Model Overview:

Integrated Assessment Model for Biomethane Viability Assessment

FFCRC RP1.2-04

June 2024

RP1.2-04

Integrated model for biomethane injection in gas networks

Authors:

Culley S.A., Smith, O., Zecchin A.C., Maier H.R., The University of Adelaide

Project team:

Holger Maier, The University of Adelaide

Sam Culley, The University of Adelaide

Olivia Smith, The University of Adelaide

Aaron Zecchin, The University of Adelaide

Jing Tian, The University of Adelaide

Tara Hosseini, The University of Adelaide

Jeffry Robert, The University of Adelaide

Peter Ashman, The University of Adelaide

Sandra Kentish, The University of Melbourne

Patrick Lowry, AGIG

Jarrod Irving, AGIG

Brent Davis, Jemena

Alhoush Elshahomi, Jemena

Dennis R Van Puyvelde, Energy Networks Australia

Craig Clarke, GHD

Andre Lopes, Worley

Bart Calvert, APA

Mohamed Hammad, DMIRS

Australian Government
Department of Industry, Science and Resources

Cooperative Research Centres Program

This work is funded by the Future Fuels CRC, supported through the Australian Government's Cooperative Research Centres Program. We gratefully acknowledge the cash and in-kind support from all our research, government and industry participants.

IMPORTANT DISCLAIMER

ACKNOWLEDGEMENT

This work is funded by the Future Fuels CRC, supported through the Australian Governments' Cooperative Research Centres Program. The cash and in-kind support from the industry participants is gratefully acknowledged.

PROJECT INFORMATION	
Project number	RP1.2-04
Project title	Integrated model for biomethane injection in gas networks
Research Program	RP1
Milestone Report Number	N/A
Description	This report outlines the scope and methods behind the integrated assessment model and user interface for techno economic viability assessments of biomethane projects. Its purpose is to inform users of a related online tool and provide tool users with an overview of the model underpinning the tool.
Research Provider	University of Adelaide (SET)
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: Patrick Lowry (AGIG) Advisor Teams: Jemena: Alhoush Elshahomi, Brent Davis Energy Networks Australia: Dennis R Van Puyvelde GHD Group: Craig Clarke Worley: Andre Lopes APA: Bart Calvert DMIRS: Mohamed Hammad
Related Commonwealth Schedule	RP1.2.2 Techno-economic models and software for future fuel production technology completed. RP1.5.3 Feasibility studies for new demonstration project(s) in Australia delivered.
Project start/completion date	May 2021/Oct 2024
IP Status	**Open** – available publicly to all parties outside the CRC.
Approved by	N/A
Date of approval	N/A

Table of Contents

Table of Figures

Summary of Report

The bioenergy roadmaps for Australia illustrate that there is a significant opportunity to reduce greenhouse gas emissions while utilising existing gas networks with waste-to-gas schemes - specifically the production and injection of biomethane. However, there are still a limited number of projects in Australia that are injecting biomethane into the grid, despite the proven commercial success in Europe and the US. There is a need to explore the main factors that affect the techno-economic viability of these projects in Australia, and identify the most viable opportunities for projects. Consequently, the overarching objective of project RP1.2-04 is to develop a user-friendly integrated assessment model that enables a high-level quantitative assessment to be performed easily and reliably by end users at locations of interest.

This report details the integrated assessment model that is being developed as part of FFCRC project RP1.2-04, and in particular, its web-based user interface. The assessment model enables the exploration of the techno-economic viability of biomethane projects, where anaerobic digestion plants produce and collect gas that will primarily be injected into the grid. This model is built on the research that was done as part of RP1.2-03, including the final framework report (Culley et al., 2021b), and the two site assessments of Griffith (NSW) and Adelaide (SA) (Culley et al., 2021a; Culley et al., 2020). When performing the site assessments, region specific data was used in the analysis, and the formation of the techno-economic assessment was co-developed with project end-users who had nominated the site. Since those site-specific assessments, research and modelling has been undertaken to generalise the functionality of the assessment model to be applied to a wide range of case studies across Australia. This includes the anaerobic digestion dataset published as part of this project (Robert et al., 2023). This also included the design of an interface around the integrated assessment model, so that end users can more easily interact with the tool, provide site specific information about a project, and see an overview of the key results (Figure i).

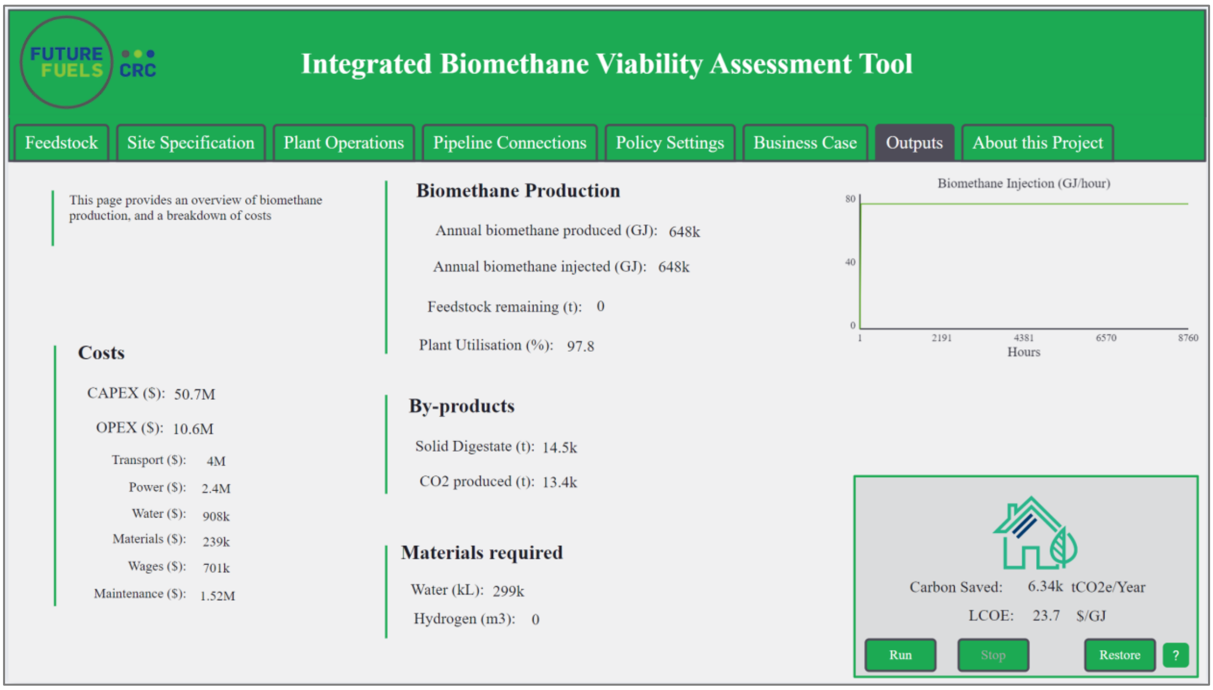

Figure i – The output page in the interface for the integrated assessment model

This report details the current version of the integrated assessment model, with the goal of providing an overview for any end-users of this project and an explanation of how to use the tool. Further iteration of the model, as well as improvements to its useability, are still ongoing as part of FFCRC projects, running until the end of this year. An initial prototype of the model is being made available to enable a greater range of feedback to be received, and thereby greatly improve the final version of the tool. The integrated assessment model and accompanying interface can accessed through the FFCRC website during this testing phase, and any feedback should be directed to Dr. Sam Culley (sam.culley@adelaide.edu.au).

1. INTRODUCTION

1.1 Background

The conversion of waste to bioenergy is regarded as an emerging opportunity to decarbonise energy systems in Australia, capable of meeting up to 20% of Australia's energy requirements by 2050 (Carlu et al., 2019; ENEA and Deloitte, 2021). As gas delivers 44% of Australia's household energy, there is a significant opportunity to reduce greenhouse gas emissions while utilising existing gas networks with waste-to-gas schemes - specifically the production and injection of biomethane. Europe is the world's leading producer of biomethane, with 350 plants feeding into the gas grid in 2015 (Scarlat et al., 2018). Despite the opportunity and the significant commercial success in Europe, the production of biomethane and its injection into existing gas networks is currently almost non-existent in Australia (only one operating plant to date). Consequently, the overarching objective of this project is to develop a user-friendly integrated assessment model that enables users to explore the high-level viability of biomethane grid injection projects at locations of interest.

1.2 Purpose of this report

This summary report details the user interface of the integrated assessment model that has been developed as part of FFCRC project RP1.2-04. The assessment model enables the exploration of the techno-economic viability of biomethane projects, where anaerobic digestion plants produce and collect gas that will primarily be injected into the grid. This model is built on the research that was done as part of RP1.2-03, including the final framework report (Culley et al., 2021b), and the two site assessments of Griffith (NSW) and Adelaide (SA) (Culley et al., 2021a; Culley et al., 2020). The report provides a guide to interact with the user interface, for users to easily explore the tool, and perform a techno-economic viability assessment of a project with specific site information provided by the user.

When performing the site assessments, region specific data was used in the analysis, and the formation of the techno-economic assessment was co-developed with project end-users who had nominated the site. Since those site-specific assessments, research and modelling has been undertaken to generalise the functionality of the assessment model to be applied to a wide range of case studies across Australia. Further iteration of the model, as well as improvements to its useability, are still ongoing as part of FFCRC projects, running until the end of this year. An initial prototype of the model is being made available to enable a greater range of feedback to be received, and thereby greatly improve the final version of the tool.

This summary report details the user interface, including information on how to use the tool, in Section 2. Section 3 also details the overall framing and scope of the techno-economic assessment performed, including key definitions of the measurements of viability.

2. THE USER INTERFACE

To enable use of the integrated assessment model across a range of case studies in Australia, and make the process more user-friendly, a front-end interface for the integrated assessment model has been developed in Stella Architect (Isee systems, 2020). This user interface is directly linked with the underlying model, which is simulated online. The interface first provides some context for the project (Section 2.1). Then, users can work through a series of pages in the interface to customise assumptions and parameters involved in techno-economic assessment of biomethane projects (Section 2.2). Finally, a high-level summary of the main outputs is provided (Section 2.3). The categories included as part of the interface are as follows:

- Feedstock (how much and what type of feedstock is available?)
- Site specification (how far is the feedstock from the proposed plant?)
- Plant operation (how will the AD reactor be operated?)
- Pipeline connection (what is the demand and injection pressure?)
- Policy settings (what subsidies and tariffs are available?)
- Business case (what are revenue streams and assumptions in cost/benefit?)
- Outputs (how much gas is produced, what are the by-products and costs?)

2.1 Model welcome and about pages

Upon launching the interface, users will see a description of the integrated assessment model, and a brief overview of the role renewable gas can play in the renewable energy transition (Figure 1). When pressing the “get started” button, users are brought to the main panels (Section 2.2), where they can interact with the pages listed above. The final page is called “About this project”, which provides a list of contributors to the project who have helped co-develop the integrated assessment model (Figure 2). This page also contains a link to a “model overview” which provides a snapshot of the underlying model.

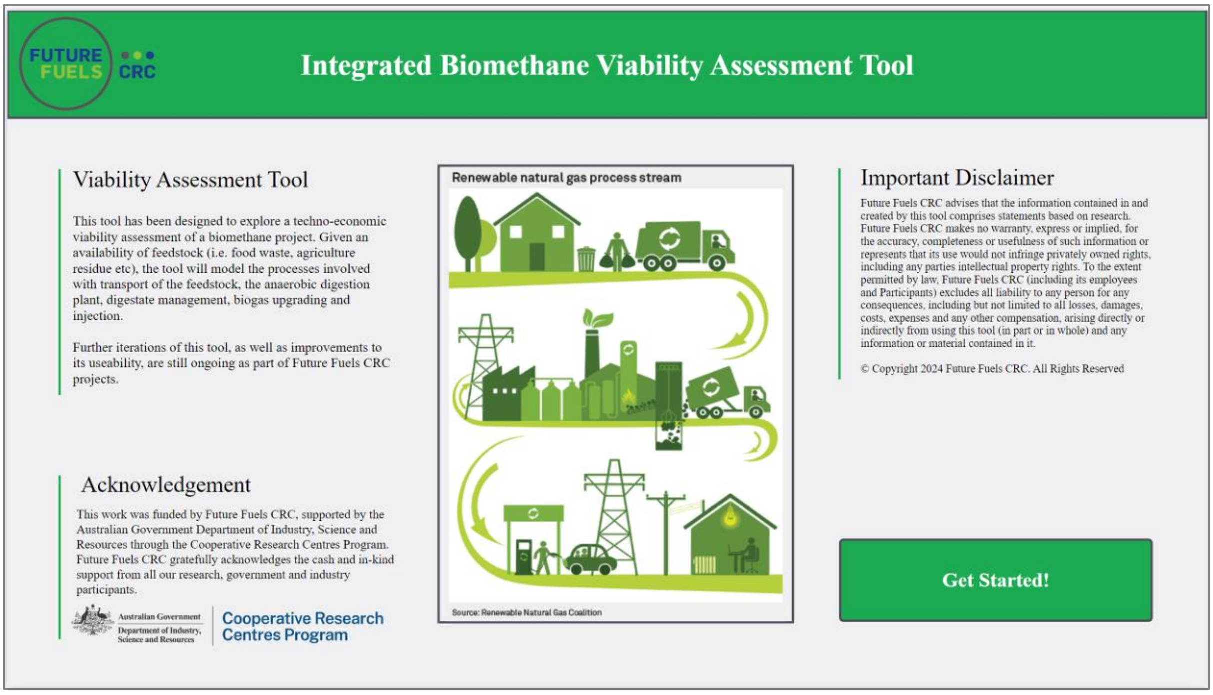

Figure 1: The front page of the interface for the integrated assessment model

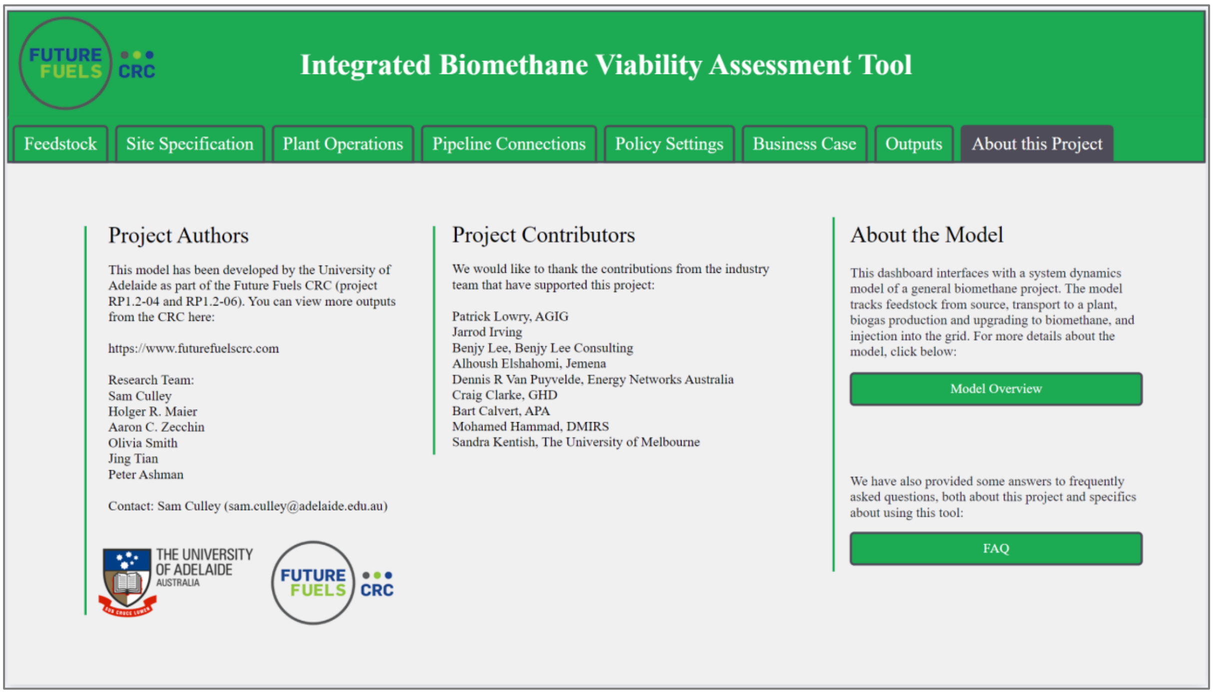

Figure 2: The about the project page for the integrated assessment model

2.2 Interfacing with the assessment model.

The first page in the interface is the starting point for a techno-economic assessment, and a critical component to the success of biomethane projects; the feedstock that is available (Figure 3). Users have the option to enter the feedstock available in tonnes either annually, or if more information is known, at a monthly time step. This is particularly important for agricultural feedstock sources that varying significantly through the year. Feedstock amounts are entered in wet tonnes, which is important for the techno-economic viability assessment as any feedstock transport costs depend on the wet weight of the feedstock.

On every page there is also a quick summary of key techno-economic outputs (Levelised cost of energy and carbon saved, described in Section 3.2), and the ability to run the model. This is to allow a quick exploration of the high-level impact that change in a parameter has, without having to navigate to the outputs page that contains a full breakdown. There is also an option to restore the model to default parameter values.

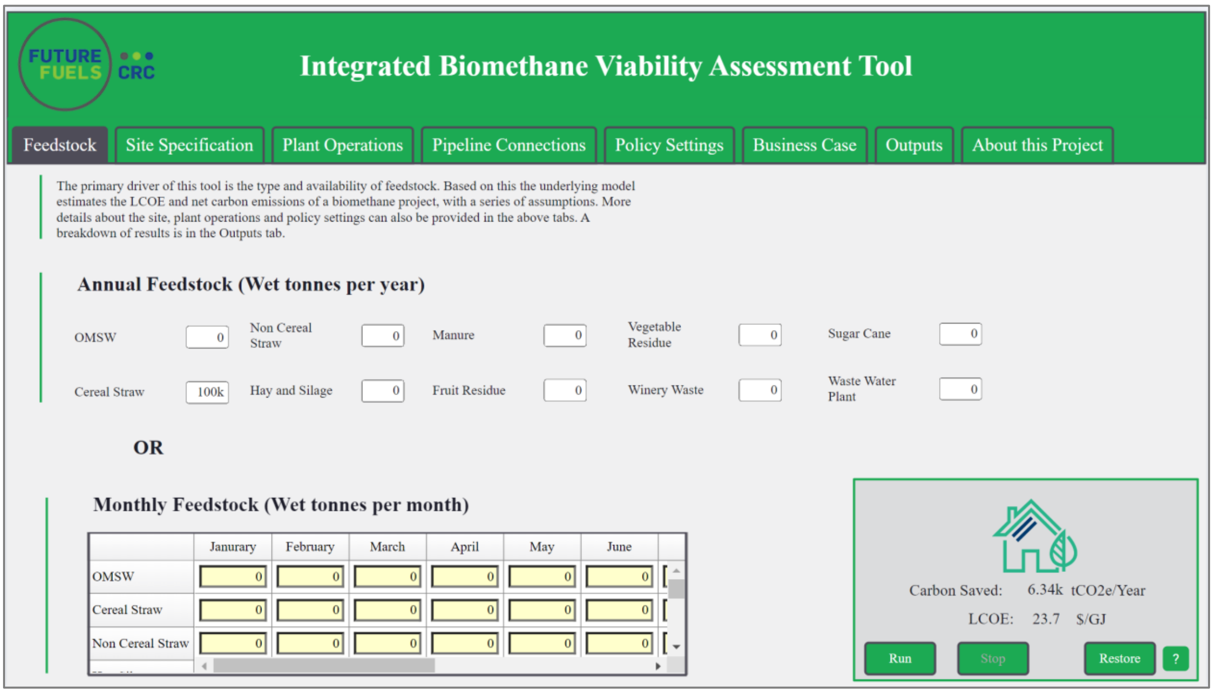

Figure 3: The feedstock input page in the interface

The second page allows users to change some of the details about the site where the project will be located. This is divided into three sections, location/transport, plant costs and emissions factors.

- The plant costs simply allow users to change the prices of electricity, gas and water, maintenance and wages at the site, which could vary based on state, provider, and also the extent to which more localised renewable power sources like wind and solar are used in the project. These values will be used to estimate operation costs of the plant, given the energy and water requirements.
- The location and transport sections primarily refer to the distance between the feedstock source and the proposed plant. An array of inputs is used for distances from feedstock to plant, to allow for the exploration of hub scale projects, with co-digestion of multiple feedstocks. There are also separate costs of transport, which should be used to represent both the cost of transporting the physical waste, but also any purchasing or harvesting of waste residues required (e.g. collecting straw stems/chaff or manure). There is also an input for the distance of the main biogas plant from a biomethane upgrading and compression station, in case the biogas plant is not located directly on a pipeline.
- Finally, emissions factors are also included to allow for the carbon estimates, as these vary by location. National averages are used as a default.

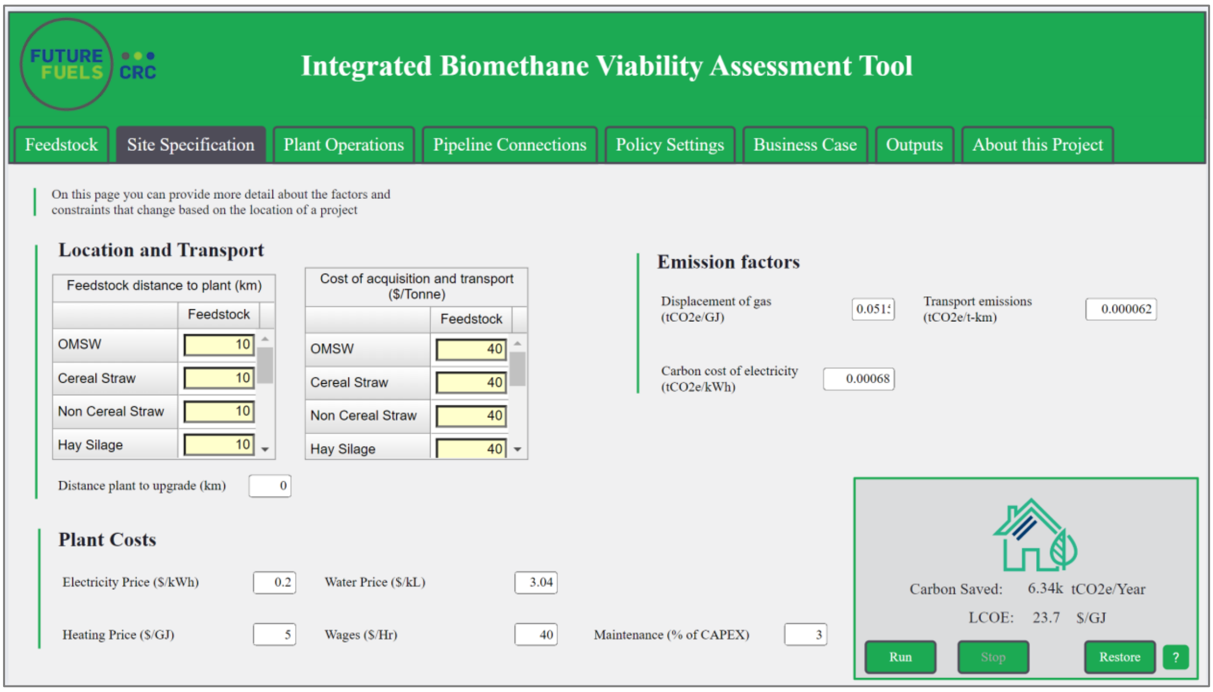

Figure 4: The case study specification page in the interface

The third page is focussed on the anaerobic digestion plant operation. Users can control the configuration of three main areas: the anaerobic digestion reaction type, the method of isolating and removing carbon dioxide, and also handling of the digestate byproduct. The anaerobic digestion reaction settings can control the temperature of the reaction (supported data includes differences for mesophilic and thermophilic reactions) and whether the reaction is wet or dry. These settings will require different levels of energy, heat and water but will also affect the biomethane yields gained. Thermophilic reactions tend to produce higher biomethane outputs, but at an additional cost of operation.

Before biomethane is injected into the pipeline, the carbon dioxide needs to be removed from the biogas. Three methods are currently built into the integrated assessment model: pressure swing absorption, water scrubbing and membrane separation. Once this carbon dioxide has been separated, there is also the option to explore methanation (a process used to mix hydrogen with the carbon dioxide to create more biomethane). Whether this technology is economically viable will depend a large amount on the price of hydrogen, which has been left as an input. There are two options provided for the treatment of digestate, a by-product associated with running the plant. The first option is to treat the solid digestate so that it can be sold for a profit. The second option is to choose a cost of disposal of the digestate if it is not being sold on but instead has to be removed from the site.

As a note on cost estimates, two parameters with the largest impact on the CAPEX (Capital Expenditure) estimate are on this input page: Plant size and CO_2 removal technology. Cost curves are used in the underlying model for both, which have been published based on costing data from European case studies (with adjustments made for the Australian market).

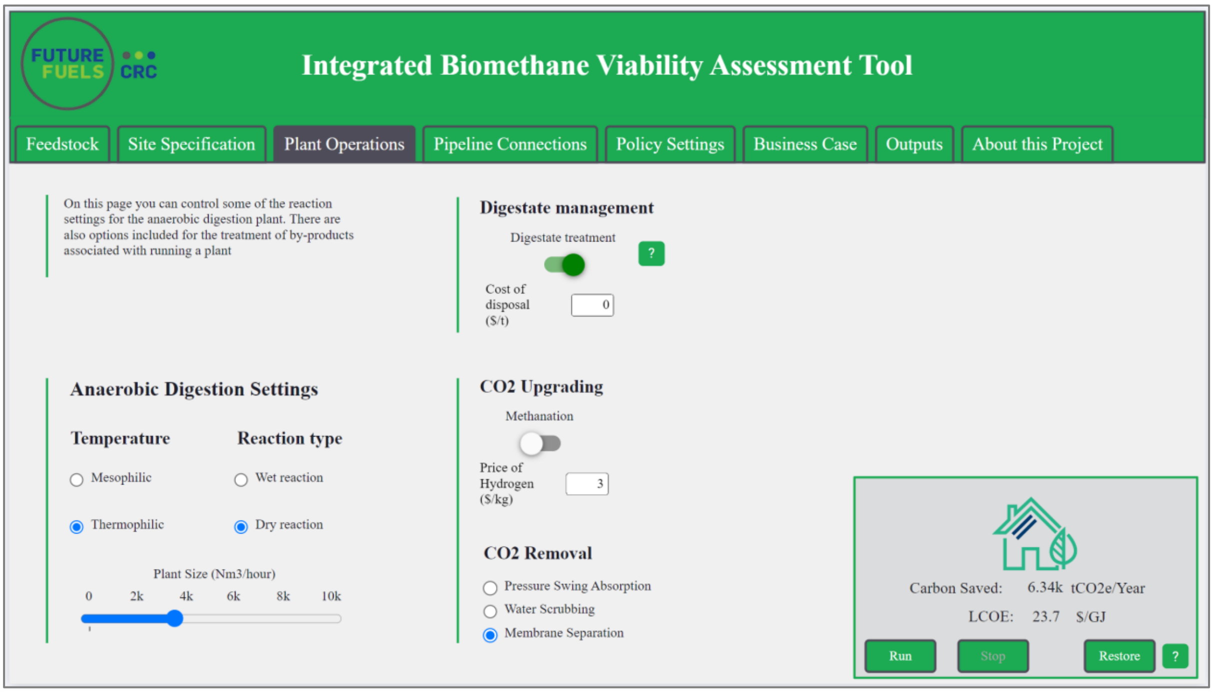

Figure 5: The plant operation input page in the interface

The fourth page focuses on the connection to the gas network. At this point in the process, the biogas has been upgraded in quality and is at the required specification for injection into the grid (based on AS4645). In the underlying model, in addition to carbon dioxide this has included the removal of excess water vapour, and hydrogen sulphide. There are a few limiting factors at this point that have a significant impact on the overall viability of a project. The first of these is whether the project will connect to a distribution line or a transmission line. This will impact the connection pressure required, which can add significant costs to the project. The injection pressure is also required as an input, which is used in the CAPEX estimate for cost of compression.

The other is the demand for biomethane in the pipeline. In some areas of Australia, it will be possible to oversupply biomethane given the amount of feedstock available and the local demand for gas in a distribution network. In some cases this presents a trade-off between having to pay higher costs for injection pressures, versus being able to provide biomethane in larger quantities. This should be explored for each case study, as a further advantage for higher injection pressure in transmission networks (beyond just increased demand). The average demand through the year is used to control for this.

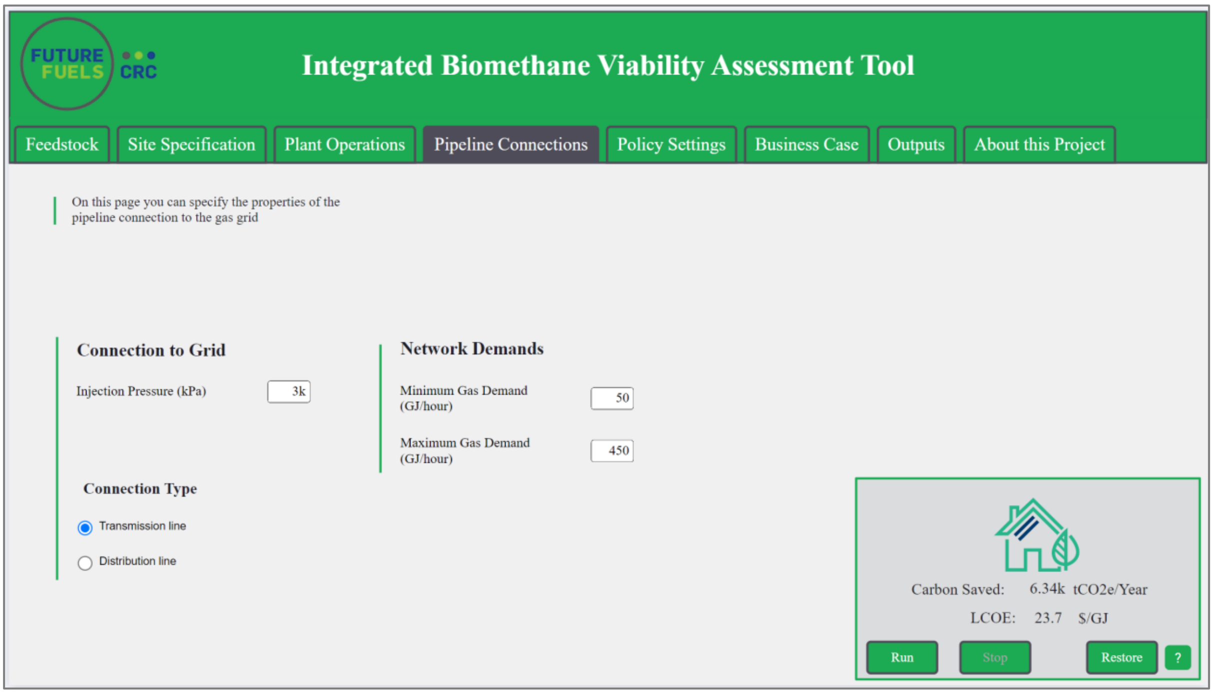

Figure 6: The pipeline connection page in the interface

The fifth and sixth pages of the interface focus on the policy settings and business case parameters. The policy settings allow the exploration of two types of financial support: reductions to the capital costs of a plant, or a continuous income stream for the project (Figure 7). The reduction to capital cost is in the form of a onetime grant to offset CAPEX, which is meant to represent subsidies by providers such as ARENA, as well as any state government funding. The income streams over time can be input in the form of a renewable heat incentive scheme ($/GJ) based on gas injected into the grid, and also carbon incentives of conversion credit and displacement credit ($/t$CO_2$e) based on carbon emissions avoided. Note that currently the conversion abatement does not follow ACCU methodologies in estimating the emissions avoided, in part as there are limited feedstocks supported. The calculation uses best available data from research studies, and has been included to broadly explore the difference between feedstocks, but for specific projects this will change significantly based on the prior use of the feedstock.

Figure 8 shows the page containing options for the business case and project revenue. The first three inputs in this page are related to possible revenue streams. The first is a profit associated with selling the digestate produced as part of the anaerobic digestion. As mentioned previously, with some treatment, this can be used as a fertilizer, and so the tool allows the exploration of a profit stream from the digestate to offset overall costs. The second is a gate fee associated with the delivery of feedstock. For some waste streams, waste levies are already being paid for disposal, which presents the opportunity to charge a fee for processing the waste at the anaerobic digestion plant. This essentially acts as an offset for the cost of transport. The final revenue stream considers any purchase of the CO_2 stream that is captured during biomethane upgrading. The final two business case parameters include the project life and discount rate, used to calculate the LCOE.

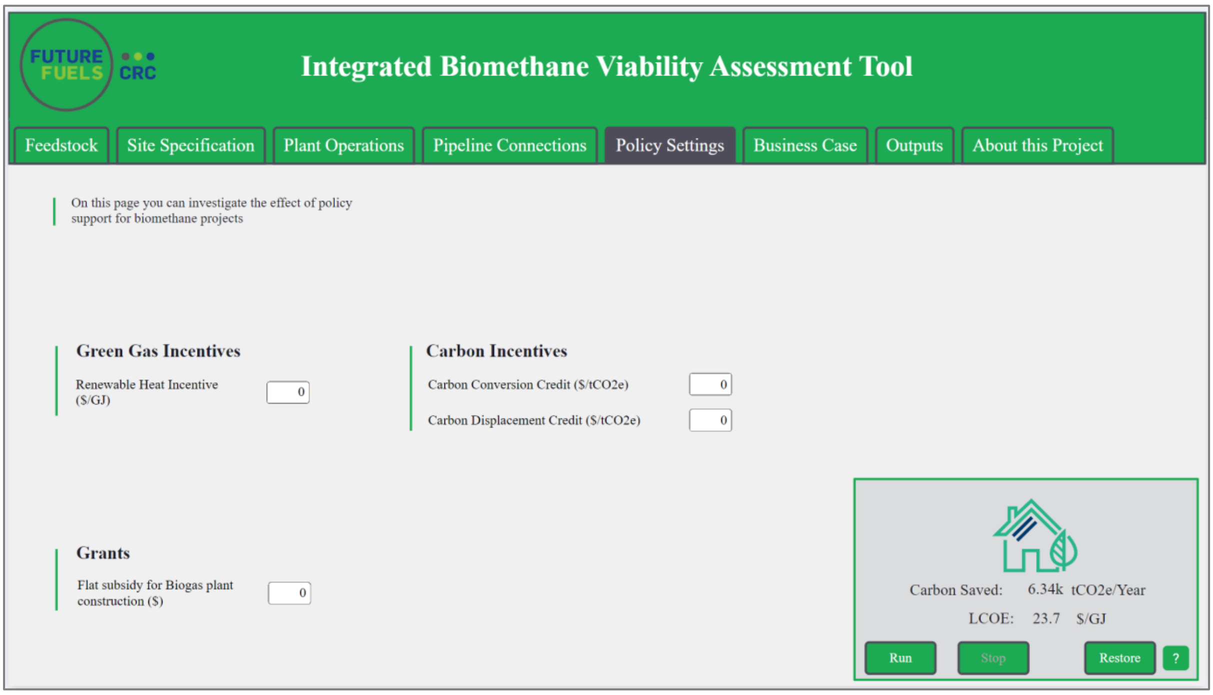

Figure 7: The policy setting input pages in the interface

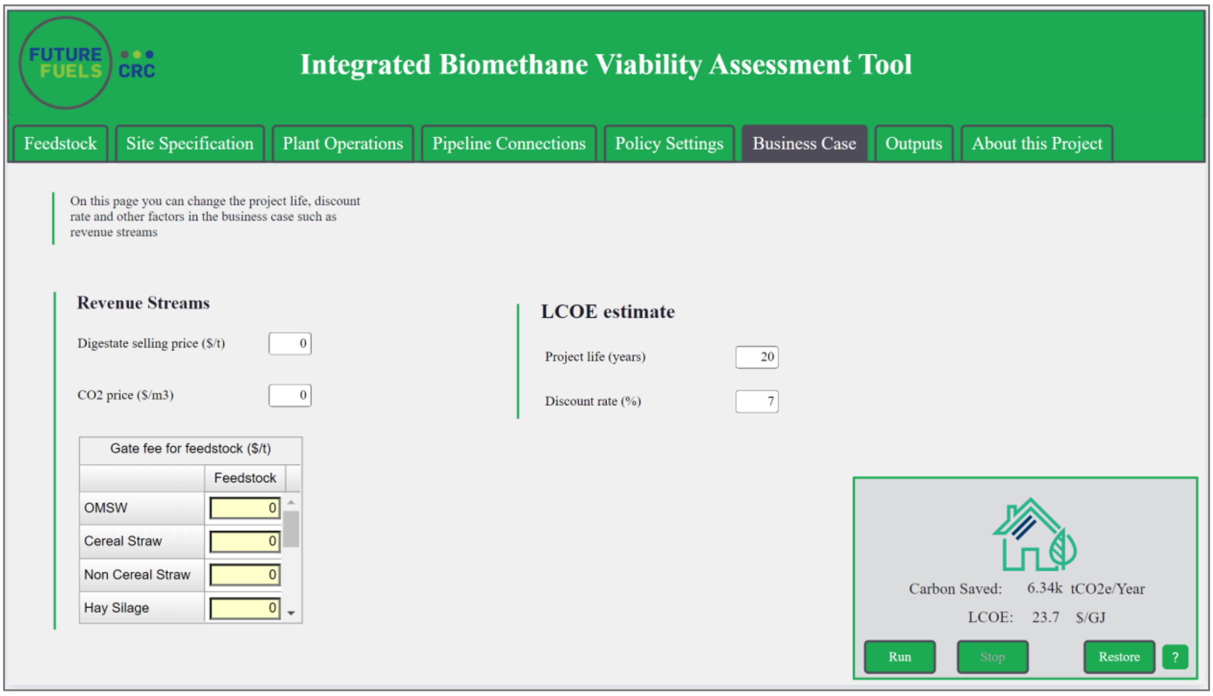

Figure 8: The policy setting input pages in the interface

2.3 Outputs from the integrated assessment model.

The final page in the interface for the integrated assessment model is a list of outputs from the techno-economic assessment. These outputs are organised into a breakdown of:

- costs;
- the volumes of biomethane produced;
- any by-products produced; and,
- the materials required to operate the plant.

Costs are separated into CAPEX and OPEX (Operational Expenditure), with OPEX broken down and reported annually in the categories of: transport (and acquisition) of feedstock, power, water, an estimation of wages and maintenance, and a sum of materials needed to upgrade the biogas. The biomethane production summarises the annual GJ produced from the feedstock, and the annual amount injected (which will only be different if constrained by pipeline demand). There are also two outputs that help size the plant: feedstock remaining and plant utilisation. The feedstock remaining term will indicate any feedstock that was delivered to the plant at cost, but not processed as it was greater than the size of the plant (and the maximum loading rate into an anaerobic digestor reactor) would allow. There is also a plant utilisation output, that shows the percentage of the given feedstock loading rate vs. the maximum given plant size selected. Its inclusion in the interface is to indicate that, when it is less than 100%, a smaller plant size should be selected for the feedstock provided.

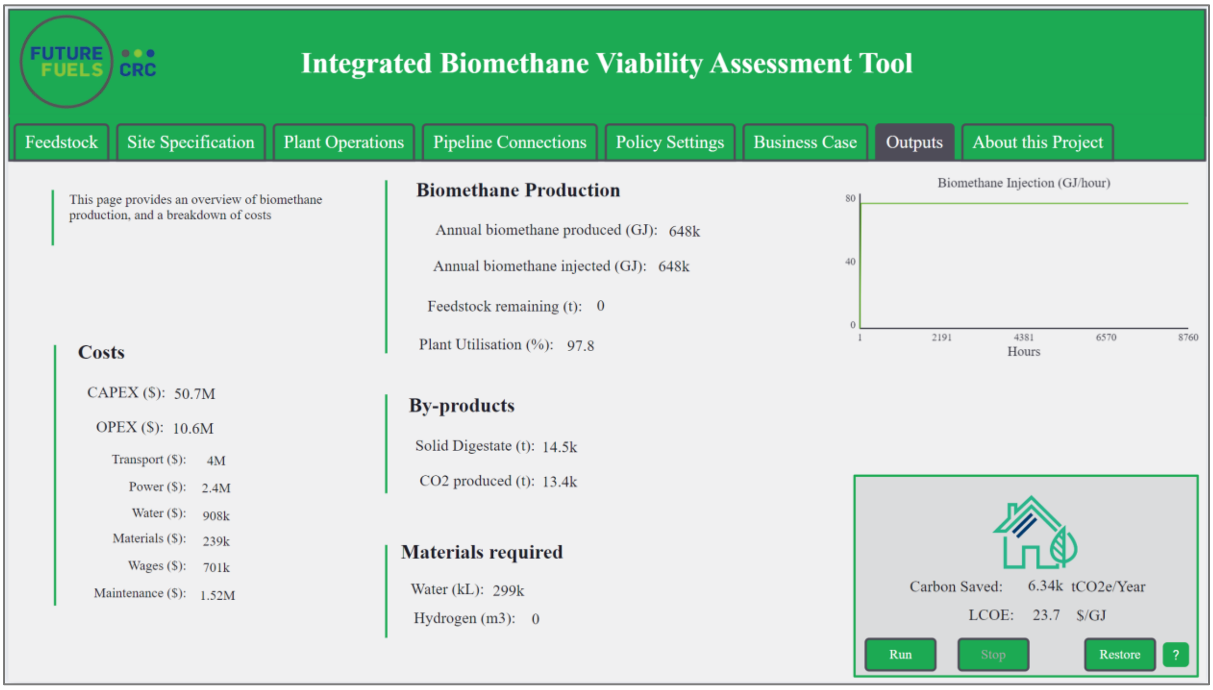

Figure 9: The output page in the interface

The by-products reported on in this assessment are the annual solid digestate and CO_2 produced, both expressed in tonnes. The digestate has commercial value as fertilizer in some applications, depending on the regulations present in the state for the proposed project. The green CO_2 can also have commercial applications, in farming, green fuels (such as methanol) and as a food grade product. Finally, the materials required track some of the other major resource streams required to run a plant, which will have an impact on where the project can be located (due to resource constraints). This includes the hydrogen that is used in methanation, and/or the water required, which will depend on the moisture content of the AD plant, and the feedstock types.

3. OVERVIEW OF THE ASSESSMENT AND SCOPE OF THE TOOL

To provide insight into the modelling approach underlying the software outlined in Section 2. This section details the scope of the integrated assessment model, including the conceptualisation of the biomethane production chain (Section 3.1). It also introduces the metrics reported on as part of the techno-economic viability assessment (Section 3.2).

3.1 Scope of integrated assessment model

A high-level description of the processes modelled by the quantitative system model is shown in Figure 10. The first product is the feedstock, which is collected, and transported to the biogas plant (processes 1-2, Figure 10). At the biogas plant, the feedstock is pre-treated to form a slurry (process 3), which mixes all available feedstocks with water. At the anaerobic digestion (AD) stage, this slurry produces both biogas and digestate (process 5, products 15 and 16). The digestate is dewatered, where it can be refined and sold as fertilizer (processes 6 and 7). The biogas is then treated to remove the CO_2, water vapour, and H_2S (processes 8 and 9). There is also an optional process of upgrading the removed residual CO_2 to CH_4 via methanation (process 10), which occurs before the biomethane is compressed and injected into the transmission pipeline (processes 11-12) (Culley et al., 2023).

Throughout all these processes, the techno-economic metrics from Section 3.2 (LCOE and net carbon saved) are calculated for each, and then totalled at the end of all the processes. Note that in the case of LCOE, it is only the operational costs that are calculated in each section. For the capital costs, the size of the biomethane plant is estimated based on the peak biogas flows at the stage of anaerobic digestion, which includes the equipment required for pre-treatment, digestate management and biogas upgrading. Note that the digestate modelling is high level i.e. net revenue and net emissions avoided are assumed, and the transport of the digestate is not modelled in detail. The CAPEX for gas compression and storage are the only elements calculated independently, as this will depend on the gas pipeline constraints more than the AD plant. More details are provided in Report 2 of this project (Culley et al., 2023).

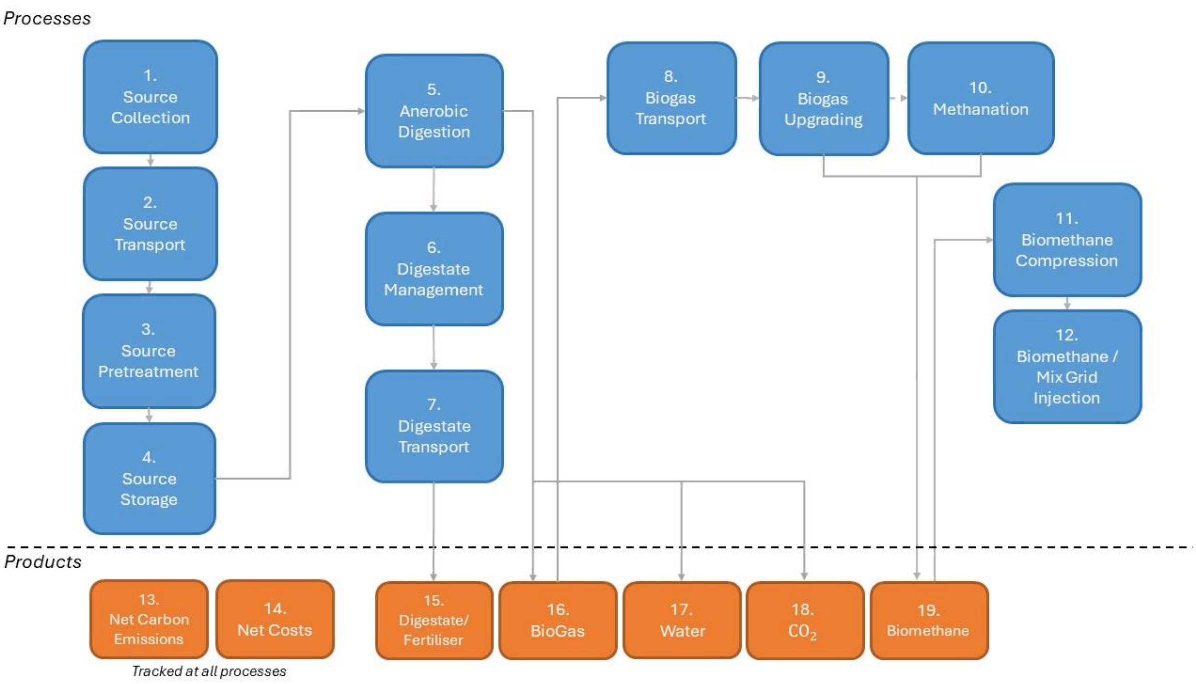

Figure 10: A framework illustrating the end-to-end processes and products to consider in a viability assessment of biomethane grid injection.

This conceptualisation has led to the development of a detailed system dynamics model, which tracks the underlying products as they move through the biomethane processes, and calculates costs, carbon emissions and other metrics throughout (Figure 11). The System Dynamics paradigm was selected as a suitable framework for the assessment as a series of stocks and flows allow a simple representation of a supply chain. In addition, the temporal dynamics of biomethane supply due to feedstock availability and actual gas demand in the pipelines can be directly modelled, and high level feedbacks and trade-offs can be readily explored. The Stella Architect software (isee systems, 2020) was selected as the preferred approach for developing the system dynamics model, as it allows a very visual way to demonstrate the model (Figure 11), parameters can be changed easily, and the software supports the developed of a front-end interface.

One of the most critical parts of the modelling of biomethane project viability is the biomethane potential of the feedstocks, which is determined as part of the anaerobic digestion stage (Figure 10, 11). In this project, supporting modelling was performed separately using detailed physic-based chemical process simulation software called Aspen Plus (aspentech, 2020), and are used by the system dynamics model (Robert et al., 2023). It is the combination of these two modelling approaches that makes the tool an integrated assessment model.

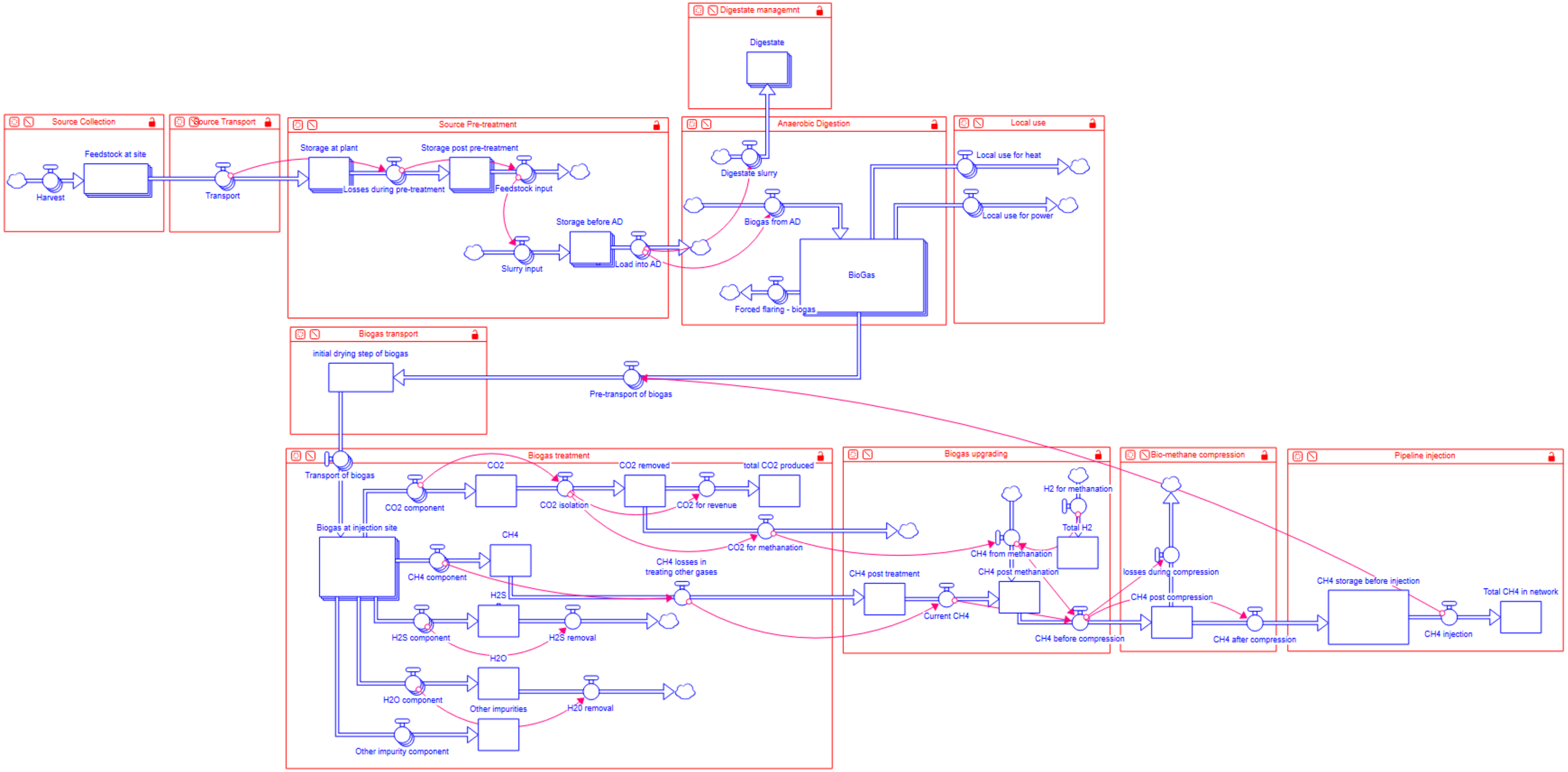

Figure 11: A detailed resolution of key processes and interactions in the production and grid injection of biomethane

.

3.2 Techno-economic indicators

In order to consider a more rounded business case, as mentioned, two metrics are considered as part of this assessment, one for cost and one for GHG emissions. The cost metric used is the Levelised Cost of Energy (LCOE), and the carbon metric is a measure of net Greenhouse Gas (GHG) reduction from the European Biogas Association (EBA, 2020).

3.2.1 LCOE

The LCOE (measured in $/GJ) is estimated by calculating the total discounted lifetime costs (or, the net present value), divided by the total discounted energy output. In select scenarios where a revenue stream is present (from selling byproducts or a government policy etc.), the standard calculation of LCOE is adjusted to include the annualised net project costs, not total project costs. The primary reason for this is to acknowledge that revenue streams reduce the gap between the LCOE and the market price of natural gas so that projects can be profitable, allowing for a consistent comparison across the analysis. But it is important to note in these cases that the inherent cost of the biomethane production is not changed. This modified LCOE metric will be denoted in the report using LCOE* and is measured in $/GJ, allowing for comparison with the purchase price of traditional fuels such as the price of natural gas. LCOE is calculated using the following equation:

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{M_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Equation 1 – Levelised Cost of Energy

where, n = lifetime (years), r = discount rate (%), t = project year, I_0 = CAPEX ($) amount, M_t = net cost in year t ($, note that in some relevant scenarios, we subtract revenue from costs), and, E_t = energy produced in year t (GJ). In this assessment, the sensitivity of LCOE to a range of factors will therefore be determined by their impact on the CAPEX and OPEX of running a biomethane project. However, the discount rate and project lifetime will also have a significant effect on the LCOE metric. This is explored more in Section 3.2.1, where the effect of these parameters on the baseline LCOE breakdown is demonstrated.

3.2.2 Net Carbon Saved

The method of estimating the carbon emissions adopted in this assessment is based on both the European Biogas Association (Figure 12), the Australia emissions reduction fund calculations (Regulator;, 2022), and an assessment of biomethane opportunities for New Zealand (BECA, 2021). The greenhouse gas emissions reduction potential is estimated by taking the net difference between emissions caused from the project (transport of feedstock, flaring/leakage of gas, and emissions from grid power), and the carbon abatement (displacement of natural gas, avoidance of feedstock emissions and any avoidance from byproducts). In this study, the emissions tracked are as follows:

Carbon emission sources:

- Transport;
- Carbon from electricity grid;
- Leakage from AD reactors;
- Leakage from biogas upgrading;
- Scope 3 fugitive emissions from gas networks;

Carbon abatement sinks:

- Avoided from feedstock decomposition/prior use;
- Net abatement from digestate use instead of fertiliser (if treating and selling digestate);
- Displaced natural gas from grid.

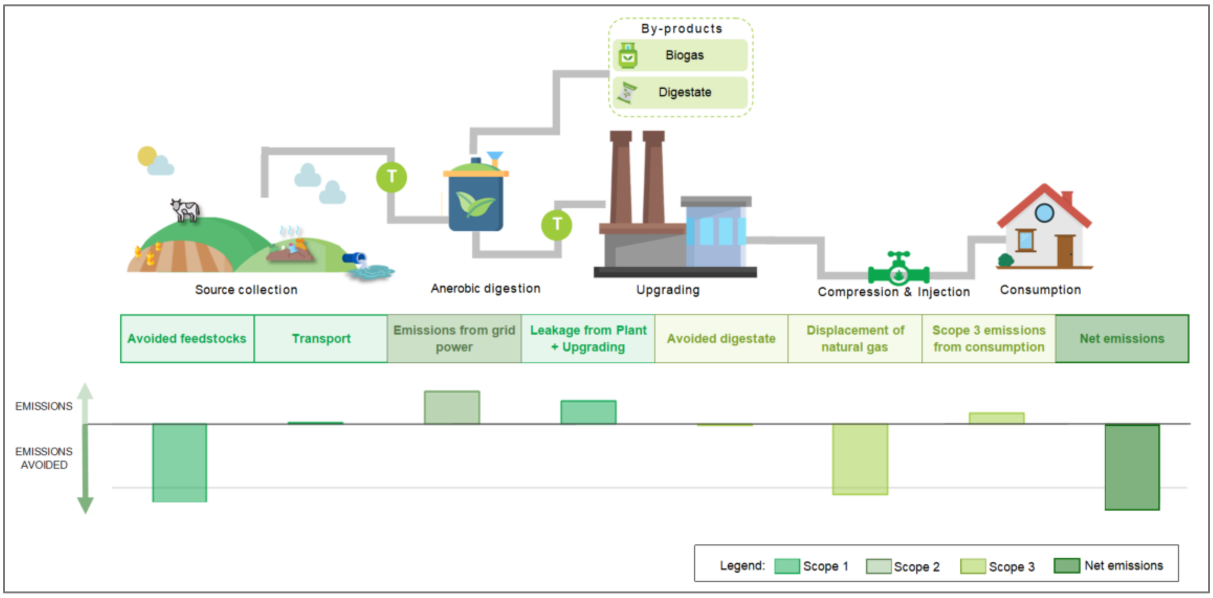

Figure 12: Illustrative diagram of carbon emissions during the biomethane process adapted from Beca (BECA, 2021).

4. NEXT STEPS AND FUTURE WORK

This report details the current version of the integrated assessment model, with the goal of providing an overview for any end-users of this project and an explanation of how to use the tool. Further iteration of the model, as well as improvements to its useability, are still ongoing as part of FFCRC projects, running until the end of this year.

An initial prototype of the model is being made available to enable a greater range of feedback to be received, and thereby greatly improve the final version of the tool. The integrated assessment model and accompanying interface can accessed through the FFCRC website during this testing phase, and any feedback should be directed to Dr. Sam Culley (sam.culley@adelaide.edu.au).

5. REFERENCES

aspentech, 2020. Aspen Plus.

BECA, 2021. Biogas and Biomethane in NZ - Unlocking New Zealand's Renewable Natural Gas Potential.

Carlu, E., Truong, T., Kundevski, M., 2019. Biogas opportunities for Australia.

Culley, S.A., C., Z.A., Hosseini, T., R., M.H., 2021a. Adelaide Case Study Report - Viability Assessment. University of Adelaide: FFCRC.

Culley, S.A., R., M.H., C., Z.A., 2021b. Final Framework Report. University of Adelaide: FFCRC.

Culley, S.A., Zecchin, A.C., Hosseini, T., Maier, H.R., 2020. Griffith Case Study Report – Viability Assessment.

Culley, S.A., Zecchin, A.C., Maier, H.R., 2023. Integrated Assessment Model: FFCRC.

EBA, 2020. The contribution of the biogas and biomethane industries to medium-term greenhouse gas reduction targets and climate-neutrality by 2050.

ENEA, Deloitte, 2021. Australia's Bioenergy Roadmap.

isee systems, 2020. Stella Architect.

Regulator;, C.E., 2022. Biomethane Method Package 2022 – Simple Method Guide.

Robert, J.R., Culley, S.A., C., Z.A., R., M.H., 2023. Anaerobic digestion database. The University of Adelaide: FFCRC.

Scarlat, N., Dallemand, J.-F., Fahl, F., 2018. Biogas: Developments and perspectives in Europe. Renewable Energy 129 457-472.

Future Fuels CRC

Enabling the Decarbonisation of Australia's Energy Networks

www.futurefuelscrc.com

info@futurefuelscrc.com

Australian Government
Department of Industry, Science and Resources

Cooperative Research Centres Program