Dairy Biogas Cluster Feasibility Study

BC Ministry of Agriculture & Food

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Author

This report was written by GHD Limited (ghd.com) in collaboration with BC Ministry of Agriculture and Food.

The Power of Commitment

Executive Summary

Anaerobic digestion and biogas upgrading are growing technologies capable of processing farm wastes such as manure into renewable natural gas (RNG) which is a renewable fuel source. These projects support the BC Climate Change Accountability Act which target a greenhouse gas reduction of 40% by 2030, and they may offer a further monetary benefit to project owners which could include dairy farmers.

BC Ministry of Agriculture and Food (BCMAF) has conducted previous studies evaluating the feasibility of RNG projects on dairy farms, and it was concluded that large farms are required to achieve a return on investment. BCMAF contracted GHD Limited (GHD) to complete a study further evaluating RNG feasibility for clusters of smaller dairy farms.

The assessed clusters were specified to process manure (51% of feedstock) and off-farm food waste (49% of feedstock), they used a centrifuge nutrient management system, accepted a $25 per tonne tipping fee for food waste, sold RNG at $30 per gigajoule, and transported RNG by pipeline to be injected to the local natural gas grid. The full list of assumptions and cluster specific parameters used in the study are outlined in this report. The study found that the clusters may be feasible once they have achieved 68,800 Gigajoules of RNG production per year which corresponds to a cluster with roughly 400 mature cow equivalents (see Section 2 which further describes mature cow equivalents) producing 14,000 tonnes manure per year, and 13,500 tonnes food waste per year.

The study conducted further assessment of factors influencing feasibility using a baseline cluster scenario with the same inputs as the other clusters but excluding any nutrient management system. The assessment found that the distance between farms, nutrient management technology, inclusion of food waste in the RNG facility, food waste tipping fees, and several other factors outlined in this report may have a significant impact on cluster feasibility.

The study included the development of an MS Excel based feasibility model. The model accepted various inputs specific to different clusters and provided high-level discounted cash flow assessments for potential clusters in BC. The assessed clusters were feasible above the RNG production rate of 68,800 Gigajoules RNG per year with estimated net present values ranging from $0 (breakeven) up to over $6,000,000 for larger clusters.

The presented cost estimates, conclusions, and all other report content are subject to, and must be read in conjunction with, the limitations and the assumptions set out in Section 1 and all other limitations outlined throughout the report.

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1. Introduction

BC Ministry of Agriculture & Food (BCMAF) contracted GHD Limited (GHD) to complete a centralized biogas facility study (Study). The Study included input from BC Dairy, and the evaluation of farm data provided by BC dairy farmers that opted into the Study. The Study evaluated feasibility of on farm centralized biogas clusters for BC dairy farms using discounted cash flow (DCF) analysis. The Study further evaluated how different inputs impact feasibility.

Assessed clusters contained a total herd up to 710 head and would consist of an anaerobic digestion (AD) and renewable natural gas (RNG) facility (Facility) located on a central dairy farm with nearby dairy farms providing manure for digestion. The Facility would accept off-farm food waste at 49% of total feedstock by mass. Digestate would be processed using a centrifuge (excluded in the baseline cluster), then returned to each farm to be land applied. Surplus digestate would be exported to neighbouring farms for beneficial reuse. The produced RNG would be transported to the nearest distribution network for injection into the natural gas grid.

The Study included development of an MS Excel based feasibility model (Model). The Model completed DCF analysis and estimated capital expenditure (CAPEX), operational expenditure (OPEX), net present value (NPV), and other key feasibility parameters based on selected inputs. The inputs were dynamic and included choosing which farms to cluster, selecting Facility equipment, setting RNG sale value, and choosing manure and RNG transportation methods. The Model was used to assess potential clusters and complete further analysis presented in this report.

1.1 Purpose

The purpose of the Study was to determine what cluster size was feasible, what influences feasibility, and to identify if potentially feasible clusters existed for participating farmers. The conclusions and outcome of the Study were meant to provide dairy farmers high level information and guidance that allows a straightforward assessment of if their farms and neighbouring farms could potentially support a biogas cluster.

Preliminary cost estimates were estimated for 10 biogas clusters using participating farms. The presented cost estimates were preliminary, prepared based on conceptual systems and supporting information, with the maturity of the assessed projects at this stage resulting in a wide range in cost certainty. The intent of the estimates was for project screening, estimation of feasibility, and concept evaluation and should not be relied upon to develop any project.

The report also investigated what factors and cluster parameters influence feasibility. Assessed parameters included Facility nutrient recovery technologies, distance between participating farms, and food waste tipping fees.

This report presents the methodology of the Study, feasibility estimates for assessed clusters, further investigation of input impacts on feasibility, and Study conclusions.

1.2 Scope and limitations

This report has been prepared by GHD for BC Ministry of Agriculture & Food and may only be used and relied on by BC Ministry of Agriculture & Food for the purpose agreed between GHD and BC Ministry of Agriculture & Food as set out in section 1 of this report.

GHD otherwise disclaims responsibility to any person other than BC Ministry of Agriculture & Food arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 1.3 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by BC Ministry of Agriculture & Food and BC dairy farmers and others who provided information to GHD, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared the Cluster Feasibility Model ("Model") for, and for the benefit and sole use of, BC Ministry of Agriculture & Food to support Cluster Scenario screening, comparison of estimated feasibilities, and further evaluation as outlined in Section 1 of this report and must not be used for any other purpose or by any other person.

The Model is a representation only and does not reflect reality in every aspect. The Model contains simplified assumptions to derive a modelled outcome. The actual variables will inevitably be different to those used to prepare the Model. Accordingly, the outputs of the Model cannot be relied upon to represent actual conditions without due consideration of the inherent and expected inaccuracies. Such considerations are beyond GHD's scope.

Excluding GHD provided information as outlined in the Model, the information, data and assumptions ("Inputs") used as inputs into the Model are from publicly available sources or provided by or on behalf of the BC Ministry of Agriculture & Food, (including possibly through stakeholder engagements). GHD has not independently verified or checked Inputs beyond its agreed scope of work. GHD's scope of work does not include review or update of the Model as further Inputs becomes available.

The Model is limited by the mathematical rules and assumptions that are set out in the Report or included in the Model and by the software environment in which the Model is developed.

The Model is a customised model and not intended to be amended in any form or extracted to other software for amending. Any change made to the Model, other than by GHD, is undertaken on the express understanding that GHD is not responsible, and has no liability, for the changed Model including any outputs.

GHD has prepared the preliminary cost estimates set out in this report ("Cost Estimate") using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD outlined in Section 1.

The Cost Estimate has been prepared for the purpose outlined in Section 1 and must not be used for any other purpose.

The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that any development/project can or will be undertaken at a cost which is the same or less than the Cost Estimate.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

1.3 Assumptions

Where reasonable, Model inputs were developed from farm specific data, published literature information, publicly available information, and GHD industry knowledge. Where input data was unknown (due to the maturity of the projects at this time, most inputs were unknown), it was developed based on assumptions. Some assumptions were inputs requested by BCMAF, while others were developed by GHD as outlined below:

- BCMAF Assumptions:
  - Assume $25/tonne tipping fee for food waste.
  - Assume RNG sale value of $30/GJ.
  - Assume injection station interconnection costs are $1,500,000 for 160,000 GJ/year.
  - Assume land for Facility is available at no cost.
  - Assume added contingency cost at 10% of project costs.

    - Assume farmers within a cluster do not need to purchase additional equipment (excluding costs for the Facility) such as hauling equipment, or additional manure/digestate storage.
    - Exclude operator salaries for hauling and for Facility operation from OPEX estimates.
    - Assume biogas composition is 65% methane (CH_4) and 35% carbon dioxide (CO_2).
    - Equipment installation and Facility electrical, mechanical, structural, geotechnical, and balance of plant costs assumed to be 20% of equipment costs.
- Further Assumptions:
    - DCF analysis assumptions:
        - Discount rate is 10%.
        - Annual inflation is 2%.
        - Facility lifetime is 20 years.
    - CAPEX does not consider costs associated with:
        - permitting and applications.
        - weigh scale and scale house.
        - buildings to house equipment.
        - buildings for office space.
        - roadwork (i.e. access roads, turnaround loop).
        - other items not explicitly outlined in the Model.
    - OPEX does not consider costs associated with:
        - operator salaries (per BCMAF guidance).
        - administrative staff salaries.
        - scale house operator salaries.
        - ongoing permitting/approvals and reporting.
        - other items not explicitly outlined in the Model.
    - OPEX costs are scaled from other projects based on equipment costs and facility size. Actual OPEX is dependent on facility specific conditions, consumables used by specific equipment, and equipment power and gas consumption.
    - Assumed biogas contains 2000 ppm hydrogen sulfide (H_2S).
    - Assumed 80% volatile solids (VS) destruction is achieved in Facility AD.
    - Assumed 97% Facility uptime.
    - Assumed 2% Facility methane slip.
    - Assumed 25% of liquids are recycled in AD process if the process includes solid liquid separation.
    - Assumed clusters of a similar size (based on annual RNG production) have similar results (NPV, CAPEX, OPEX, etc.).
    - For optional inputs assessment:
        - Assumed one full time operator required per 50,000 GJ RNG.
        - Assumed $100,000 annual salary for full time operator.

2. Methodology

2.1 Background Information

The Study included reviewing existing data, and development of a survey, in collaboration with BCMAF and BC Dairy, which was distributed among participating dairy farmers. The survey collected farm specific information including milking herd details, replacement stock details, estimated manure production, and farm acreage available for digestate application. Collected data was assessed and compared with published literature studies, industry standards, and assumptions (outlined in Section 1.3) to estimate key operating information such as methane generation potential and solids content of the manure at each farm. Locations of the dairy farms were assessed and several geographic regions containing multiple farms were identified as potential cluster locations.

Total milking herd and replacement stock were converted to mature cow equivalents (MCE). MCE is a measure indicating how many average mature dairy cows (weighing 640 kilograms (1,400 pounds)) would produce an equivalent amount of manure as a set of replacement stock (BCMAF, 2015). MCE was used throughout the Study rather than milking herd size as it accounts for variation in the ratio of replacement stock to milking cows between farms, and it accounts for locations that only house replacement stock. Any further reference to total herd size in this report is in MCE unless otherwise specified. The number of replacement stock per mature cow equivalent is broken down by age group in Table 2.1.

Table 2.1 Mature Cow Equivalents by Age Group (BCMAF, 2015)

Age Group	Number per MCE
Milking Cow	1
Dry Cow	1
Heifers (10 – 24 months)	2
Calves (3 – 10 months)	4
Calves (0 – 3 months)	10

Farm information was entered in the Model and informed further feasibility assessment. Further reference data was collected for key inputs including food waste characteristics, CAPEX and OPEX estimates for equipment, and performance ratings of nutrient recovery technologies. Once the Model had a full database of farm specific information, reference data, and methodologies, it was used to complete feasibility assessments for the clusters and further analysis presented in Section 3.

2.2 Development of Cluster Scenarios

Farm locations were plotted to a map and grouped into geographic regions containing 2 – 10+ farms within 12 kilometers of a central location. Table 2.2 outlines four of the identified regions that were assessed in the Study.

Table 2.2 Dairy Farm Geographic Groups

Geographic Group	Milking herd size	Manure (tpy)	Net RNG Yield* (GJ/year)
Group 1 – Lower Mainland	900	30,000	10,000
Group 2 – Lower Mainland	6,200	300,000	100,000
Group 3 – Lower Mainland	900	50,000	15,000
Group 4 – South Central Interior	1,100	50,000	15,000

****RNG yield of manure (excluding food waste) assuming 80% VS destruction and accounting for uptime and capture efficiency***

The regions were broken into clusters of 2 – 3 farms containing a total herd (MCE) ranging from 260 – 710. No clusters above 710 head were assessed as it was assumed large farms are feasible based on prior BCMAF studies and because the Model estimated a positive NPV for all clusters containing over 410 head. The full list of assessed clusters is presented in the Results, Table 3.1.

2.3 Feasibility Analysis

2.3.1 Cluster Feasibility

Cluster feasibility was assessed by entering farm details in the Model using cluster specific inputs where possible and default inputs where information was not available. The Model then completed DCF analysis and estimated NPV, CAPEX, OPEX, RNG production, and other parameters such as total feedstock and nutrient recovery of the farms that were selected for analysis.

Limited information was known about project specifications and site conditions at this time (i.e. local RNG market value, availability of farms for digestate land application, achievable food waste tipping fees) which introduced uncertainty in the provided cost estimates. To mitigate error, GHD used literature resources, industry standards, and relevant experience to inform assumptions for default Model inputs where possible. The default inputs aimed to represent a ‘typical’ cluster so they would apply to a wide range of clusters; however, Model inputs would likely vary should a project be developed in the future. All results are subject to Section 1.

Key default inputs are outlined in Table 2.3 below. The full list of default inputs is outlined in Appendix A following the text.

Table 2.3 Key Model Inputs

Input	Value	Reasoning
RNG sale price	$30/GJ	BCMAF requested value.
Food waste tipping fee	$25/tonne	BCMAF requested value.
Food waste portion of total feedstock	49%	BCMAF requested value.
Biogas CH_4 content	65%	BCMAF requested value.
Include digestate transportation costs	Yes	All clusters will have excess digestate requiring land application. This accounts for fuel and vehicle maintenance costs but excludes labour.
Include operator salaries	No	BCMAF requested input.
Nutrient Management System	Centrifuge	BCMAF requested input. This input was set to “no nutrient recovery” for the baseline cluster as discussed in Section 2.3.3.
Recycle liquid digestate as process water	Yes	Recycling water increases NPV. Only possible if the Facility includes a centrifuge or active recovery system.
Include recovered nutrient sale	No	Noted by BCMAF that it would be challenging to sell digestate due to the high volume and low nutrient concentration.

Input	Value	Reasoning
RNG transportation method	Pipeline	Assumed that a transmission line with capacity (and capability to inject RNG) is available near all cluster locations.
Volatile solids destruction rate	80%	80% is an industry standard assumption for volatile solids destruction rate in anaerobic digesters.

2.3.2 Minimum Viable Facility Size

Further assessment was conducted to determine the breakeven point where NPV was $0. This point represents a 'minimum viable size' for a biogas cluster where smaller clusters would generally have a negative NPV and larger a positive.

The clusters were plotted to a graph and a formula was developed relating RNG production and NPV. The formula was used to determine the exact RNG production rate that corresponds to $0 NPV. NPV was plotted against RNG production because RNG was strongly tied to herd size and manure production which is information typically known by dairy farmers. Averages of farm specific data collected for the Study were used to infer what approximate herd size corresponds to the breakeven point. The breakeven herd size acts as a straightforward preliminary assessment for farmers to check if they could potentially support a feasible cluster.

NPV is also impacted by CAPEX and OPEX which are each impacted by many different Model inputs such as distance between farms, selected nutrient recovery technology, and the portion of food waste processed at the Facility. Using RNG for this analysis is not a perfect assessment, but it would be more difficult to determine a common variable representative of CAPEX or OPEX that is as readily known by dairy farmers as herd size.

Notably, CAPEX, OPEX, and NPV are also dependent on the selected default inputs. The defaults were selected in collaboration with BCMAF to represent a standard cluster, so the findings may act as a preliminary indicator of cluster feasibility, but it is possible that the breakeven point is not applicable. An assessment with the Model could disagree with conclusions based on the breakeven point, particularly if a cluster is near the breakeven.

2.3.3 Inputs Assessment

As noted in Section 2.3.1, there was uncertainty with selected Model inputs accounted for by using defaults for the clusters. In practice, site conditions and project specifications are variable, and it is likely that the defaults differ from actual cluster parameters. To account for this, further assessment was conducted to determine how altering the default inputs used for a baseline cluster impacted feasibility.

The baseline cluster used for this analysis was an altered version of Cluster 3. The baseline used the same inputs as Cluster 3 and all outlined defaults, except BCMAF requested it did not use any form of nutrient recovery whereas other clusters use a centrifuge. This allows the impact of the different types of nutrient recovery technology to be assessed. Cluster 3 was selected as its total herd was 410 MCE which is near the average size of the clusters, excluding those with large farms, of 440 MCE. Cluster 3 also consisted of multiple small farms rather than one or two large farms which was representative of the collected farm data (primarily contained smaller farms). Assessment of the baseline estimated NPV of $3,000,000, and 80,000 GJ/year RNG production.

This assessment was broken down into an 'optional inputs assessment' which investigated the impact of optional inputs, and a sensitivity analysis which followed typical sensitivity assessment practices for key numeric inputs. Optional inputs in the Model specify if the assessment should include or exclude certain cost items and equipment, or they specify a type of equipment used in the assessment. Numeric inputs are rational numbers that characterize specific cluster parameters. The assessed numeric inputs were always included in the Model regardless of other inputs, their defaults were based on assumptions, and their values could reasonably fall within a range of ±25% (or more) of the default value. Table 2.4 outlines the assessed inputs and their default values.

Table 2.4 Assessed Optional and Numeric Inputs

Input	Type	Default
Nutrient recovery technology	Optional	None
Operator salaries	Optional	Exclude
RNG transport method	Optional	Pipeline
Manure biochemical methane potential (BMP)	Numeric	~350 – 400 Liters per kilogram volatile solids (dependant on milking herd, replacement stock, and manure details)
Food waste portion of total feedstock	Numeric	49%
Food waste tipping fees	Numeric	$25 per tonne
Distance between farms	Numeric	Dependant on selected farms

3. Results and Discussion

3.1 Cluster Scenario Modeling

Results are presented in Table 3.1 below. The Model results were used to compare the NPV and RNG production between each cluster. A detailed summary of results including CAPEX, OPEX, and revenue is provided in Appendix B.

Table 3.1 Cluster Feasibility Comparison

Cluster	Total Herd Size*	Manure (tonnes/ year)	Food Waste (tonnes/ year)	Estimated NPV ($)	Estimated RNG Production (GJ/year)	Max Distance Between Farms
Cluster 1	710	19,000	18,500	$5,100,000	110,000	20 km
Cluster 2	520	17,500	17,000	$6,100,000	105,000	5 km
Cluster 3	410	13,500	13,000	$2,000,000	80,000	10 km
Cluster 4	540	17,000	16,000	$4,200,000	96,000	20 km
Cluster 5	530	14,000	13,500	$2,700,000	84,000	15 km
Cluster 6	260	7,500	7,000	-$4,000,000	43,000	80 km
Cluster 7	400	9,500	9,000	-$1,800,000	53,000	5 km
Cluster 8	490	13,000	12,500	$600,000	75,000	50 km
Cluster 9	410	11,000	10,500	-$1,000,000	63,000	40 km
Cluster 10	410	12,000	11,500	$100,000	68,000	5 km

***In MCE as outlined in Section 2**

The presented cost estimates were preliminary, prepared based on a conceptual system and supporting information, with the maturity of the assessed projects at this stage resulting in a wide range in cost certainty. The intent of this estimate was for project screening, estimation of feasibility, and concept evaluation and should not be relied upon to develop any project.

In addition to the limitations and assumptions discussed in Section 1, the capacity of reference projects used to generate cost estimates in the Model ranged from 80,000 GJ/year – 160,000 GJ/year which corresponds to approximately 350 – 700 head (plus food waste). The cost estimates may be scaled to projects with a capacity within or near this range as the required equipment, space, operations considerations, permitting considerations, and other general project considerations are more likely be similar. For projects significantly beyond this range, scaling the cost estimate would not be applicable. The largest assessed cluster was Cluster 1 which was near the reference project range containing 710 head and 110,000 GJ/year RNG. The smallest assessed cluster was Cluster 6 which was below the reference project range and so its estimated feasibility may contain more error than the other assessments; however, this cluster does concur with Cluster 7 and Cluster 9 that small clusters are not estimated to be feasible and so was included in this analysis. All other clusters were within the reference project range.

Clusters beyond the range of Cluster 6 and Cluster 1 were not assessed as this range was out of scope. It was also assumed based on the results that regardless of inputs, clusters would generally not be feasible if smaller than Cluster 6, and they would typically be feasible if larger than Cluster 1. To properly estimate feasibility for larger clusters, the Model should reference costs for larger equipment, and costs for additional equipment, operations considerations, and other project considerations associated with projects of a larger scale.

The Model assessment estimated that all clusters excluding Cluster 6, Cluster 7 and Cluster 9 have a positive NPV. Notably, Cluster 1 and Cluster 2 have similar RNG production but Cluster 2's NPV is $1,000,000 greater than Cluster 1. This may be due to the distance between farms as Cluster 2 is 15 km closer than Cluster 1. Distance impacts were further assessed in Section 3.3.

3.2 Minimum Viable Facility Size

To determine the breakeven point/minimum viable facility size, the assessed clusters were plotted to a chart shown in Figure 3.1.

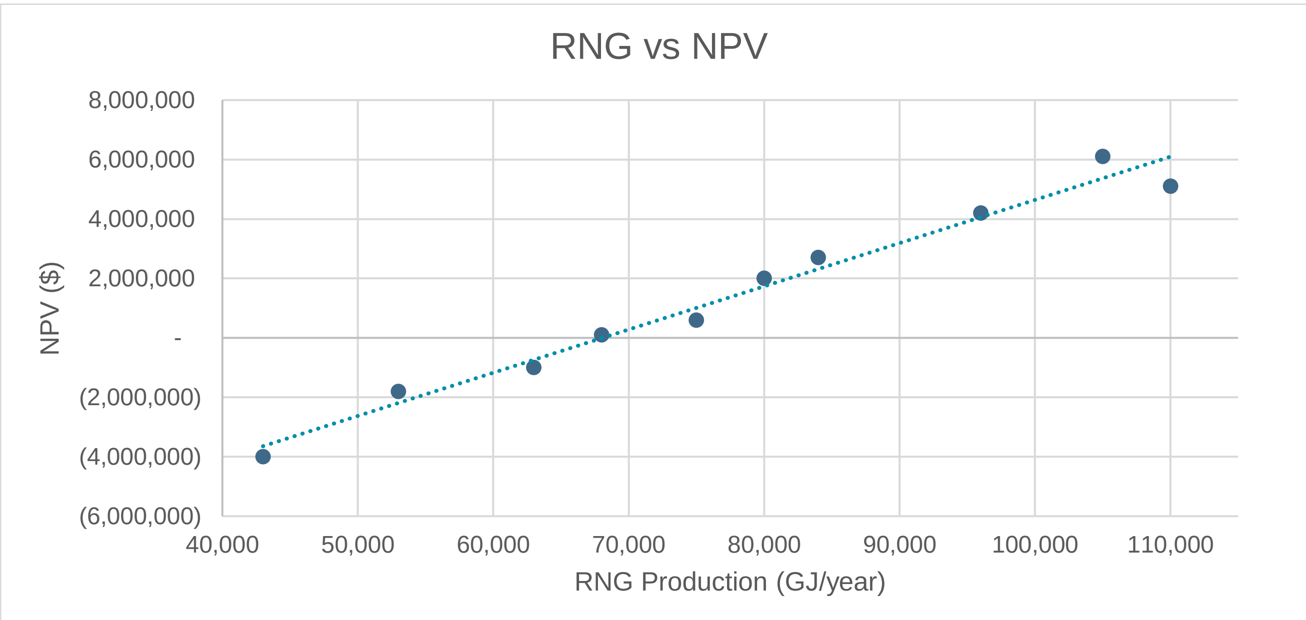

Figure 3.1 Relationship of NPV and RNG Production

Figure 3.1 presents a linear relationship between RNG production and NPV. The relationship is demonstrated in Formula 3.1 below.

Formula 3.1 RNG vs NPV

*Net Present Value ($) = 145 [$/GJ] * (RNG Production [GJ/year]) – $10,000,000*

A more practical breakeven point was developed using Figure 3.2 which highlights the relationship between herd size and NPV.

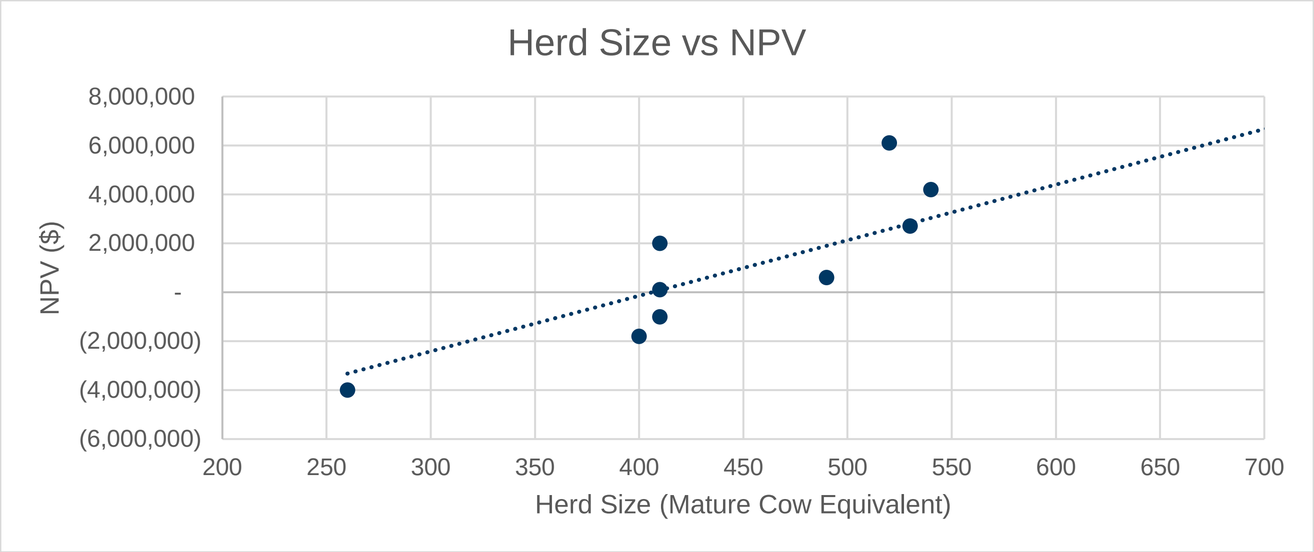

Figure 3.2 Relationship of Herd Size and NPV

Formula 3.2 Herd size vs NPV

*Net Present Value ($) = 22,717[$/head] * (Herd Size [head]) – $9,000,000*

The breakeven point using Formula 3.1 is 68,800 GJ/year and using Formula 3.2 is 400 head. There is some variation in the RNG production per head between clusters and so these formulas represent two different breakeven points for each cluster. RNG production contains less variation as it accounts for varying manure BMP, total solids, and other parameters and is therefore more reliable if a clusters RNG production is known. Herd size is still valuable as it also provides a preliminary estimate of feasibility, and herd size is typically known making this a straightforward evaluation.

If default inputs are adjusted, the breakeven point will likely change. The exact breakeven point is also dependant on cluster specific inputs such as distance between farms and exact manure composition; the sensitivity analysis provides further context.

3.3 Inputs Assessment

3.3.1 Optional Inputs

Optional input impacts were assessed using the baseline cluster as discussed in Section 2.3.3. Each input was changed while maintaining the same default values for all other inputs. The impact of each input on NPV is presented in Table 3.2 below.

Table 3.2 Optional Input Feasibility Impacts

Optional Item	Input	NPV
Baseline	**No change to inputs**	**$3,100,000**
Nutrient recovery – centrifuge	Nutrient recovery: Centrifuge	$2,000,000 Decrease of $1,100,000 (35%)
Nutrient recovery – active system*	Nutrient recovery: Active system	$1,600,000 Decrease of $1,500,000 (50%)
Include operator salaries	Include operator salaries: Yes	$600,000

Optional Item	Input	NPV
		Decrease of $2,500,000 (80%)
Transport RNG 10 km by truck instead of by pipeline	RNG transport: Truck Trucking distance: 10	$3,000,000 Decrease of $100,000 (<5%)
Transport RNG 25 km by truck instead of by pipeline	RNG transport: Truck Trucking distance: 25	$2,800,000 Decrease of $300,000 (10%)
Transport RNG 50 km by truck instead of by pipeline	RNG transport: Truck Trucking distance: 50	$2,600,000 Decrease of $500,000 (15%)

Active nutrient recovery consists of a flocculation or membrane system (similar cost and performance based on Model reference data) with in-line dewatering using a centrifuge

The optional inputs assessment found that, for the baseline cluster, a centrifuge decreased NPV by 35%, and an active system decreased NPV by 50%. This highlights the importance of nutrient management as it could have a significant impact over 10% on NPV. Some farms may not have as much available land to spread nutrients in which case a centrifuge may result in a more positive NPV as it provides a lower concentration liquid phase digestate which can be spread in larger quantities per hectare without exceeding nutrient capacities. The exact impact of the selected nutrient recovery will depend on project specific details, and it should be assessed prior to developing any project.

The inclusion of operator salaries was found to have a significant impact on NPV resulting in a 80% decrease. The assessment of CNG trucking found that there was not a significant impact to baseline NPV (<=10%) for distances up to 25 km, and unless NPV for a cluster is already low, trucking CNG should not cause the Model to evaluate a negative NPV. CNG trucking could have a significant impact if it must be trucked further, and at 50 km it was found to decrease NPV by 15% which could more likely alter cluster feasibility.

3.3.2 Sensitivity Analysis

For the sensitivity analysis, assessed inputs were adjusted +-5%, +-10%, and +-25% and the impact to NPV and RNG production were recorded. The full list of assessed inputs included:

- Manure BMP
- Food waste portion of feedstock
- Food waste tipping fees
- Distance between farms

The sensitivity analysis was conducted using the baseline cluster. The results of the analysis are presented in Table 3.3. Results of the distance analysis are presented in Table 3.4.

Table 3.3 Sensitivity Analysis Results

Input Parameter	±5%	±10%	±25%
Default (No Modifications)	NPV: $3,100,000 RNG Production: 80,000 GJ/year		
Manure BMP	+5% NPV: +$100,000 (<5%) RNG Production: +400 (<1%) -5% NPV: -$100,000 (<5%) RNG Production: -400 (<1%)	+10% NPV: +$200,000 (5%) RNG Production: +800 (1%) -10% NPV: -$200,000 (5%) RNG Production: -800 (1%)	+25% NPV: +$500,000 (15%) RNG Production: +2,000 (2%) -25% NPV: -$500,000 (15%) RNG Production: -2,000 (2%)

Input Parameter	±5%	±10%	±25%
Food waste portion of feedstock	+5% NPV: +$1,500,000 (50%) RNG Production: +6,000 (8%) -5% NPV: -$1,400,000 (50%) RNG Production: -5,500 (7%)	+10% NPV: +$3,300,000 (100%) RNG Production: +16,000 (20%) -10% NPV: -$2,600,000 (85%) RNG Production: -13,000 (16%)	+25% NPV: +$10,100,000 (325%) RNG Production: +44,200 (55%) -25% NPV: -$5,600,000 (180%) RNG Production: -27,800 (35%)
Food waste tipping fees (RNG production is 80,000 GJ/year in all Scenarios)	+5% NPV: +$150,000 (5%) -5% NPV: -$150,000 (5%)	+10% NPV: +$350,000 (10%) -10% NPV: -$350,000 (10%)	+25% NPV: +$800,000 (25%) -25% NPV: -$800,000 (25%)

The Table 3.3 results indicate that small changes to these inputs could have a significant impact on project financials. Key findings:

– Adjusting manure BMP had the least significant impact on NPV. Changes were linearly correlated at a rate of ~$100,000 NPV per 5% change to BMP.
– Adjusting food waste portion of feedstock accepted at the Facility had a significant impact on NPV. The relationship was somewhat linear at a rate of ~$1,500,000 per 5% change to portion of accepted food waste. The impact to NPV was more significant at higher portions and less significant at lower portions .
– Adjusting food waste tipping fees was more significant than BMP, but much less significant than the food waste portion of feedstock. The relationship was relatively linear at a rate of ~$150,000 NPV per 5% change to tipping fee.

The impact of the distance between farms was measured using a separate method than the above. The baseline distance was 10 km so a 25% change is only 2.5 km which is not a relevant analysis. Most assessed farms are more than 2.5 km from any neighbouring farms. It was more relevant to understand what the limit was, and how far apart clustered farms could be while still achieving a positive NPV assessment.

The impact of distance on the baseline was tested for 5 km, 25 km, 50 km, and 100 km. The NPV and OPEX impacts are recorded below for each distance. OPEX is included as it is the primary output impacted by changes to distance.

Table 3.4 Distance Sensitivity Analysis

Travel Distance	NPV	OPEX
Default (10 km)	$3,100,000	$500,000
5 km	+$50,000 (<5%)	-$1,000 (<1%)
25 km	-$300,000 (10%)	+$32,000 (6%)
50 km	-$700,000 (20%)	+$73,000 (15%)
100 km	-$1,500,000 (50%)	+$156,000 (31%)

The transport distance assessment indicates that travel distance can have a significant impact on NPV especially at great distances. The relationship was relatively linear at a rate of ~$80,000 NPV per each 5 km between farms.

Based on the sensitivity analysis, it is recommended food waste sources are identified and secured and the tipping fees are negotiated and agreed upon by waste haulers prior to the development of any project as both items have a significant impact on NPV. Manure BMP did not have as significant of an impact on project metrics; however, it did show that higher BMP is favourable. Manure should be characterized via lab analyses prior to commencing a biogas project to confirm the assumed BMPs the Study are applicable. It is also recommended that clustered farms are located as close together as possible, and that farms over 50 km apart should not typically be clustered. Additionally, it must be noted that these results were all developed for the baseline cluster, and they may vary from different clusters. These findings should never be used to extrapolate information for other clusters and the findings should only be relied upon as an indication of how these inputs may impact overall NPV.

3.4 Ownership Models Assessment

In addition to the other completed analyses, BCMAF requested an assessment breaking down how costs would be shared under the following ownership models:

- Equal between all farms
- Proportional to herd size
- Proportional to methane generation (calculated based on manure properties at each farm)
- Single farm ownership

An altered version of the baseline cluster was used for this assessment where the cumulative inputs (i.e. total manure and food waste tonnages, total RNG production, total distance between farms, etc.) and results (i.e. NPV, CAPEX, OPEX) were the same as the original cluster; however, individual farm data such as herd size was manually altered including simplifying the total farms in the cluster to just two farms. The altered farm data was used to preserve confidentiality and is presented in Table 3.5. Table 3.6 presents the results of the assessment.

Table 3.5 Baseline Cluster (Cluster 3) Altered Farm Specific Data

Farm	Herd Size	RNG Generation (GJ/year)
Farm 1	240	5,000
Farm 2	170	3,000

Table 3.6 Ownership Models Assessment

Ownership Model	CAPEX	OPEX	NPV
Baseline (Total)	$20,100,000	$500,000	$3,100,000
Equal Ownership	Farm 1: $10,050,000 Farm 2: $10,050,000	Farm 1: $250,000 Farm 2: $250,000	Farm 1: $1,550,000 Farm 2: $1,550,000
Proportional Ownership by Herd Size	Farm 1: $12,700,000 Farm 2: $7,400,000	Farm 1: $315,000 Farm 2: $185,000	Farm 1: $1,950,000 Farm 2: $1,150,000
Proportional Ownership by RNG Generation	Farm 1: $13,100,000 Farm 2: $7,000,000	Farm 1: $325,000 Farm 2: $175,000	Farm 1: $2,050,000 Farm 2: $1,050,000
Single Farm Ownership	Farm 1: $20,100,000	Farm 1: $500,000	Farm 1: $3,100,000

4. Conclusion

Based on the results and discussion, the Model estimated there are several potentially feasible clusters that could be developed using the farms participating in the Study.

Based on further analysis of the clusters and Model inputs, the breakeven point where a project is most likely to have an NPV near $0 is at 68,800 GJ RNG/year or 400 head (MCE) plus food waste (49% of total feedstock). The breakeven points may be used as a preliminary cluster evaluation for farmers to compare their estimated RNG production (if known) or total herd size (in MCE as noted in Section 2) against. If a cluster parameter is less than the breakeven, it is unlikely the cluster would be feasible, if it is near the breakeven, then it could potentially have a positive NPV depending on cluster specific inputs, and if it is much greater than the breakeven then it would likely be feasible using the default inputs (subject to Section 1). A more complete analysis should be conducted prior to any development as the breakeven assessment neglects cluster specific inputs that could have a significant impact on NPV.

The optional input assessment found the following inputs could have a significant impact to NPV:

- Operator salaries
- Nutrient recovery

Transporting RNG by truck rather than pipeline was not found to have a significant impact to NPV (<=10%) for the baseline, but at 25 km it decreased NPV by 15% which could be significant.

Sensitivity analysis indicated that manure BMP can range between ±10% without a significant impact to NPV (<=10%) but at 25% it did alter NPV for the baseline by 15%. Food waste tipping fees had a significant impact over 10% on NPV at a change of ±10% and greater. Food waste portion of feedstock had a significant impact to NPV of over 50% for a 5% change, up to 100% at a 10% change, and up to 325% at a 25% change for the baseline.

Findings and results presented within this report are subject to the limitations and assumptions outlined in Section 1. Presented estimates are subject to change and should not be relied upon to develop a project.

Regards

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5. References

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Appendices

Appendix A

Default Input Assumptions

The following table outlines the default input assumptions used for cluster assessments in the Study unless a different input was specified.

Table 1 Default Model inputs

Parameter	Default Input
Food waste tipping fee:	$25/tonne
Food waste portion of total feedstock:	49%
Include Operator Salaries:	No
Nutrient Recovery Method:	Centrifuge
Recycle Liquid Digestate as Process Water:	Yes at 25%
Include Digestate Transport Costs:	Yes
RNG Transport Method:	Pipeline
RNG Injection Method:	Interconnection
Months of On-Site Digestate Storage at Facility:	2-months
Engineering and Design Added Cost	10%
General Requirements Added Cost	10%
Biogas CO2%	35%
Biogas CH4%	65%
Biogas H2S Content	2000 ppm
Volatile Solids Destruction in AD	80%
Facility Up-time	97%
Methane Slip	2%
Target AD Moisture Content (TS)	10%
Truck Haul Cost	$2.26/km
RNG Sale Price	$30/GJ
Manure/Digestate Storage Cost	$87.50/m^3
Digestate/Manure Delivery Frequency	Daily
Digestate/Manure Transport Vehicle	Straight Truck
Digestate Density	1000 kg/m^3
Other Construction Added Costs	20%
Contingency Costs	10%
Full Time Operator Salary	$100,000/year
Operator Requirement	50,000 GJ/operator

Appendix B

Detailed Cluster Analysis Results

Table 2 ***Detailed cluster feasibility assessment results***

Cluster Scenario	Total Herd Size	Manure (tonnes/ year)	Food Waste (tonnes/ year)	Estimated CAPEX ($)	Estimated OPEX ($/year)	Estimated Gross Revenue ($/year)	Estimated NPV ($)	Estimated RNG Production (GJ/year)	Max Distance Between Farms
Cluster 1	710	19,000	18,500	$28,300,000	$630,000	$4,000,000	$5,100,000	110,000	20 km
Cluster 2	520	17,500	17,000	$24,900,000	$590,000	$3,700,000	$6,100,000	105,000	5 km
Cluster 3	410	13,500	13,000	$21,200,000	$500,000	$2,800,000	$2,000,000	80,000	10 km
Cluster 4	540	17,000	16,000	$24,000,000	$600,000	$3,400,000	$4,200,000	96,000	20 km
Cluster 5	530	14,000	13,500	$21,600,000	$520,000	$3,000,000	$2,700,000	84,000	15 km
Cluster 6	260	7,500	7,000	$14,600,000	$470,000	$1,500,000	-$4,000,000	43,000	80 km
Cluster 7	400	9,500	9,000	$16,800,000	$400,000	$1,900,000	-$1,800,000	53,000	5 km
Cluster 8	490	13,000	12,500	$20,600,000	$550,000	$2,700,000	$600,000	75,000	50 km
Cluster 9	410	11,000	10,500	$18,500,000	$490,000	$2,200,000	-$1,000,000	63,000	40 km
Cluster 10	410	12,000	11,500	$19,400,000	$460,000	$2,400,000	$100,000	68,000	5 km