waste within the categories considered. The feedstock categories used in this assessment are:

- Cereal straw (e.g. wheat, eats, barley);
- Non-cereal straw (e.g. cotton, canola);
- Hay and silage;
- Manure (from sheep, cattle, pigs and poultry);
- Vegetable residues;
- Fruit residues;
- Winery waste (grape marc);
- The organic fraction of Municipal Solid Waste (MSW);
- Sugarcane trash and bagasse.

Note that these feedstocks, and the ABBA data set, have a strong focus on agricultural residues. There are many other sources of organic waste that can be used in bioenergy projects that are not considered in this assessment, such as waste water treatment plants, major food processing/manufacturing plants, fats, oils and grease traps.

Annual tonnes of feedstock (reported as wet tonnes, dry tonnes, or volatile solids depending on the data type and state) are provided for a set of different statistical mapping levels across Australia. This data was first standardised to wet tonnes (dividing by the fraction of total suspended solids), as this allows for consistent calculation of transport loads, and estimated bio-methane available. It was then downscaled to the 5 x 5 km resolution, by calculating the tonnes/km^2 for each statistical area. An example output map is shown in Figure 1, which details the cereal straw residues across Australia.

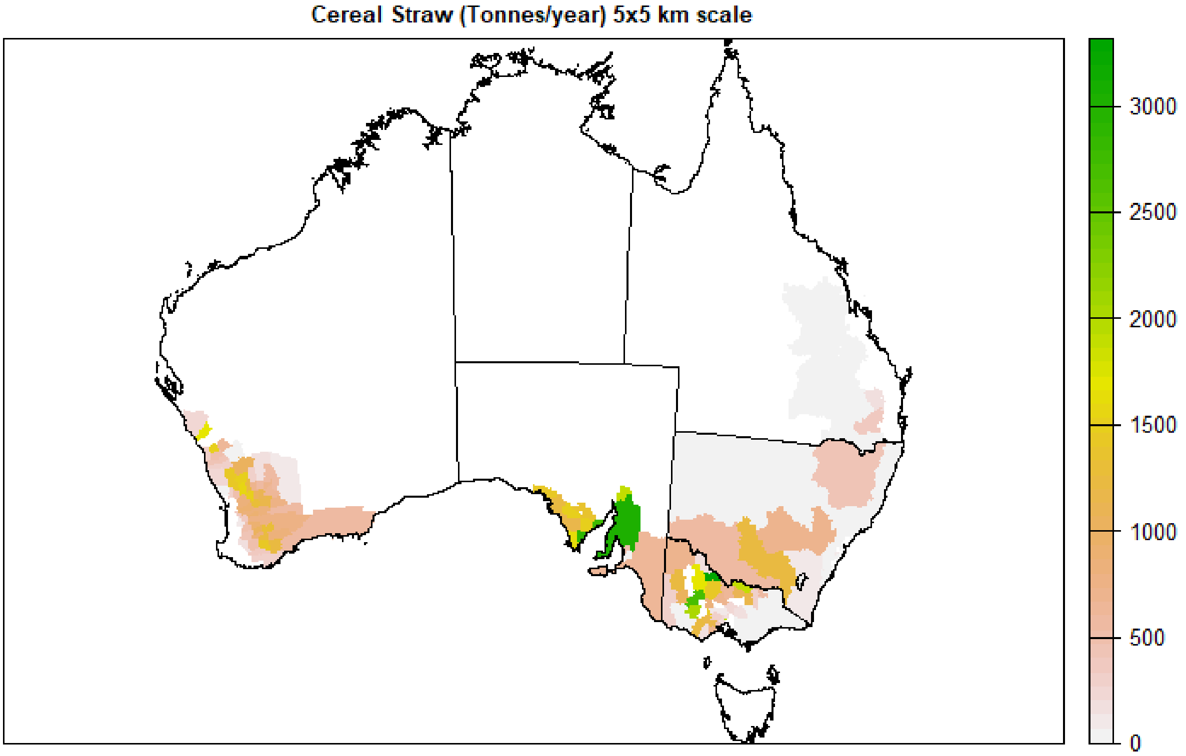

Figure 1: Annual wet tonnes of cereal straw residues

2.2 Infrastructure proximity

This data estimates the distances that a potential anaerobic digestion plant would be from key infrastructure. The full report (Culley et al., 2022) includes both transmission and distribution gas pipelines, and prospective hydrogen hubs. For brevity, this summary report focuses only on transmission pipelines. The Australian pipeline data used in this assessment is from Geoscience Australia, which lists pipelines for oil and gas[3]. The data was split to only include gas transmission pipelines, and then turned into a binary raster (Figure 2, top). This raster could then be converted into a layer of distance from the pipeline, shown in Figure 2 (bottom). Note that as the pipeline data is from earlier than 2018, is does not contain the northern Gas pipeline (from NT to QLD) that was constructed by Jemena. Given there is no feedstock at this location (Section 2.1) this does not affect the analysis in this report.

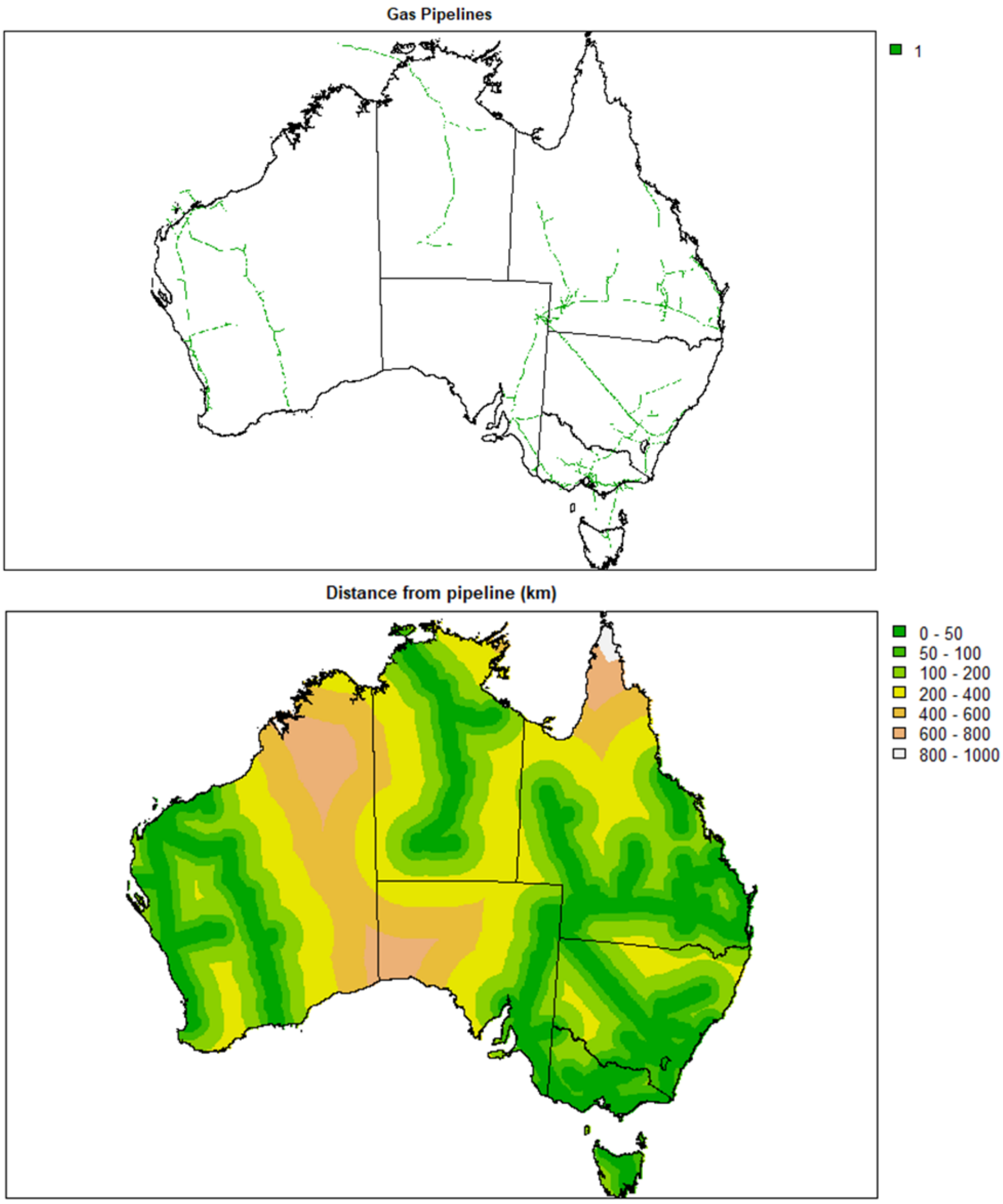

Figure 2: Gas transmission pipelines (top) and the distance from the closest section of pipeline (bottom).

2.3 Market/economic factors

There are several economic factors that need to be considered when estimating the levelised cost of energy for bio-methane projects. Many economic factors were assumed to be constant across Australia (e.g. transport costs,

[3] https://data.gov.au/dataset/ds-dga-5ff102cb-5d48-4a0e-9af9-3d2dda90b67d/details, accessed Nov 2021.

constructions costs, revenue from digestate) and these are discussed in Section 4. However, economic factors that vary across Australia are included as spatial data. Specifically, for this assessment, the cost of utilities (i.e. wholesale prices of power, heat, water) was collected with a value for each state. Annual average values were used for all utilities' prices. Electricity and gas prices were taken from AEMO outlooks for 2018, and water prices were taken from each capital city, for 2020/21.

2.4 Prohibitive factors

The final set of spatial data is a catchment scale land use survey, enabling consideration of where a bio-methane plant cannot be built. This data was already available as a raster, at the 50 x 50 m scale (Figure 3). For this assessment, the resolution was decreased by a factor of 100 to match the 5 x 5 km scale of the other input data. Land use has been mapped using version 8 of the Australian Land Use and Management Classification (ABARES, 2016). These categories were used to determine which part of Australia was suitable for a bio-methane plant location or not. This classification is described in Section 3.

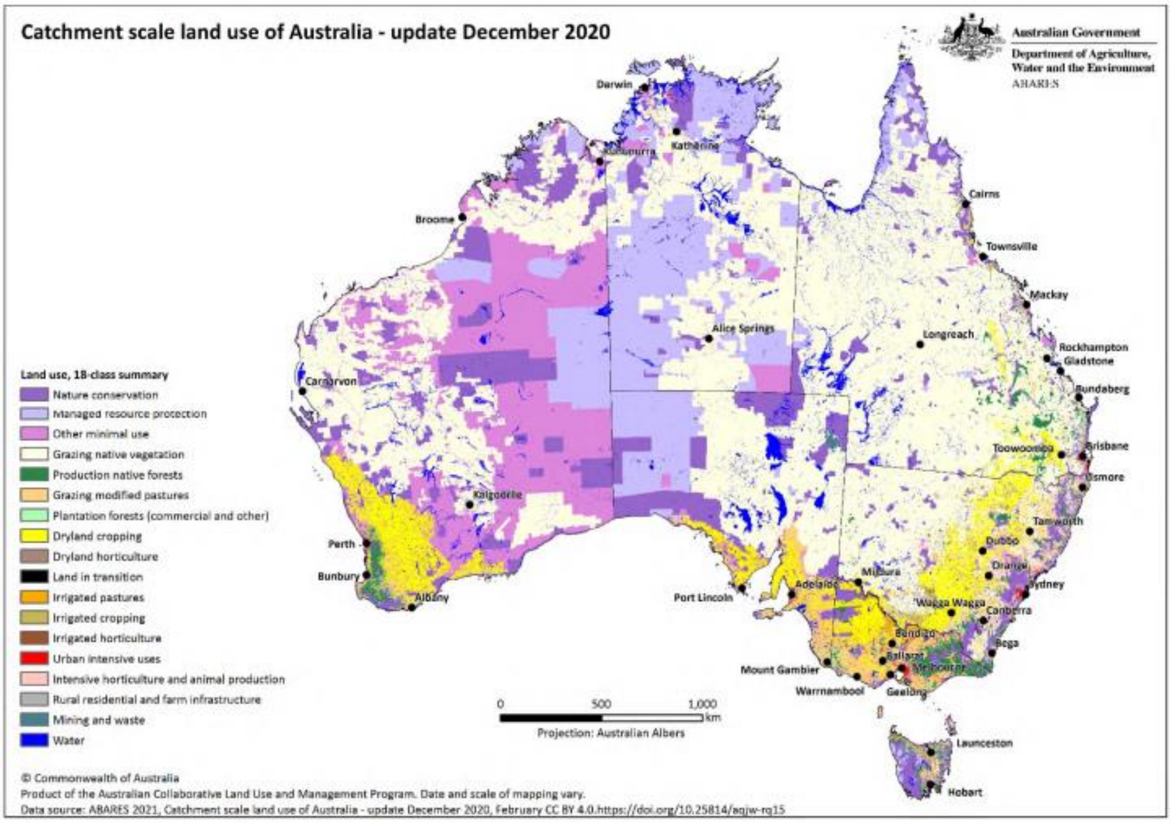

Figure 3: Catchment scale land use survey of Australia (ABARES, 2016)

3. SUITABILITY ANALYSIS

This section describes the suitability analysis approach that was used to determine the locations of viable sites for bio-methane projects. A suitability analysis is a form of spatial assessment that identifies locations through a systematic, multi-factor analysis of the different aspects of the range of spatial input maps considered (typically physical, cultural and economic factors) (Anderson, 1987; Banai-Kashani, 1989). The result is a final map that provides an area's suitability, ranging from high to low in suitability rank. Note that this is a 'top-down' approach, meaning the weightings and factors are applied across all of Australia at a relatively coarse resolution, which does not consider any specific interactions that might occur at particular locations. Because of this, the sites selected will be summarised at a high level, providing an approximate location.

Following the suitability analysis methodology, the relevant factors used were classified by level of suitability i.e. "most suitable", "suitable" and "least suitable". The factors used here were divided into supply of energy, proximity to infrastructure, and prohibitive factors (Figure 4), which were selected through consultation with the end-users of this project. Then, the layers were combined to determine the most suitable sites. Section 3.1 describes the classifications used to sort the input data, and Section 3.2 describes the results of combining these layers and the resulting locations of the viable sites.

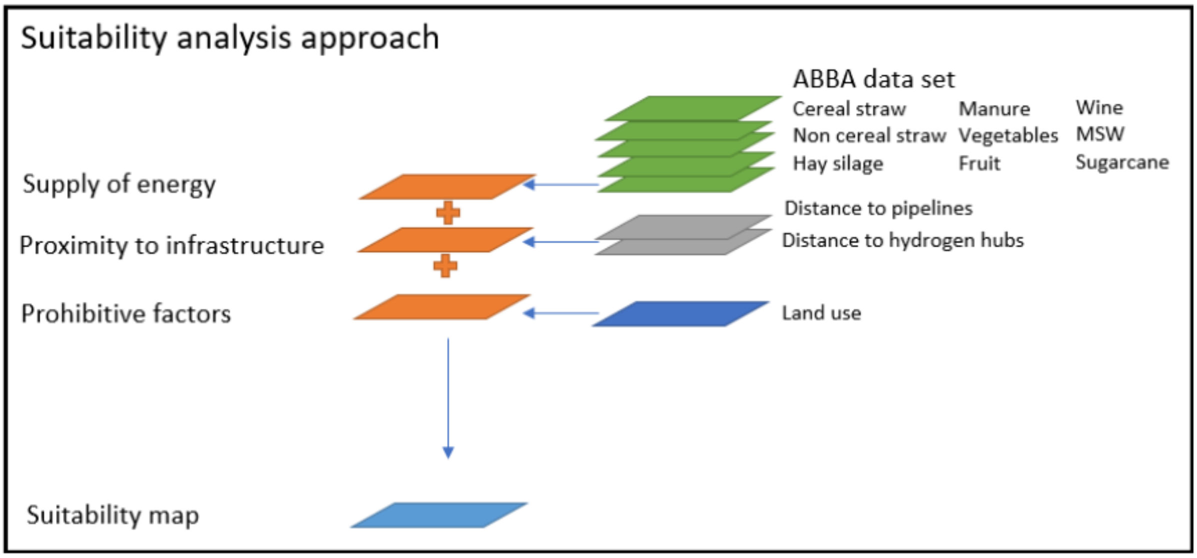

Figure 4: Approach for the suitability analysis used. Input layers of spatial map data are first classified based on suitability, and then are combined to provide an overall suitability map of bio-methane projects

3.1 Classifications

The approach used to determine the classifications for the energy supply layers was to first assume a plant would be located at a particular cell in the maps, and then to determine how much feedstock would be available given a pre-specified collection radius. A collection radius of 50 km was used in this work, as beyond this distance transport costs of feedstock become significant. Once the total feedstock that would be available at a point was determined for each layer, it could be classified based on the size of the plant.

For large-scale projects, values of 10 Tonnes (T) per day were used as a minimum plant size threshold for the "least suitable" category (~15 TJ per annum), and 240 T per day was used as a threshold above which a plant would be "most suitable" (~400 TJ per annum). It was assumed that projects of this size would connect to transmission lines, as the scale of bio-methane production would be too large for connection to distribution lines. An example, the resulting classification for cereal straw residue is shown in Figure 5.

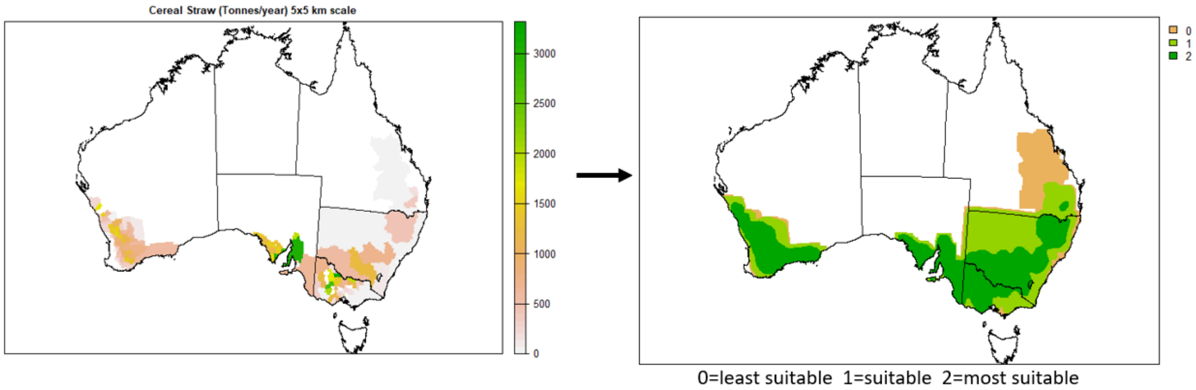

Figure 5: Suitability classification of large-scale cereal straw plants based on feedstock available, with raw data shown in left panel and the resulting suitability score in the right panel.

For distances from transmission pipelines, distances under thresholds of 50 km and 100 km were used for "most suitable" and "suitable" classifications, respectively. For the land use data, the classification method used was to specify a set of categories of land use to be prohibitive, and the remaining suitable. This was performed at the scale of the original land use data (i.e. 50 x 50 m), and was then aggregated to match the 5 x 5 km scale of the rest of the input data. The most common value in the 5 x 5 km cell (prohibitive, or suitable) was taken as the aggregated value. The following land uses were selected to be prohibitive classes upon which to build an anaerobic digester plant:

- Nature conservation;
- Plantation forests;
- Transport infrastructure;
- Mining;
- Lakes/rivers/reservoirs;
- Coastal/marsh/wetlands.

3.2 Suitable locations

To produce the suitability map, the reclassified feedstock data was first combined into a single layer in the suitability analysis. The nine feedstock layers were combined, using a weighted average with respect to biogas yield per wet tonne. This was done to take into account that a tonne of manure is not as valuable as a tonne of municipal solid waste with respect to eventual bio-methane yields (Carlu et al., 2019). Finally, the suitability analysis was completed by taking the average of the feedstock layer and the proximity to the infrastructure layer and filtering out any sites prohibited by land use. The result is a suitability map such as that shown in Figure 6, where sites are shown if, at a minimum, they were suitable for both distance from infrastructure and energy supply layers. The results indicate that the only state that does not support a large-scale bio-methane hub is Tasmania (excluding the territories). This was which was due to insufficient agricultural residues to support a large-scale plant, although Tasmania can support small-scale plants as detailed in the full report (Culley et al., 2022). Nationally, this analysis indicates that the most viable site is just south of Adelaide[4]. More details about each of the sites in Figure 6 are provided in Section 4, using the heatmaps of LCOE produced.

[4] Given all feedstock layers were combined together to provide overall suitability, this means that sites near Adelaide make the most use of different types of feedstock. This is not necessary the most commercially viable site.

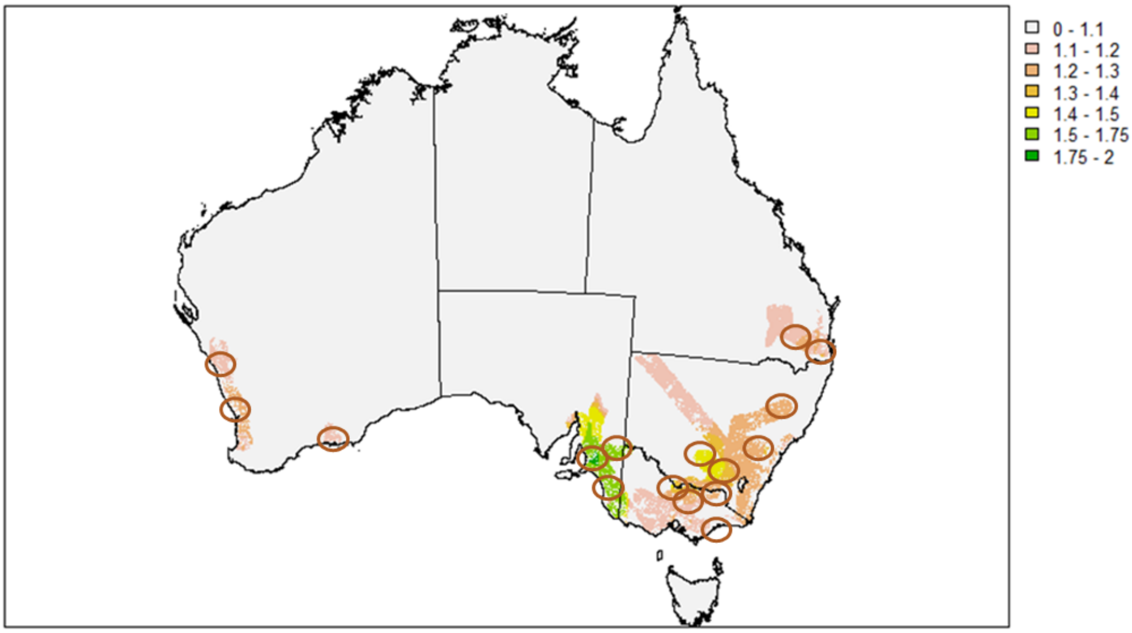

Figure 6: Suitability map for large-scale bio-methane projects. Sites are shown with zero meaning "least suitable" and 2 meaning "most suitable". The most suitable sites in each state are circled in red.

4. LCOE HEATMAPS

To estimate the viability of a bio-methane project at a specific potential location (especially the sites identified in Figure 6), four major categories of maps were created: Energy from feedstock, cost of transport, cost of production, and revenues (Figure 7). The LCOE was then estimated by considering the total energy available from the feedstock (Section 4.1), and the net total costs of processing the feedstock (Sections 4.2-4.3). This provides the final result of a heatmap of LCOE values of a plant for each location across Australia (Section 4.4).

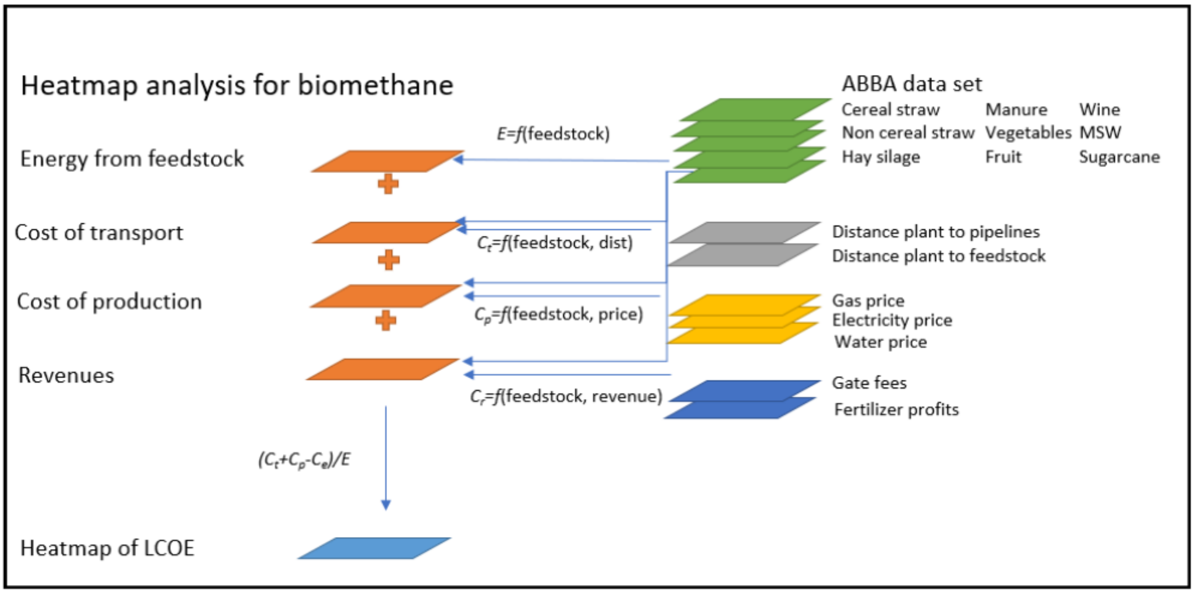

Figure 7: Approach used to apply the proto-type viability assessment model and develop viability heatmaps for bio-methane production in Australia. The total bio-methane energy (E), transport costs (C_t), productions costs (C_p) and revenues (C_r) are estimated using functions from the proto-type model, f(), to estimate the LCOE.

4.1 Bioenergy from feedstock

The bio-methane available across Australia was estimated from the feedstock supply data (Section 2.1), and the previously mentioned set of yield estimates for each feedstock type. First, the total feedstock available, given a plant location, was calculated assuming the collection radius of 50km as used in Section 3. Then, the annual bio-methane available if all the feedstock were to be used for anaerobic digestion could be estimated by multiplying the feedstock amounts by their biogas yield, the heating value of bio-methane, and the fraction of gas assumed to be methane[5]. Using this process gives an overview of annualised PJ available at a 5 x 5 km resolution for plant location, and is shown in Figure 8[6].

[5] The fraction of gas assumed to be methane was taken to be 0.60, which is commonly used in techno-economic assessments in the absence of chemical process modelling or experimental data IEA, 2020. Outlook for biogas and biomethane: Prospects for organic growth.. The heating value of bio-methane was taken as 0.036 GJ/m^3 ibid..

[6] Note that this calculation is meant to represent the PJ output should a plant be located there, and so no plant could also be located within 100km without overlapping on available feedstock.

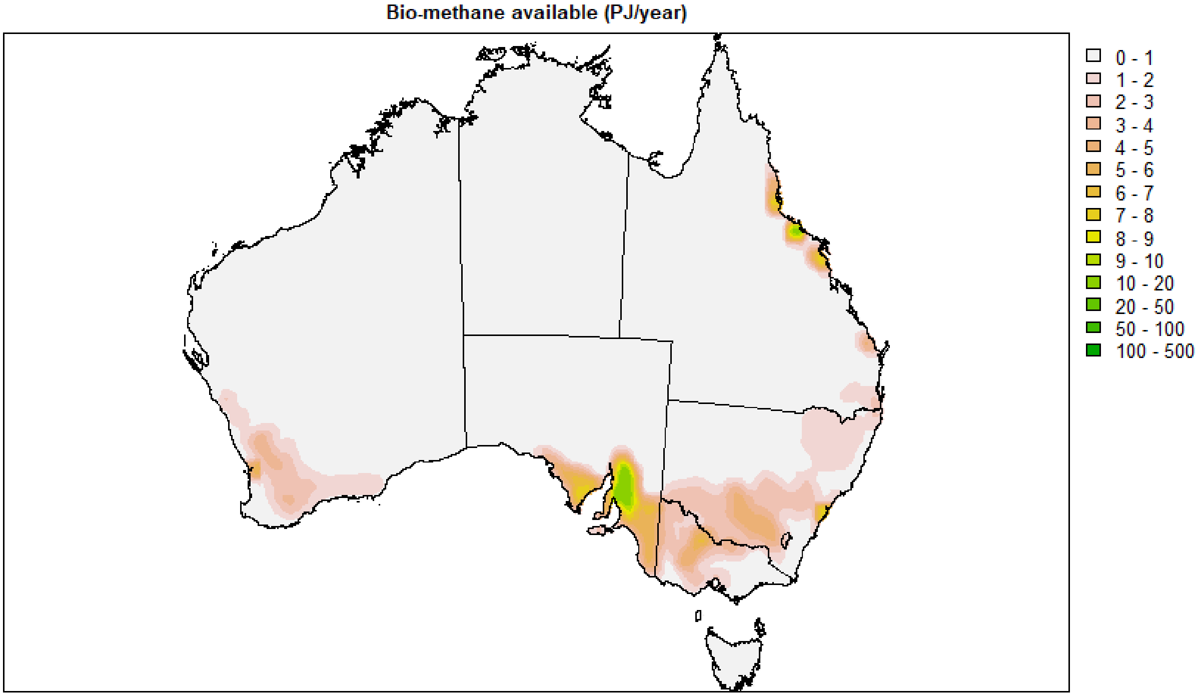

Figure 8: A map of the annual bio-methane available from nearby feedstock residues (PJ/year), should a plant be located there. Note that each plant location would collect all the feedstock within a radius of 50 km.

4.2 Costs

The cost of transport was divided into two components: the cost of collecting feedstock, and the cost of transporting the biomethane to the pipeline. The cost of collecting feedstock and transporting it to the plant was calculated to be an annual operational cost. The feedstock was assumed to be transported via trucks, whereas the biomethane was transported to the transmission line via a newly constructed pipeline. The capital and operational costs of bio-methane production are estimated using the parameters and structure of the proto-type biomethane viability assessment model. First, the capital costs for construction of the plant and connection to the gas pipeline were calculated based on the peak design gas flow rate of the plant, and then the operational costs for running the plant were calculated based on the total bio-methane produced. Details of the parameters used can be found in the full report (Culley et al., 2022).

4.3 Revenue options

Several revenue streams were considered in this analysis, in line with those included in previous techno-economic viability assessments for potential bio-methane locations in Australia, as part of RP1.2-03. The first consideration in this assessment was the profit that is availabe from treating and selling digestate[7], and the second revenue stream was a gate fee for disposing of the waste[8]. Both these revenue streams were used in the generation of the LCOE heatmap, to offset the OPEX totals.

4.4 Final heatmaps

Given the estimation of bioenergy from feedstocks, costs of transport and production, and revenue streams, the LCOE of bio-methane projects can be calculated. First, the net present value (NPV) at each location in Australia is estimated, given the total capital costs, operational costs, a project life of 20 years, and a discount rate of 10%. Then, the annual GJ production of bio-methane (Section 4.1) is also discounted over the project life with the same discount rate. Finally, the cost per GJ were calculated based on the NPV and a discounted annual GJ. This is shown in Figure 9 for all locations with an annual GJ output greater than 1TJ. This analysis suggests that the LCOE

[7] This was estimated by first assuming the tonnes of digestate available from processing feedstock (10%), and then assuming a selling profit per tonne ($50).
[8] The gate fee was assumed to be a flat rate of $40/tonne.

of operation of bio-methane plants mostly ranges from $10/GJ to $25/GJ. The most commercially viable locations are major cities in each state, and a belt of sugarcane along north-eastern Queensland.

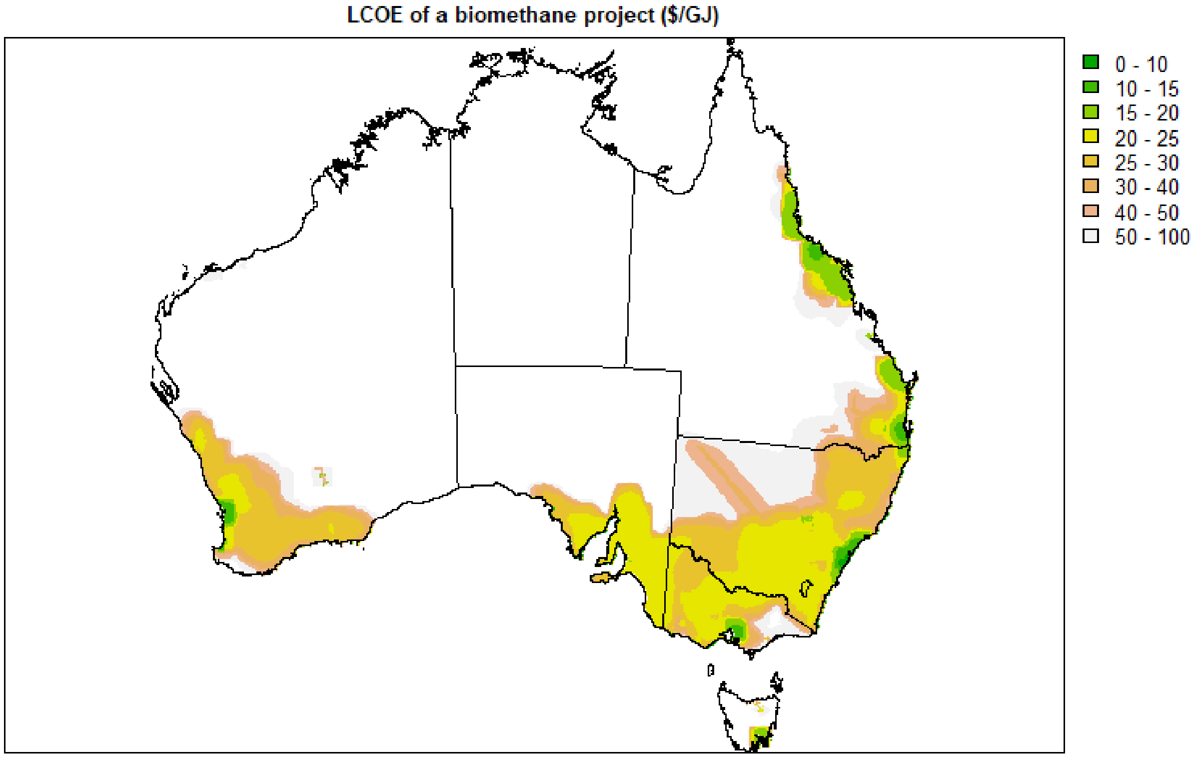

Figure 9: Estimated LCOE of a bio-methane project across Australia, assuming all available feedstock is processed, with a digestate profit of $50/tonne and a gate fee of $40/tonne.

The underlying data for this LCOE heatmap was also used to determine feedstock available, distance from pipeline, estimated GJ/year output and LCOE for the large-scale bio-methane projects identified by the suitability analysis (Table 1). This shows that the locations of Perth (WA) and Boonah (QLD) are the sites with the lowest LCOE. However, the LCOE of the other identified sites is significantly higher than the current typical price of gas (~$10/GJ), ranging from $15/GJ-$25/GJ, despite having two revenue streams to offset costs (Section 4.3). The primary reason for this is that the suitability analysis determines the locations that have the largest quantity of different feedstock sources available, and therefore potential bio-methane, regardless of when it is available throughout the year. When the LCOE is estimated, it accounts for the fact that if a feedstock is available only for four months of the year, the plant needs to be sized three times larger than if all that feedstock were available steadily through the year, if it is to process all the available bioenergy.

Figure 10 shows a map of the plant utilisation percentages, assuming all the feedstock is processed only when it is available around harvest. This is why the locations with the lowest LCOE are not the sites in Australia that have the most feedstock, but those that have more constant supplies, like sugarcane residue production or heavy municipal solid waste supplies. This highlights the need for an easy and consistent approach to estimating the techno-economic viability of a proposed project, to understand the opportunities and barriers present. For the locations determined from the suitability analysis, a plant designed around a more consistent supply of feedstock (either through energy crops, or a reduced capacity) will provide a much more commercially viable plant, as the capacity will be better utilised throughout the year. This is demonstrated in Figure 11, where different heatmaps are generated assuming no storage of feedstock (Figure 11, top) and full storage of feedstock, and hence full utilization of the constructed plant (Figure 11, bottom). The LCOE values in the case of many plants that use agricultural feedstock with no storage range from $25-$35/GJ, whereas the LCOE values for plants with full storage of feedstock assumed are $5-$15/GJ.

Table 1: Sites identified from suitability analysis, and the resulting feedstock, distance from transmission line, and estimated PJ/year output. An estimate of LCOE is also provided, with a range showing the assumption that all feedstock is available evenly through the whole year (lower value) and the assumption that the agricultural feedstock is only available during the period of harvest (higher value).

State	Location	Feedstock available (wet T/year)	Averaged distance from transmission pipeline (km)	Estimated biomethane available (PJ/year)	Estimated LCOE ($/GJ)
SA	**Adelaide**	2.7M	25	7.6	20.8 (11.7 – 23.6)
	Lucindale	2.3M	38	5.5	23.4 (12.3 – 27.4)
	Berri	2.4M	14	6.2	23.1 (11.8 – 26.8)
Victoria	**Echuca**	0.7M	43	4.2	22.3 (9.8 – 30.8)
	Shepparton	0.7M	7	3.3	22.4 (10.0 – 30.5)
	Wodonga	1.0M	20	1.0	21.7 (10.2 – 29.5)
NSW	**Griffith**	0.8M	5	4.6	21.6 (8.9 – 30.3)
	Tamworth	0.5M	0	2.8	21.7 (9.2 – 30.3)
	Bathurst	0.3M	7	1.8	21.8 (10.3 – 29.8)
	Wagga Wagga	0.8M	0	4.5	21.4 (8.9 – 30.0)
QLD	**Toowoomba**	1.3M	5	1.4	20.7 (13.4 – 25.7)
	Boonah	1.4M	35	2.5	17.1 (15.4 – 18.0)
WA	**Perth**	1.1M	5	4.7	11.6 (10.3 – 12.34)
	Esperance	0.1M	0	1.1	22.8 (10.1 – 31.7)
	Geraldton	0.2M	0	0.9	22.1 (10.1 – 30.4)

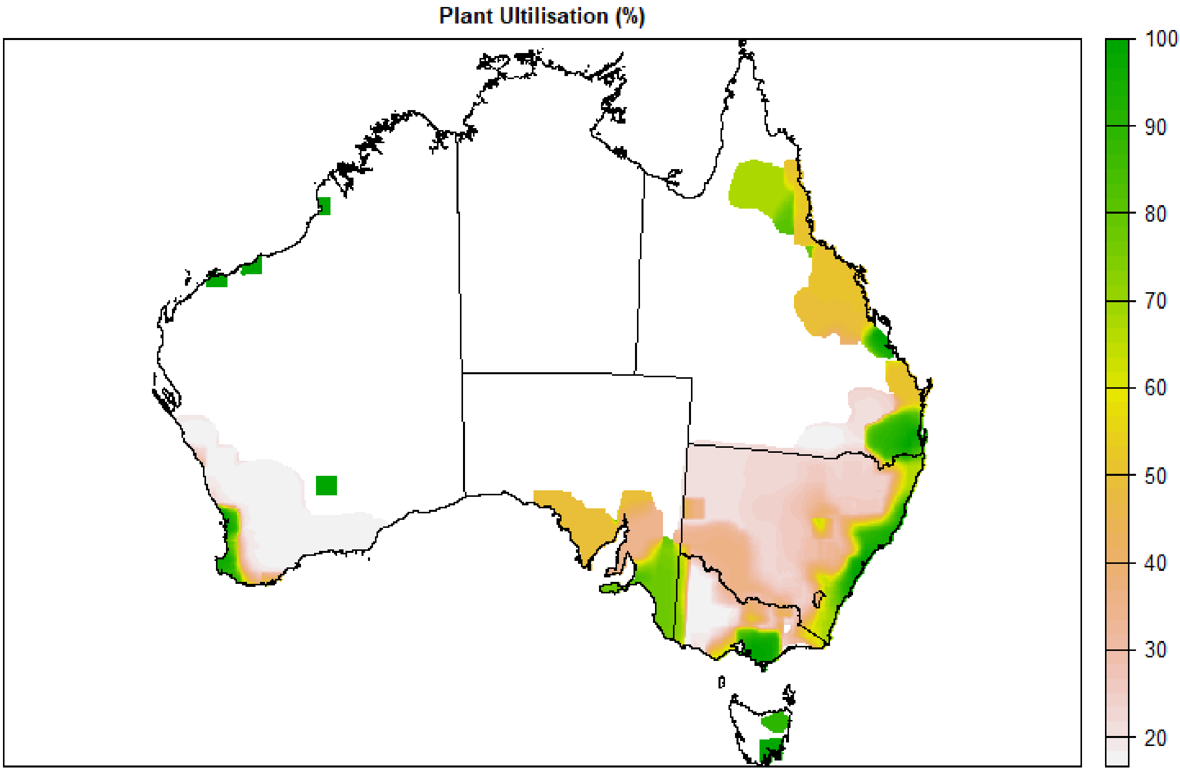

Figure 10: The utilisation percentage of a bio-methane plant, assuming it processes all feedstock when it is available with no storage.

This difference in price is quite significant, demonstrating the importance of being able to utilise a plant throughout the year (Figure 11). However, the cost of doing so is not currently modelled in this assessment, meaning it is unclear what price would be suitable to pay for a consistent feedstock supply. This could either be through sorting the agricultural feedstock beyond just the period of harvest or purchasing energy crops in the remaining seasons. Alternatively, the energy from the agricultural biomass could be harvested through methods outside of anaerobic digestion, such as gasification, which would form a biochar from the feedstock to help with storage.

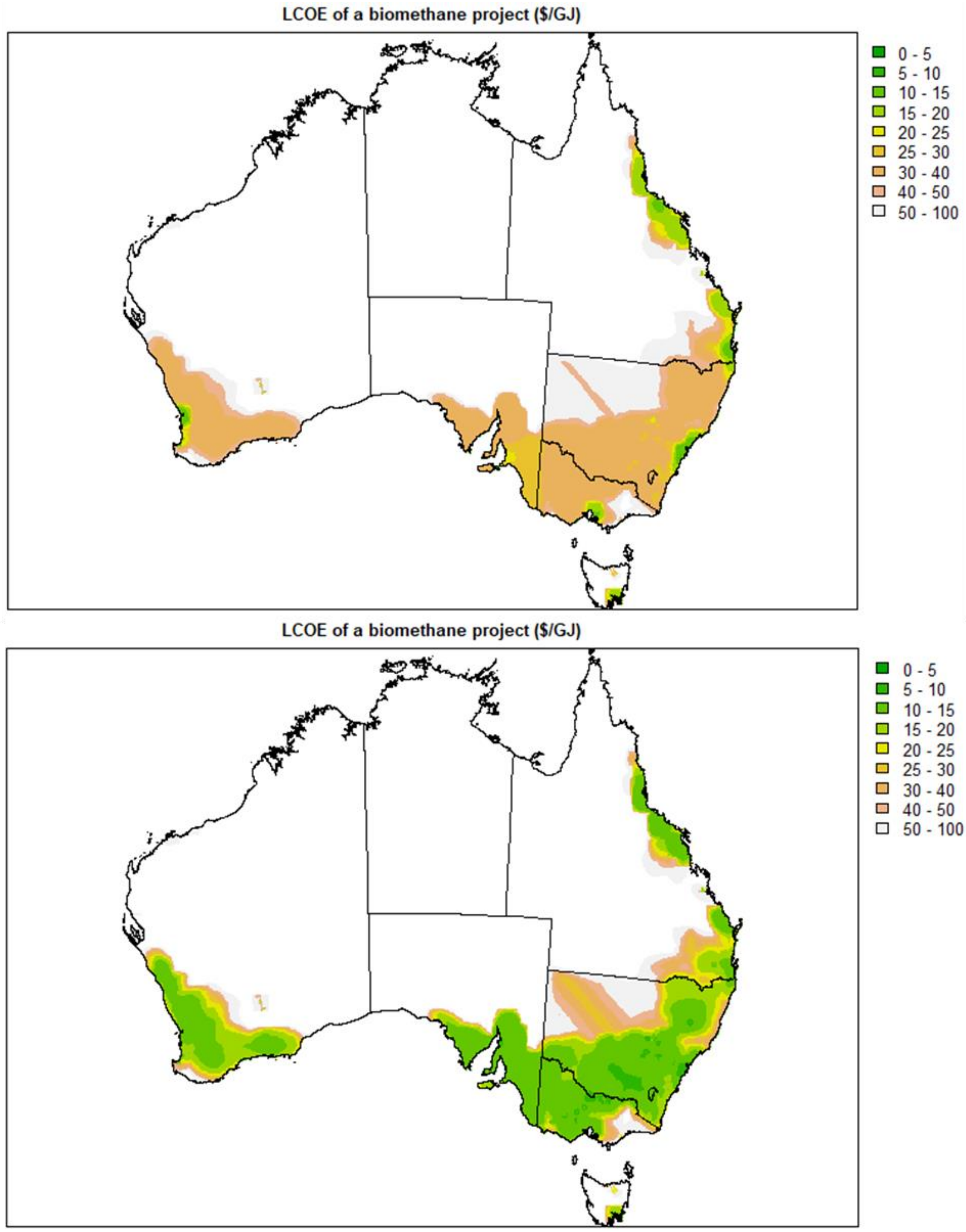

Figure 11: Heatmaps of LCOE when the plants are sized to produce the maximum available bio-methane considering i) no storage of agricultural feedstock (top), and ii) even availability of all feedstock types throughout the year (bottom)

5. IMPLICATIONS AND RECOMMENDATIONS FOR INDUSTRY

Key implications and recommendations for industry are identified as follows:

- The LCOE of bio-methane projects can increase when attempting to harvest large quantities of agricultural waste that are only available for some parts of the year. Despite producing the largest quantities of bio-methane, the resulting plant capacity is not efficient. Consequently, the most commercially viable locations are major cities in each state (with constant supplies of MSW), and the belt of sugarcane along north-eastern Queensland. However, the use of these feedstocks can be quite competitive (they can be used for electricity cogeneration or composting) and so further analysis is required at smaller scales to understand the availability of these resources for bio-methane production at a particular site.
- While there is a large amount of potential bioenergy in each state, the amount that is commercially capturable is lessened, given reliance of being close to infrastructure and a reliance on feedstock supply throughout the year. The number of commercially capturable bio-methane sites in each state would increase with supporting policies like renewable gas incentives, as well as ways to reduce the cost of transport (Culley et al., 2022).

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