
TWELVE SITE FEASIBILITY STUDIES

Anaerobic Digestion Feasibility Study



Prepared For:



Agricultural Research and Development Corporation
(A Wholly Owned Subsidiary of The B.C. Agriculture Council)

and

Farms A - L
BRITISH COLUMBIA

Prepared By:



CH-Four Biogas Inc.

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DISCLAIMER

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Farm A

Anaerobic Digestion Feasibility Study

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1.0 FARM A EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm A” in Abbotsford. The system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm A would process dairy manure, hog manure and non-agricultural feedstocks to produce renewable energy and other beneficial co-products.

This study concludes that the proposed AD system on Farm A would be economically viable with 49% non-agricultural feedstock, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.166/kWh;
- Electricity tariff of \$0.10/kWh and funding of 40% (\$2,059,949); or
- Biomethane tariff of \$16.01/GJ;
- Biomethane tariff of \$15.28 will produce 8.2% ROI with no funding.

If Farm A were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions*:

- Electricity tariff of \$0.235/kWh;
- Electricity tariff of \$0.10/kWh and funding of 60% (\$1,732,817); or
- Biomethane tariff of \$30.60/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 60% (\$2,220,566).

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

2.0 FARM A PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure information presented herein is understood in the proper context and with all necessary supporting information.

2.1 Site Description

Farm A is a dairy operation in Abbotsford, B.C. that milks 300 cows at their location. With the inclusion of cows housed for neighbouring farms, total herd size is approximately 600 cows. The immediate neighbour to the south of Farm A is a 300 animal farrow to finish hog operation with existing manure storage 30 metres away. Alley scrapers are used for manure collection in all the barns

While Farm A has a 150 head certified organic operation approximately 500 metres away, because of the distance and geographical obstacles, manure from this operation is not considered viable for inclusion in this study.

2.2 Project-Specific Considerations

2.2.1 Electrical Interconnection

B.C. Hydro estimates that approximately 800m of single-phase line requires upgrading to three-phase service. According to preliminary estimates, there is availability for up to 999kW at Farm A, and interconnection costs have been estimated at \$500,000.

2.2.2 Natural Gas Interconnection

Farm A has natural gas available on-site. However, to inject the required amount of biomethane into the grid, FortisBC estimates approximately \$1,000,000 in upgrades would be necessary. Because of this, the farmer will need to work with FortisBC to try and reduce the interconnection costs.

2.2.3 Availability of Feedstocks

Based on information provided by Farm A, the following feedstocks have been identified as currently available:

- Dairy Manure:
 - 300 milkers and 300 neighbour's cows.
- Hog Manure:
 - 300 animal farrow to finish hog operation.

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG):
 - Considered a high-energy non-agricultural feedstock; and
 - Sourced from food processing facilities.
- Source Separated Organics (SSO):
 - Considered a low-energy non-agricultural feedstock; and
 - Consisting of organic compostable materials, such as spoiled produce and plate scrapings.

2.3 Co-Products

AD systems enable the production of a number of beneficial co-products. The following section discusses Farm A's co-product opportunities.

2.3.1 Thermal Energy

Thermal energy could be available for use at Farm A through the integration of a co-generation unit or biogas boiler. While the farm operation does not have any significant heat loads, minor heating requirements could be met.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm A could range from 450,000btu – 2,200,000btu using a co-generation unit, or 750,000btu – 4,000,000btu using high-efficiency, direct combustion.

2.3.2 Livestock Bedding

Farm A spends approx \$72,000/year on sawdust for livestock bedding. Digestate material from the AD system would be a suitable replacement for livestock bedding if properly managed after the digestion process. Depending on the technology selected and desired moisture content, livestock bedding production post-AD typically involves a solid separator and optional drying.

Farm A currently has a solid separator installed. This system is suitable for integration with the AD system with minor piping and pumping amendments. The cost of these amendments should be considered in light of the potential savings associated with bedding replacement.

2.3.3 Tipping Fees

Farm A has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

2.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP. These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of any excess nutrients.

Farm A currently has a deficiency of Nitrogen and Potash, which is compensated through the purchase of synthetic fertilizer.

3.0 FARM A PROJECT OPTIONS

3.1 Option 1: 25% Non-Agricultural Feedstocks

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|-------------------------|--------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>31 m³</i> | <i>220 m³</i> | <i>11,400 m³</i> |
| <i>Hog manure</i> | <i>14 m³</i> | <i>103 m³</i> | <i>5,400 m³</i> |
| <i>FOG</i> | <i>8 m³</i> | <i>54 m³</i> | <i>2,800 m³</i> |
| <i>SSO</i> | <i>8 m³</i> | <i>54 m³</i> | <i>2,800 m³</i> |
| TOTAL | 61 m³ | 431 m³ | 22,400 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,500 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>3,816 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.5kgVS/day</i> |
| <i>HRT:</i> | <i>26 days</i> |
| <i>CHP unit:</i> | <i>390 kW</i> |
| <i>Upgrading unit capacity</i> | <i>300 m³/hr</i> |

Option 1 uses a mixture of available manure and 25% non-agricultural feedstocks. The proposed AD system includes a 1,500m³ digester and a 390kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 159m³/hour.

3.2 Option 2: 49% Non-Agricultural Feedstocks

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|-------------------------|--------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>31 m³</i> | <i>220 m³</i> | <i>11,400 m³</i> |
| <i>Hog manure</i> | <i>14 m³</i> | <i>103 m³</i> | <i>5,400 m³</i> |
| <i>FOG</i> | <i>22 m³</i> | <i>161 m³</i> | <i>8,400 m³</i> |
| <i>SSO</i> | <i>22 m³</i> | <i>161 m³</i> | <i>8,400 m³</i> |
| TOTAL | 89 m³ | 645 m³ | 33,600 m³ |

| | |
|--|------------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,500 m³</i> |
| <i>No of digesters:</i> | <i>2</i> |
| <i>Biogas production:</i> | <i>9,264 m³ per day</i> |
| <i>Organic loading rate:</i> | <i>3.6kgVS/day</i> |
| <i>HRT:</i> | <i>22 days</i> |
| <i>CHP unit:</i> | <i>960 kW</i> |
| <i>Upgrading unit capacity</i> | <i>800 m³/hr</i> |

Option 2 uses a mixture of available manure and 49% non-agricultural feedstocks. The proposed AD system includes 2 x 1,500m³ digesters and a 960kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 386m³/hour.

4.0 FARM A REQUIRED TARIFFS

4.1 Energy Tariff and Funding Requirements

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--|-------------------------------------|---|--|
| 1: 25% | \$0.235 | 60% | \$30.60 | 60% |
| 2: 49% | \$0.166 | 40% | \$16.01 | 0%* |

Note*: 0% indicates the AD system is able to make greater than 5% ROI using \$15.28/GJ

4.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to capital input, this AD system would require high energy tariffs of \$0.235/kWh or \$30.60/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 60% funding if it produces electricity for sale to the SOP, or 60% if it produced biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is not considered economically viable.

Option 2: As a result of the higher energy output proportionate to the capital input, this AD system would require energy tariffs of \$0.166/kWh or \$16.01/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 40% funding if it produces electricity for sale to the SOP. As such, there is a high probability that this option will be economically viable for biomethane production using \$15.28/GJ as the maximum available tariff. However, this will depend upon interconnection costs, FortisBC's ability to accept the biomethane into their grid, and the ability to generate economic value from co-products.

There is also a low probability that this option will be economically viable for electricity production. However, this will depend upon interconnection costs, the ability to generate economic value from co-products, and at least a \$0.03/kWh – \$0.07/kWh higher electricity tariff or the availability of some funding. While the required electricity tariff or funding amount for Farm A's AD system are within reason when compared to other jurisdictions, they are currently unavailable in B.C.

5.0 FARM A CONCLUSION

While installation of an AD system at Farm A is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amount, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities.

Option 2, biomethane production, is considered economically viable for Farm A based on the information provided and used in this study. Option 2, electricity production, may also be economically viable for Farm A if a slightly higher electricity tariff or funding becomes available.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

6.0 FARM A PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary - FARM A | | | | | | | | |
|---|-----------------------|--------------------|-----------------------|--------------------|------------------------------------|--------------------|------------------------------------|--------------------|
| Electricity Production | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/grant money under SOP | | Option 2 - w/grant money under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,500 | 2 | 1,500 | 1 | 1,500 | 2 | 1,500 |
| Dairy Manure (m3/yr) | | 11,400 | | 11,400 | | 11,400 | | 11,400 |
| Hog Manure (m3/yr) | | 5,400 | | 5,400 | | 5,400 | | 5,400 |
| Source Separated Organics (SSO) (m3/yr) | | 2,800 | | 8,400 | | 2,800 | | 8,400 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 2,800 | | 8,400 | | 2,800 | | 8,400 |
| Total Feedstock Volume (m3/yr) | | 22,400 | | 33,600 | | 22,400 | | 33,600 |
| Engine operating time (hr/day) | | 21.9 | | 21.9 | | 21.9 | | 21.9 |
| Engine Size kW | | 390 | | 960 | | 390 | | 960 |
| Electricity Production (kWh/yr) | | 3,074,760 | | 7,568,640 | | 3,074,760 | | 7,568,640 |
| Electricity Production (kWh/day) | | 8,541 | | 21,024 | | 8,541 | | 21,024 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$513,000 | | \$1,026,000 | | \$513,000 | | \$1,026,000 |
| Co-Gen Plant (non-containerized) | | \$624,000 | | \$1,152,000 | | \$624,000 | | \$1,152,000 |
| Powerhouse & Plumbing | | \$137,000 | | \$274,000 | | \$137,000 | | \$274,000 |
| Off-Farm Reception | | \$125,000 | | \$200,000 | | \$125,000 | | \$200,000 |
| High Voltage Connection (BC Hydro) | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (non-BC Hydro) | | \$110,000 | | \$220,000 | | \$110,000 | | \$220,000 |
| Low Voltage Electrical Distribution | | \$170,000 | | \$340,000 | | \$170,000 | | \$340,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$156,000 | | \$78,000 | | \$156,000 |
| Project Development (7%) | 7% | \$143,990 | | \$256,760 | | \$143,990 | | \$256,760 |
| Engineering & Project Management (10%) | 10% | \$205,700 | | \$366,800 | | \$205,700 | | \$366,800 |
| Risk Management (20%) | 20% | \$481,338 | | \$858,312 | | \$481,338 | | \$858,312 |
| Total Capital Expenditure | | \$2,888,028 | | \$5,149,872 | | \$2,888,028 | | \$5,149,872 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.235 | \$722,569 | 0.166 | \$1,256,394 | 0.100 | \$307,476 | 0.100 | \$756,864 |
| Tipping Fees (SSO) | \$30 | \$84,000 | | \$252,000 | | \$84,000 | | \$252,000 |
| Tipping Fees (FOG) | \$15 | \$42,000 | | \$126,000 | | \$42,000 | | \$126,000 |
| Total Revenue | | \$848,569 | | \$1,634,394 | | \$433,476 | | \$1,134,864 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$61,495 | | \$151,373 | | \$61,495 | | \$151,373 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$15,374 | | \$37,843 | | \$15,374 | | \$37,843 |
| Labour for System Operation (h/day, \$50/h, 1hr/100kW) | 4 | \$71,175 | 10 | \$175,200 | 4 | \$71,175 | 10 | \$175,200 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$12,914 | | \$31,788 | | \$12,914 | | \$31,788 |
| Reinvestments | 1% | \$28,880 | | \$51,499 | | \$28,880 | | \$51,499 |
| Total Operating Cost | | \$189,838 | | \$447,703 | | \$189,838 | | \$447,703 |
| Net Operational Income | | \$658,730 | | \$1,186,691 | | \$243,638 | | \$687,161 |
| Financing | | | | | | | | |
| Total Investment | | \$2,888,028 | | \$5,149,872 | | \$2,888,028 | | \$5,149,872 |
| Grant(s) | | \$0 | | \$0 | 60% | \$1,732,817 | 40% | \$2,059,949 |
| Loan | 100% | \$2,888,028 | 100% | \$5,149,872 | 40% | \$1,155,211 | 60% | \$3,089,923 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI Before Tax | | 10.0% | | 10.1% | | 5.1% | | 5.4% |
| Average Income Before Tax | | \$287,423 | | \$519,716 | | \$147,644 | | \$277,097 |

7.0 FARM A PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary - FARM A | | | | | | | | |
|--|-----------------------|--------------------|-----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| Biogas Upgrading | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,500 | 2 | 1,500 | 1 | 1,500 | 2 | 1,500 |
| Dairy Manure (m3/yr) | | 11,400 | | 11,400 | | 11,400 | | 11,400 |
| Hog Manure (m3/yr) | | 5,400 | | 5,400 | | 5,400 | | 5,400 |
| Source Separated Organics (SSO) (m3/yr) | | 2,800 | | 8,400 | | 2,800 | | 8,400 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 2,800 | | 8,400 | | 2,800 | | 8,400 |
| Total Feedstock Volume (m3/yr) | | 22,400 | | 33,600 | | 22,400 | | 33,600 |
| Biogas Production (m3/hr) | | 159 | | 386 | | 159 | | 386 |
| Biogas Production (m3/yr) | | 1392840 | | 3381360 | | 1392840 | | 3381360 |
| Energy Production (GJ/hr) | | 3.339 | | 8.106 | | 3.339 | | 8.106 |
| Energy Production (GJ/yr) | | 29,250 | | 71,009 | | 29,250 | | 71,009 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$513,000 | | \$1,026,000 | | \$513,000 | | \$1,026,000 |
| Biogas Upgrading System | | \$1,200,000 | | \$1,500,000 | | \$1,200,000 | | \$1,500,000 |
| Off-Farm Reception | | \$125,000 | | \$200,000 | | \$125,000 | | \$200,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| FortisBC Interconnection | | \$500,000 | | \$500,000 | | \$500,000 | | \$500,000 |
| Low Voltage Electrical | | \$170,000 | | \$340,000 | | \$170,000 | | \$340,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$156,000 | | \$78,000 | | \$156,000 |
| Project Development (7%) | 7% | \$184,520 | | \$264,040 | | \$184,520 | | \$264,040 |
| Engineering & Project Management (10%) | 10% | \$263,600 | | \$377,200 | | \$263,600 | | \$377,200 |
| Risk Management (20%) | 20% | \$616,824 | | \$882,648 | | \$616,824 | | \$882,648 |
| Total Capital Expenditure | | \$3,700,944 | | \$5,295,888 | | \$3,700,944 | | \$5,295,888 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 30.60 | \$895,039 | 16.01 | \$1,136,847 | 15.28 | \$446,934 | 15.28 | \$1,085,011 |
| Tipping Fees (SSO) | \$30 | \$84,000 | | \$252,000 | | \$84,000 | | \$252,000 |
| Tipping Fees (FOG) | \$15 | \$42,000 | | \$126,000 | | \$42,000 | | \$126,000 |
| Total Revenue | | \$1,021,039 | | \$1,514,847 | | \$572,934 | | \$1,463,011 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$13,928 | | \$33,814 | | \$13,928 | | \$33,814 |
| Labour for System Op. (h/day; \$35/h, 1hr/50m3 biogas) | 3 | \$40,625 | 8 | \$98,623 | 3 | \$40,625 | 8 | \$98,623 |
| AD Elec. Consumption (7% of Prod. Equiv. @ \$0.06/kWh) | 7% | \$11,700 | | \$28,403 | | \$11,700 | | \$28,403 |
| Upgrading System Electricity Consumption | | \$37,000 | | \$55,000 | | \$37,000 | | \$55,000 |
| Reinvestments | 1% | \$37,009 | | \$52,959 | | \$37,009 | | \$52,959 |
| Total Operating Cost | | \$163,862 | | \$292,399 | | \$163,862 | | \$292,399 |
| Net Operational Income | | \$857,177 | | \$1,222,448 | | \$409,072 | | \$1,170,612 |
| Financing | | | | | | | | |
| Total Investment | | \$3,700,944 | | \$5,295,888 | | \$3,700,944 | | \$5,295,888 |
| Grant(s) | | \$0 | | \$0 | 60% | \$2,220,566 | 0% | \$0 |
| Loan | 100% | \$3,700,944 | 100% | \$5,295,888 | 40% | \$1,480,378 | 100% | \$5,295,888 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.6% | | 8.2% |
| Average Income Before Tax | | \$368,808 | | \$527,697 | | \$207,072 | | \$433,612 |

Farm B

Anaerobic Digestion Feasibility Study

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8.0 FARM B EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm B” in Rosedale. The system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm B would process dairy manure and non-agricultural organic feedstocks to produce renewable energy and other beneficial co-products.

This study concludes that the proposed AD system on Farm B would be economically viable with 49% non-agricultural feedstock, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.173/kWh;
- Electricity tariff of \$0.10/kWh and funding of 42.5% (\$2,364,364); or
- Biomethane tariff of \$16.25/GJ;
- Biomethane tariff of \$15.28/GJ will produce 7.9% ROI with no funding.

If Farm B were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions*:

- Electricity tariff of \$0.196/kWh;
- Electricity tariff of \$0.10/kWh and funding of 57.5% (\$2,777,112); or
- Biomethane tariff of \$18.60/GJ;
- Biomethane tariff of \$15.28/GJ will produce 5.3% ROI with no funding.

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

9.0 FARM B PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure the information presented herein is understood in the proper context and with all necessary supporting information.

9.1 Site Description

Farm B is a dairy operation in Rosedale, B.C. that milks 1,400 cows at their location. The total number of on-site animals is 1,600. Young stock and some dry stock are kept at a separate location approximately 6km away. Due to the distance, manure from the second location is not considered viable for inclusion in this study.

Farm B uses sand bedding and a flush system for manure management. A sand separation system and solid separator are currently installed and operational at Farm B. It is assumed that the manure is heavily diluted with washwater.

9.2 Project-Specific Considerations

9.2.1 Electrical Interconnection

Farm B has three-phase service available on-site. According to preliminary estimates, there is availability for up to 999kW at Farm B, and interconnection costs have been estimated at \$375,000.

9.2.2 Natural Gas Interconnection

Farm B has natural gas available on-site. Interconnection costs have been estimated at \$500,000, with limits on the amount of biomethane FortisBC can inject into their grid.

9.2.3 Availability of Feedstocks

Based on information provided by Farm B, the following feedstocks have been identified as currently available:

- Dairy Manure:
 - Available from 1,400 milkers and an additional 200 animals on-site creating 30,280 tonnes/year of manure, mixed with 7,570 tonnes of wash water creating a mixture at approximately 5% TS.

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG):
 - Considered a high-energy non-agricultural feedstock; and
 - Sourced from food processing facilities.
- Source Separated Organics (SSO):
 - Considered a low-energy non-agricultural feedstock; and
 - Consisting of organic compostable materials, such as spoiled produce and plate scrapings.

9.3 Co-Products

AD systems enable production of a number of beneficial co-products. The following section discusses Farm B's co-product opportunities.

9.3.1 Thermal Energy

Thermal energy could be available for use at Farm B through the integration of a co-generation unit or biogas boiler. Less than 200 metres north of Farm B is a poultry operation that may have high heat loads. As such, thermal energy produced by the AD system could be used by the poultry operation.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm B could range from 450,000btu – 4,000,000btu using a co-generation unit, or 600,000btu – 4,500,000btu using high-efficiency, direct combustion.

9.3.2 Livestock Bedding

Farm B spends approximately \$50,000/year on sand for livestock bedding. Digestate material from the AD system would be a suitable replacement for livestock bedding if properly managed after the digestion process. Furthermore, the use of digestate bedding could alleviate some of the technical challenges associated with managing sand as a bedding material and/or a residue in the AD system. Depending on the separation technology selected and desired moisture content, livestock bedding production post-AD typically involves a solid separator and optional drying.

9.3.3 Tipping Fees

Farm B has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

9.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export, or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP.

These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of excess nutrients.

Farm B currently spends approximately \$150,000/year on synthetic fertilizers, of which the majority is nitrogen.

10.0 FARM B PROJECT OPTIONS

10.1 Option 1: 25% Non-Agricultural Feedstocks

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|--------------------------|--------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>104 m³</i> | <i>728 m³</i> | <i>37,850 m³</i> |
| <i>FOG</i> | <i>17 m³</i> | <i>121 m³</i> | <i>6,300 m³</i> |
| <i>SSO</i> | <i>17 m³</i> | <i>121 m³</i> | <i>6,300 m³</i> |
| TOTAL | 138 m³ | 970 m³ | 50,450 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,500 m³</i> |
| <i>No of digesters:</i> | <i>2</i> |
| <i>Biogas production:</i> | <i>7,488 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.4 kg VS/day</i> |
| <i>HRT:</i> | <i>27 days</i> |
| <i>CHP unit:</i> | <i>770 kW</i> |
| <i>Upgrading unit capacity:</i> | <i>325 m³/hr</i> |

Option 1 uses a mixture of available manure and 25% non-agricultural feedstocks. The proposed AD system includes two (2) 1,500m³ digesters and a 770kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 312m³/hour.

10.2 Option 2: 49% Non-Agricultural Feedstocks

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|--------------------------|----------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>104 m³</i> | <i>728 m³</i> | <i>37,850 m³</i> |
| <i>FOG</i> | <i>23 m³</i> | <i>163 m³</i> | <i>8,500 m³</i> |
| <i>SSO</i> | <i>23 m³</i> | <i>163 m³</i> | <i>8,500 m³</i> |
| TOTAL | 150 m³ | 1,054 m³ | 54,850 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,500 m³</i> |
| <i>No of digesters:</i> | <i>2</i> |
| <i>Biogas production:</i> | <i>9,624 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.6 kg VS/day</i> |
| <i>HRT:</i> | <i>22 days</i> |
| <i>CHP unit:</i> | <i>999 kW</i> |
| <i>Upgrading unit capacity:</i> | <i>800m³/hr</i> |

Option 2 uses a mixture of available manure and 49% non-agricultural feedstocks. The proposed AD system includes 2 x 1,500m³ digesters and a 999kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 401m³/hour.

11.0 FARM B REQUIRED TARIFFS

11.1 Energy Tariff and Funding Requirements

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--------------------------------------|-------------------------------|------------------------------------|-------------------------------------|
| 1: 25% | \$0.196 | 57.5% | \$18.60 | 0%* |
| 2: 49% | \$0.173 | 42.5% | \$16.25 | 0%* |

Note*: 0% indicates the AD system is able to make greater than 5% ROI using \$15.28/GJ

11.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to capital input, this AD system would require somewhat high energy tariffs of \$0.196/kWh or \$18.60/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 57.5% funding if it produces electricity for sale to the SOP. Given the low likelihood of this electricity tariff or amount funding being available in the foreseeable future, this option is only considered potentially economically viable for biomethane production. However, this will depend upon interconnection costs, FortisBC's ability to accept the biomethane into their grid, and the ability to generate economic value from co-products.

Option 2: As a result of the higher energy output proportionate to the capital input, this AD system would require energy tariffs of \$0.173/kWh or \$16.25/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 42.5% funding if it produces electricity for sale to the SOP. As such, there is a high probability that this option will be economically viable for biomethane production. However, this will depend upon interconnection costs, FortisBC's ability to accept the biomethane into their grid, and the ability to generate economic value from co-products.

There is also a low probability that this option will be economically viable for electricity production. However, this will depend upon interconnection costs, the ability to generate economic value from co-products, and at least a \$0.03/kWh – \$0.07/kWh higher electricity tariff or availability of some funding. While the required electricity tariff or funding amount for Farm B's AD system are within reason when compared to other jurisdictions, they are currently unavailable in B.C.

12.0 FARM B CONCLUSION

While installation of an AD system at Farm B is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amount, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities.

As a result of the inclusion of a high volume of washwater used in Farm B's flush system, the capital cost associated with the AD system is higher than would be if alternative manure management techniques were employed. Consideration of the capital cost increases associated with the use of flush manure washwater should be given when evaluating system installation and any changes to farm practice.

Option 2, biomethane production, is considered economically viable for Farm B based on the information provided and used in this study. Option 1, biomethane production, could be economically viable for Farm B, while Option 2, electricity production, may also be economically viable for Farm B if a slightly higher energy tariff or funding becomes available.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

13.0 FARM B PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary - FARM B | | | | | | | | |
|---|-----------------------|--------------------|-----------------------|--------------------|------------------------------------|--------------------|------------------------------------|--------------------|
| Electricity Production | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/grant money under SOP | | Option 2 - w/grant money under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 2 | 1,500 | 2 | 1,500 | 2 | 1,500 | 2 | 1,500 |
| Dairy Manure (m3/yr) | | 37,850 | | 37,850 | | 37,850 | | 37,850 |
| Source Separated Organics (SSO) (m3/yr) | | 6,300 | | 8,500 | | 6,300 | | 8,500 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 6,300 | | 8,500 | | 6,300 | | 8,500 |
| Total Feedstock Volume (m3/yr) | | 50,450 | | 54,850 | | 50,450 | | 54,850 |
| Engine operating time (hr/day) | | 21.9 | | 21.9 | | 21.9 | | 21.9 |
| Engine Size kW | | 770 | | 999 | | 770 | | 999 |
| Electricity Production (kWh/yr) | | 6,070,680 | | 7,876,116 | | 6,070,680 | | 7,876,116 |
| Electricity Production (kWh/day) | | 16,863 | | 21,878 | | 16,863 | | 21,878 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$1,026,000 | | \$1,026,000 | | \$1,026,000 | | \$1,026,000 |
| Co-Gen Plant (non-containerized) | | \$924,000 | | \$1,098,900 | | \$924,000 | | \$1,098,900 |
| Powerhouse & Plumbing | | \$274,000 | | \$342,500 | | \$274,000 | | \$342,500 |
| Off-Farm Reception | | \$200,000 | | \$300,000 | | \$200,000 | | \$300,000 |
| High Voltage Connection (BC Hydro) | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (non-BC Hydro) | | \$220,000 | | \$275,000 | | \$220,000 | | \$275,000 |
| Low Voltage Electrical Distribution | | \$340,000 | | \$425,000 | | \$340,000 | | \$425,000 |
| System Controls and Automation (inc. hydraulics) | | \$156,000 | | \$195,000 | | \$156,000 | | \$195,000 |
| Project Development (7%) | 7% | \$240,800 | | \$277,368 | | \$240,800 | | \$277,368 |
| Engineering & Project Management (10%) | 10% | \$344,000 | | \$396,240 | | \$344,000 | | \$396,240 |
| Risk Management (20%) | 20% | \$804,960 | | \$927,202 | | \$804,960 | | \$927,202 |
| Total Capital Expenditure | | \$4,829,760 | | \$5,563,210 | | \$4,829,760 | | \$5,563,210 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.196 | \$1,189,853 | 0.173 | \$1,362,568 | 0.100 | \$607,068 | 0.100 | \$787,612 |
| Tipping Fees (SSO) | \$30 | \$189,000 | | \$255,000 | | \$189,000 | | \$255,000 |
| Tipping Fees (FOG) | \$15 | \$94,500 | | \$127,500 | | \$94,500 | | \$127,500 |
| Total Revenue | | \$1,473,353 | | \$1,745,068 | | \$890,568 | | \$1,170,112 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$121,414 | | \$157,522 | | \$121,414 | | \$157,522 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$30,353 | | \$39,381 | | \$30,353 | | \$39,381 |
| Labour for System Operation (h/day, \$50/h, 1hr/100kW) | 8 | \$140,525 | 10 | \$182,318 | 8 | \$140,525 | 10 | \$182,318 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$25,497 | | \$33,080 | | \$25,497 | | \$33,080 |
| Reinvestments | 1% | \$48,298 | | \$55,632 | | \$48,298 | | \$55,632 |
| Total Operating Cost | | \$366,086 | | \$467,932 | | \$366,086 | | \$467,932 |
| Net Operational Income | | \$1,107,267 | | \$1,277,136 | | \$524,482 | | \$702,179 |
| Financing | | | | | | | | |
| Total Investment | | \$4,829,760 | | \$5,563,210 | | \$4,829,760 | | \$5,563,210 |
| Grant(s) | | \$0 | | \$0 | 57.5% | \$2,777,112 | 42.5% | \$2,364,364 |
| Loan | 100% | \$4,829,760 | 100% | \$5,563,210 | 42.5% | \$2,052,648 | 57.5% | \$3,198,846 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.2% | | 5.0% |
| Average Income Before Tax | | \$483,599 | | \$557,355 | | \$251,877 | | \$278,855 |

14.0 FARM B PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary - FARM B | | | | | | | | |
|--|-----------------------|--------------------|-----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| Biogas Upgrading | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 2 | 1,500 | 2 | 1,500 | 2 | 1,500 | 2 | 1,500 |
| Dairy Manure (m3/yr) | | 37,850 | | 37,850 | | 37,850 | | 37,850 |
| Source Separated Organics (SSO) (m3/yr) | | 6,300 | | 8,500 | | 6,300 | | 8,500 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 6,300 | | 8,500 | | 6,300 | | 8,500 |
| Total Feedstock Volume (m3/yr) | | 50,450 | | 54,850 | | 50,450 | | 54,850 |
| Biogas Production (m3/hr) | | 312 | | 401 | | 312 | | 401 |
| Biogas Production (m3/yr) | | 2,733,120 | | 3,512,760 | | 2,733,120 | | 3,512,760 |
| Energy Production (GJ/hr) | | 6,552 | | 8,421 | | 6,552 | | 8,421 |
| Energy Production (GJ/yr) | | 57,396 | | 73,768 | | 57,396 | | 73,768 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$1,026,000 | | \$1,026,000 | | \$1,026,000 | | \$1,026,000 |
| Biogas Upgrading System | | \$1,200,000 | | \$1,500,000 | | \$1,200,000 | | \$1,500,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| Off-Farm Reception | | \$200,000 | | \$300,000 | | \$200,000 | | \$300,000 |
| FortisBC Interconnection | | \$500,000 | | \$500,000 | | \$500,000 | | \$500,000 |
| Low Voltage Electrical | | \$340,000 | | \$425,000 | | \$340,000 | | \$425,000 |
| System Controls and Automation (inc. hydraulics) | | \$156,000 | | \$195,000 | | \$156,000 | | \$195,000 |
| Project Development (7%) | 7% | \$243,040 | | \$279,720 | | \$243,040 | | \$279,720 |
| Engineering & Project Management (10%) | 10% | \$347,200 | | \$399,600 | | \$347,200 | | \$399,600 |
| Risk Management (20%) | 20% | \$812,448 | | \$935,064 | | \$812,448 | | \$935,064 |
| Total Capital Expenditure | | \$4,874,688 | | \$5,610,384 | | \$4,874,688 | | \$5,610,384 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 18.60 | \$1,067,557 | 16.25 | \$1,198,729 | 15.28 | \$877,004 | 15.28 | \$1,127,174 |
| Tipping Fees (SSO) | \$30 | \$189,000 | | \$255,000 | | \$189,000 | | \$255,000 |
| Tipping Fees (FOG) | \$15 | \$94,500 | | \$127,500 | | \$94,500 | | \$127,500 |
| Total Revenue | | \$1,351,057 | | \$1,581,229 | | \$1,160,504 | | \$1,509,674 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$27,331 | | \$35,128 | \$ 0.01 | \$27,331 | | \$35,128 |
| Labour for System Op. (h/day; \$35/h, 1hr/50m3 biogas) | 6 | \$79,716 | 8 | \$102,456 | 6 | \$79,716 | 8 | \$102,456 |
| AD Elec. Consumption (7% of Prod. Equip. @ \$0.06/kWh) | 7% | \$22,958 | | \$29,507 | | \$22,958 | | \$29,507 |
| Upgrading System Electricity Consumption | | \$37,000 | | \$55,000 | | \$37,000 | | \$55,000 |
| Reinvestments | 1% | \$48,747 | | \$56,104 | | \$48,747 | | \$56,104 |
| Total Operating Cost | | \$239,352 | | \$301,794 | | \$239,352 | | \$301,794 |
| Net Operational Income | | \$1,111,704 | | \$1,279,435 | | \$921,151 | | \$1,207,880 |
| Financing | | | | | | | | |
| Total Investment | | \$4,874,688 | | \$5,610,384 | | \$4,874,688 | | \$5,610,384 |
| Grant(s) | | \$0 | | \$0 | | \$0 | | \$0 |
| Loan | 100% | \$4,874,688 | 100% | \$5,610,384 | 100% | \$4,874,688 | 100% | \$5,610,384 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.3% | | 7.9% |
| Average Income Before Tax | | \$488,420 | | \$560,860 | | \$258,151 | | \$444,880 |

Farm C

Anaerobic Digestion Feasibility Study

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15.0 FARM C EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm C” in Chilliwack. The system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm C would process dairy manure, poultry waste and non-agricultural feedstocks to produce renewable energy and other beneficial co-products.

This study concludes that the proposed AD system on Farm C would be economically viable with 49% non-agricultural feedstock, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.188/kWh;
- Electricity tariff of \$0.10/kWh and funding of 55% (\$2,313,125); or
- Biomethane tariff of \$18.30/GJ; or
- Biomethane tariff of \$15.28/GJ will produce a 5.6% ROI with no funding.

If Farm C were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions*:

- Electricity tariff of \$0.290/kWh;
- Electricity tariff of \$0.10/kWh and funding of 90% (\$2,397,049); or
- Biomethane tariff of \$33.80/GJ; or
- Biomethane tariff of \$15.28/GJ and funding of 67.5% (\$2,071,672).

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

16.0 FARM C PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure information presented herein is understood in the proper context and with all necessary supporting information.

16.1 Site Description

Farm C is a dairy operation in Chilliwack, B.C. that milks 300 cows. With the inclusion of young stock and dry cows, total herd size is approximately 650 cows. Farm C also operates a 70,000 bird broiler operation which generates approximately 500 tonnes/year of poultry litter. Dairy manure is collected via automated alley scrapers while the poultry waste is moved using front-loaders.

Farm C recently acquired a neighbouring farm which is currently vacant. The acquired farm has existing 3-phase service and, as a result, is likely a favourable location to site the AD system.

16.2 Project-Specific Considerations

16.2.1 Electrical Interconnection

While Farm C does not have three-phase service, the recently acquired neighbouring farm does. The distance between the two sites is approximately 400m. It is likely economically and logistically favourable to site the AD system at the newly acquired farm location to take advantage of existing three-phase service and to pipe manure from Farm C. Interconnection costs have been estimated at \$500,000.

16.2.2 Natural Gas Interconnection

Farm C has natural gas available on-site, as does the newly acquired farm. While interconnection costs have been estimated at \$100,000 – \$400,000, FortisBC has expressed an interest in managing these costs and minimizing system contribution for interconnection. FortisBC can also accept all of the biomethane from this system into their grid.

16.2.3 Availability of Feedstocks

Based on information provided by Farm C, the following feedstocks have been identified as currently available:

- Dairy Manure:
 - 300 milkers and 350 young stock mixed with dry cows.
- Poultry Litter:
 - 70,000 bird broiler operation*.

**Note that poultry litter is a particularly challenging feedstock as a result of high nitrogen and total solids content. Operational experience and computer simulation indicates an absolute minimum dairy manure to poultry litter ratio of 5:1 is necessary. However, this ratio is highly dependent on individual feedstock characteristics and should only be used as a rough estimation. Given the high proportion of dairy manure, it is likely that poultry manure will be a viable feedstock for this AD system.*

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG):
 - Considered a high-energy non-agricultural feedstock; and
 - Sourced from food processing facilities.

- Source Separated Organics (SSO):
 - Considered a low-energy non-agricultural feedstock; and
 - Consisting of organic compostable materials, such as spoiled produce and plate scrapings.

16.3 Co-Products

AD systems enable production of a number of beneficial co-products. The following section discusses Farm C's co-product opportunities.

16.3.1 Thermal Energy

Thermal energy could be available for use at Farm C through the integration of a co-generation unit or biogas boiler. While the farm operation does not have any significant heat loads, minor heating requirements, such as for the poultry operation, could be met.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm C could range from 300,000btu – 1,200,000btu using a co-generation unit, or 700,000btu – 3,500,000btu using high-efficiency, direct combustion.

16.3.2 Livestock Bedding

Farm C spends approx \$60 – \$70,000/year on sawdust for livestock bedding. Digestate material from the AD system would be a suitable replacement for livestock bedding if properly managed after digestion process. Depending on the technology selected and desired moisture content, livestock bedding production post-AD typically involves a solid separator and optional drying.

16.3.3 Tipping Fees

Farm C has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

16.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export, or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP. These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of any excess nutrients.

17.0 FARM C PROJECT OPTIONS

17.1 Option 1: 25% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|-----------------------|---------------------------|----------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>31 m³</i> | <i>221 m³</i> | <i>11,500 m³</i> |
| <i>Poultry litter</i> | <i>1.5 m³</i> | <i>9.5 m³</i> | <i>500 m³</i> |
| <i>FOG</i> | <i>5 m³</i> | <i>38 m³</i> | <i>2,000 m³</i> |
| <i>SSO</i> | <i>5 m³</i> | <i>38 m³</i> | <i>2,000 m³</i> |
| TOTAL | 42.5 m³ | 306.5 m³ | 16,000 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,500 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>2,808 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.3kgVS/day</i> |
| <i>HRT:</i> | <i>28 days</i> |
| <i>CHP unit:</i> | <i>290 kW</i> |
| <i>Upgrading unit capacity</i> | <i>300 m³/hr</i> |

Option 1 uses a mixture of available manure and 25% non-agricultural feedstocks. The proposed AD system includes a 1,500m³ digester and a 290kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 117m³/hour.

17.2 Option 2: 49% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|-----------------------|---------------------------|----------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>31 m³</i> | <i>220 m³</i> | <i>11,500 m³</i> |
| <i>Poultry litter</i> | <i>1.5 m³</i> | <i>9.5 m³</i> | <i>500 m³</i> |
| <i>FOG</i> | <i>16 m³</i> | <i>115 m³</i> | <i>6,000 m³</i> |
| <i>SSO</i> | <i>16 m³</i> | <i>115 m³</i> | <i>6,000 m³</i> |
| TOTAL | 64.5 m³ | 459.5 m³ | 24,000 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,250 m³</i> |
| <i>No of digesters:</i> | <i>2</i> |
| <i>Biogas production:</i> | <i>6,696 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.6kgVS/day</i> |
| <i>HRT:</i> | <i>24 days</i> |
| <i>CHP unit:</i> | <i>690 kW</i> |
| <i>Upgrading unit capacity</i> | <i>300 m³/hr</i> |

Option 2 uses a mixture of available manure and 49% non-agricultural feedstocks. The proposed AD system includes 2 x 1,250m³ digesters and a 690kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 279m³/hour.

18.0 FARM C REQUIRED TARIFFS

18.1 Energy Tariff and Funding Requirements

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--------------------------------------|-------------------------------|------------------------------------|-------------------------------------|
| 1: 25% | \$0.290 | 90% | \$33.80 | 67.5% |
| 2: 49% | \$0.188 | 55% | \$18.30 | 0%* |

Note*: 0% indicates the AD system is able to make greater than 5% ROI using \$15.28/GJ

18.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to capital input, this AD system would require high energy tariffs of \$0.290/kWh or \$33.80/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 90% funding if it produces electricity for sale to the SOP or 67.5% if it produced biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is not considered economically viable.

Option 2: As a result of the higher energy output proportionate to the capital input, this AD system would require energy tariffs of \$0.188/kWh or \$18.30/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 55% funding if it produces electricity for sale to the SOP. As such, there is a high probability that this option will be economically viable for biomethane production. However, this will depend upon interconnection costs, FortisBC's ability to accept the biomethane into their grid, and the ability to generate economic value from co-products.

There is also a low probability that this option will be economically viable for electricity production. However, this will depend upon interconnection costs, the ability to generate economic value from co-products, and at least a \$0.04/kWh – \$0.08/kWh higher electricity tariff or the availability of some funding. While the required electricity tariff or funding amount for Farm C's AD system are within reason when compared to other jurisdictions, they are currently unavailable in B.C.

19.0 FARM C CONCLUSION

While installation of an AD system at Farm C is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amount, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities and characteristics. Furthermore, addition of a significant quantity of low nitrogen and low TS feedstock is also vital to enable Farm C's AD system to operate effectively.

Option 2, biomethane production, may be economically viable for Farm C based on the information provided and used in this study. Option 2, electricity production, may also be economically viable for Farm C if a slightly higher electricity tariff or funding becomes available.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

20.0 FARM C PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary - FARM C | | | | | | | | |
|---|-----------------------|--------------------|-----------------------|--------------------|------------------------------------|--------------------|------------------------------------|--------------------|
| Electricity Production | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/grant money under SOP | | Option 2 - w/grant money under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,500 | 2 | 1,250 | 1 | 1,500 | 2 | 1,250 |
| Dairy Manure (m3/yr) | | 11,500 | | 11,500 | | 11,500 | | 11,500 |
| Poultry Waste (Broiler m3/yr) | | 500 | | 500 | | 500 | | 500 |
| Source Separated Organics (SSO) (m3/yr) | | 2,000 | | 6,000 | | 2,000 | | 6,000 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 2,000 | | 6,000 | | 2,000 | | 6,000 |
| Total Feedstock Volume (m3/yr) | | 16,000 | | 24,000 | | 16,000 | | 24,000 |
| Engine operating time (hr/day) | | 21.9 | | 21.9 | | 21.9 | | 21.9 |
| Engine Size kW | | 290 | | 690 | | 290 | | 690 |
| Electricity Production (kWh/yr) | | 2,286,360 | | 5,439,960 | | 2,286,360 | | 5,439,960 |
| Electricity Production (kWh/day) | | 6,351 | | 15,111 | | 6,351 | | 15,111 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$513,000 | | \$950,000 | | \$513,000 | | \$950,000 |
| Co-Gen Plant (non-containerized) | | \$464,000 | | \$828,000 | | \$464,000 | | \$828,000 |
| Powerhouse & Plumbing | | \$137,000 | | \$205,500 | | \$137,000 | | \$205,500 |
| Off-Farm Reception | | \$125,000 | | \$175,000 | | \$125,000 | | \$175,000 |
| High Voltage Connection (BC Hydro) | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (non-BC Hydro) | | \$110,000 | | \$165,000 | | \$110,000 | | \$165,000 |
| Low Voltage Electrical Distribution | | \$170,000 | | \$255,000 | | \$170,000 | | \$255,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$117,000 | | \$78,000 | | \$117,000 |
| Project Development (7%) | 7% | \$132,790 | | \$209,685 | | \$132,790 | | \$209,685 |
| Engineering & Project Management (10%) | 10% | \$189,700 | | \$299,550 | | \$189,700 | | \$299,550 |
| Risk Management (20%) | 20% | \$443,898 | | \$700,947 | | \$443,898 | | \$700,947 |
| Total Capital Expenditure | | \$2,663,388 | | \$4,205,682 | | \$2,663,388 | | \$4,205,682 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.290 | \$663,044 | 0.188 | \$1,022,712 | 0.100 | \$228,636 | 0.100 | \$543,996 |
| Tipping Fees (SSO) | \$30 | \$60,000 | | \$180,000 | | \$60,000 | | \$180,000 |
| Tipping Fees (FOG) | \$15 | \$30,000 | | \$90,000 | | \$30,000 | | \$90,000 |
| Total Revenue | | \$753,044 | | \$1,292,712 | | \$318,636 | | \$813,996 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$45,727 | | \$108,799 | | \$45,727 | | \$108,799 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$11,432 | | \$27,200 | | \$11,432 | | \$27,200 |
| Labour for System Operation (h/day; \$50/h, 1hr/100kW) | 3 | \$52,925 | 7 | \$125,925 | 3 | \$52,925 | 7 | \$125,925 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$9,603 | | \$22,848 | | \$9,603 | | \$22,848 |
| Reinvestments | 1% | \$26,634 | | \$42,057 | | \$26,634 | | \$42,057 |
| Total Operating Cost | | \$146,321 | | \$326,829 | | \$146,321 | | \$326,829 |
| Net Operational Income | | \$606,724 | | \$965,884 | | \$172,315 | | \$487,167 |
| Financing | | | | | | | | |
| Total Investment | | \$2,663,388 | | \$4,205,682 | | \$2,663,388 | | \$4,205,682 |
| Grant(s) | | \$0 | | \$0 | 90% | \$2,397,049 | 55% | \$2,313,125 |
| Loan | 100% | \$2,663,388 | 100% | \$4,205,682 | 10% | \$266,339 | 45% | \$1,892,557 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI Before Tax | | 10.0% | | 10.1% | | 5.1% | | 5.6% |
| Average Income Before Tax | | \$265,634 | | \$423,095 | | \$137,147 | | \$236,752 |

21.0 FARM C PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary - FARM C | | | | | | | | |
|--|-----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| Biogas Upgrading | Option 1 - 25% Non-Ag | | Option 2 -49% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,500 | 2 | 1,250 | 1 | 1,500 | 2 | 1,250 |
| Dairy Manure (m3/yr) | | 11,500 | | 11,500 | | 11,500 | | 11,500 |
| Poultry Waste (Broiler m3/yr) | | 500 | | 500 | | 500 | | 500 |
| Source Separated Organics (SSO) (m3/yr) | | 2,000 | | 6,000 | | 2,000 | | 6,000 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 2,000 | | 6,000 | | 2,000 | | 6,000 |
| Total Feedstock Volume (m3/yr) | | 16,000 | | 24,000 | | 16,000 | | 24,000 |
| Biogas Production (m3/hr) | | 117 | | 279 | | 117 | | 279 |
| Biogas Production (m3/yr) | | 1,024,920 | | 2,444,040 | | 1,024,920 | | 2,444,040 |
| Energy Production (GJ/hr) | | 2.457 | | 5.859 | | 2.457 | | 5.859 |
| Energy Production (GJ/yr) | | 21,523 | | 51,325 | | 21,523 | | 51,325 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$513,000 | | \$950,000 | | \$513,000 | | \$950,000 |
| Biogas Upgrading System | | \$1,000,000 | | \$1,200,000 | | \$1,000,000 | | \$1,200,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| Off-Farm Reception | | \$125,000 | | \$175,000 | | \$125,000 | | \$175,000 |
| FortisBC Interconnection | | \$250,000 | | \$350,000 | | \$250,000 | | \$350,000 |
| Low Voltage Electrical | | \$170,000 | | \$255,000 | | \$170,000 | | \$255,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$117,000 | | \$78,000 | | \$117,000 |
| Project Development (7%) | 7% | \$153,020 | | \$216,790 | | \$153,020 | | \$216,790 |
| Engineering & Project Management (10%) | 10% | \$218,600 | | \$309,700 | | \$218,600 | | \$309,700 |
| Risk Management (20%) | 20% | \$511,524 | | \$724,698 | | \$511,524 | | \$724,698 |
| Total Capital Expenditure | | \$3,069,144 | | \$4,348,188 | | \$3,069,144 | | \$4,348,188 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 33.80 | \$727,488 | 18.30 | \$939,245 | 15.28 | \$328,876 | 15.28 | \$784,244 |
| Tipping Fees (SSO) | \$30 | \$60,000 | | \$180,000 | | \$60,000 | | \$180,000 |
| Tipping Fees (FOG) | \$15 | \$30,000 | | \$90,000 | | \$30,000 | | \$90,000 |
| Total Revenue | | \$817,488 | | \$1,209,245 | | \$418,876 | | \$1,054,244 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$10,249 | | \$24,440 | \$0.01 | \$10,249 | | \$24,440 |
| Labour for System Op. (h/day, \$35/h, 1hr/50m3 biogas) | 2 | \$29,894 | 6 | \$71,285 | 2 | \$29,894 | 6 | \$71,285 |
| AD Elec. Consumption (7% of Prod. Equiv. @ \$0.06/kWh) | 7% | \$8,609 | | \$20,530 | | \$8,609 | | \$20,530 |
| Upgrading System Electricity Consumption | | \$18,000 | | \$37,000 | | \$18,000 | | \$37,000 |
| Reinvestments | 1% | \$30,691 | | \$43,482 | | \$30,691 | | \$43,482 |
| Total Operating Cost | | \$121,043 | | \$220,337 | | \$121,043 | | \$220,337 |
| Net Operational Income | | \$696,445 | | \$988,908 | | \$297,833 | | \$833,907 |
| Financing | | | | | | | | |
| Total Investment | | \$3,069,144 | | \$4,348,188 | | \$3,069,144 | | \$4,348,188 |
| Grant(s) | | \$0 | | \$0 | 67.5% | \$2,071,672 | | \$0 |
| Loan | 100% | \$3,069,144 | 100% | \$4,348,188 | 32.5% | \$997,472 | 100% | \$4,348,188 |
| Equity | 0% | \$0 | 0% | \$0 | 0.0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.3% | | 5.6% |
| Average Income Before Tax | | \$305,734 | | \$432,875 | | \$162,333 | | \$243,107 |

Farm D

Anaerobic Digestion Feasibility Study

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22.0 FARM D EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm D” in Vanderhoof. The system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm D would process livestock manure and non-agricultural feedstocks to produce renewable energy and other beneficial co-products.

This study concludes that the proposed AD system on Farm D would be economically viable with 49% non-agricultural feedstock, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.262/kWh;
- Electricity tariff of \$0.10/kWh and funding of 80% (\$2,003,789); or
- Biomethane tariff of \$32.30/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 60% (\$1,830,535).

If Farm D were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions*:

- Electricity tariff of \$0.430/kWh;
- Electricity tariff of \$0.10/kWh and funding of 100% (\$1,668,654); or
- Biomethane tariff of \$71.00/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 100% (\$2,595,996).

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

23.0 FARM D PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure the information presented herein is understood in the proper context and with all necessary supporting information.

23.1 Site Description

Farm D is a beef feedlot operation outside of Vanderhoof, B.C. that houses approximately 1,000 head of cattle as well as approximately 200 dry dairy cows.

23.2 Project-Specific Considerations

23.2.1 Electrical Interconnection

B.C. Hydro estimates that approximately 100m of single-phase line requires upgrading to three-phase service to the farm gate. Depending on the eventual siting of the AD system, another 100m – 500m of on-site high-voltage line may also be required. According to preliminary estimates, there is availability for up to 100kW at Farm D, and interconnection costs have been estimated at \$400,000. For the purposes of the study estimates have been made based on standard AD models, but it is important to note that BC Hydro would have to agree to take the produced energy.

23.2.2 Natural Gas Interconnection

Farm D does not have natural gas available on-site, and it is understood to be an extremely long distance away. Despite interconnection being unavailable for this site, this study includes biomethane production for the purposes of informing the B.C. Anaerobic Digestion Benchmark Study. Interconnection costs have been estimated at \$250,000 – \$350,000.

23.2.3 Availability of Feedstocks

Based on information provided by Farm D, the following feedstocks have been identified as currently available:

- Cattle Manure:
 - 1,000 head of beef cattle and 200 dry dairy cattle combined for 30% TS.
- Hog Manure or On-Farm Source at 5% TS:
 - Necessary to have a 2:1 ratio of cattle manure to 5% hog manure or other on-farm source.

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG):
 - Considered a high-energy non-agricultural feedstock;
 - To stay within the normal operating parameters of the AD system, this FOG must contain <15% TS; and
 - Sourced from food processing facilities.
- Source Separated Organics (SSO):
 - Considered a low-energy non-agricultural feedstock;
 - To stay within the normal operating parameters of the AD system, this must be <15% TS when mixed with agricultural sources; and
 - Consisting of organic compostable materials, such as spoiled produce and plate scrapings.

23.3 Co-Products

AD systems enable production of a number of beneficial co-products. The following section discusses Farm D's co-product opportunities.

23.3.1 Thermal Energy

Thermal energy could be available for use at Farm D through the integration of a co-generation unit or biogas boiler. While the current farm operation does not have any significant heat loads, there are plans to incorporate greenhouses into the farm if an affordable source of heat is available.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm D could range from 250,000btu – 1,000,000btu using a co-generation unit, or 600,000btu – 3,000,000btu using high-efficiency, direct combustion.

23.3.2 Livestock Bedding

Digestate material from the AD system would be a suitable replacement for livestock bedding if properly managed after the digestion process. Depending on the separation technology selected and desired moisture content, livestock bedding production post-AD typically involves a solid separator and optional drying.

23.3.3 Tipping Fees

Farm D has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

23.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export, or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP. These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of any excess nutrients.

24.0 FARM D PROJECT OPTIONS

24.1 Option 1: 25% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|-------------------|-------------------------|--------------------------|----------------------------|
| Total manure | 14 m ³ | 98 m ³ | 5,100 m ³ |
| FOG | 2 m ³ | 16 m ³ | 850 m ³ |
| SSO | 2 m ³ | 16 m ³ | 850 m ³ |
| TOTAL | 18 m³ | 130 m³ | 6,800 m³ |

| | |
|--|---------------------------|
| <i>Minimal required digester volume:</i> | 500 m ³ |
| <i>No of digesters:</i> | 1 |
| <i>Biogas production:</i> | 1,176 m ³ /day |
| <i>Organic loading rate:</i> | 3.1 kg VS/day |
| <i>HRT:</i> | 27 days |
| <i>CHP unit:</i> | 120 kW |
| <i>Upgrading unit capacity:</i> | 150 m ³ /hr |

Option 1 uses a mixture of available manure and 25% non-agricultural feedstock. The proposed AD system includes a 500m³ digester and a 120kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 49m³/hour.

24.2 Option 2: 49% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|-------------------|-------------------------|--------------------------|-----------------------------|
| Total manure | 14 m ³ | 98 m ³ | 5,100 m ³ |
| FOG | 7 m ³ | 49 m ³ | 2,550 m ³ |
| SSO | 7 m ³ | 49 m ³ | 2,550 m ³ |
| TOTAL | 28 m³ | 196 m³ | 10,200 m³ |

| | |
|--|---------------------------|
| <i>Minimal required digester volume:</i> | 1,000 m ³ |
| <i>No of digesters:</i> | 1 |
| <i>Biogas production:</i> | 2,832 m ³ /day |
| <i>Organic loading rate:</i> | 3.4 kg VS/day |
| <i>HRT:</i> | 28 days |
| <i>CHP unit:</i> | 290 kW |
| <i>Upgrading unit capacity:</i> | 150m ³ /hr |

Option 2 uses a mixture of available manure and 49% non-agricultural feedstocks. The proposed AD system includes a 1,000m³ digester and a 290kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 118m³/hour.

25.0 FARM D REQUIRED TARIFFS

25.1 Energy Tariff and Funding Requirements

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--|-------------------------------------|---|--|
| 1: 25% | \$0.430 | 100% | \$71.00 | 100% |
| 2: 49% | \$0.262 | 80% | \$32.30 | 60% |

25.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to capital input, this AD system would require high energy tariffs of \$0.430/kWh or \$71.00/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 100% funding if it produces electricity for sale to the SOP or biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is not considered economically viable.

Option 2: Despite the higher energy output proportionate to the capital input, this AD system would still require energy tariffs of \$0.262/kWh or \$32.30/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 80% funding if it produces electricity for sale to the SOP, or 60% if it produces biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is also not considered economically viable.

26.0 FARM D CONCLUSION

While installation of an AD system at Farm D is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amounts, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities and characteristics. Furthermore, addition of a significant quantity of low TS feedstock is also vital to enable the AD system to operate.

Based on the information provided and used in this study, none of the AD system options are considered economically viable for Farm D.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

27.0 FARM D PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary - FARM D | | | | | | | | |
|---|-----------------------------|--------------------|-----------------------------|--------------------|------------------------------------|--------------------|------------------------------------|--------------------|
| Electricity Production | Option 1 - Up to 25% Non-Ag | | Option 2 - Up to 49% Non-Ag | | Option 1 - w/grant money under SOP | | Option 2 - w/grant money under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 500 | 1 | 1,000 | 1 | 500 | 1 | 1,000 |
| Dairy & Beef Manure @ 30% TS (m3/yr) | | 1,700 | | 1,700 | | 1,700 | | 1,700 |
| Hog Manure or other on-farm @ 5% TS (m3/yr) | | 3,400 | | 3,400 | | 3,400 | | 3,400 |
| Source Separated Organics <15% TS (SSO) (m3/yr) | | 850 | | 2,550 | | 850 | | 2,550 |
| Fats, Oils and Grease <15% TS (FOG) (m3/yr) | | 850 | | 2,550 | | 850 | | 2,550 |
| Total Feedstock Volume (m3/yr) | | 6,800 | | 10,200 | | 6,800 | | 10,200 |
| Engine operating time (hr/day) | | 21.9 | | 21.9 | | 21.9 | | 21.9 |
| Engine Size kW | | 120 | | 290 | | 120 | | 290 |
| Electricity Production (kWh/yr) | | 946,080 | | 2,286,360 | | 946,080 | | 2,286,360 |
| Electricity Production (kWh/day) | | 2,628 | | 6,351 | | 2,628 | | 6,351 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$300,000 | | \$400,000 | | \$300,000 | | \$400,000 |
| Co-Gen Plant (non-containerized) | | \$216,000 | | \$464,000 | | \$216,000 | | \$464,000 |
| Powerhouse & Plumbing | | \$68,500 | | \$137,000 | | \$68,500 | | \$137,000 |
| Off-Farm Reception | | \$125,000 | | \$125,000 | | \$125,000 | | \$125,000 |
| High Voltage Connection (BC Hydro) | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (non-BC Hydro) | | \$55,000 | | \$110,000 | | \$55,000 | | \$110,000 |
| Low Voltage Electrical Distribution | | \$85,000 | | \$170,000 | | \$85,000 | | \$170,000 |
| System Controls and Automation (inc. hydraulics) | | \$39,000 | | \$78,000 | | \$39,000 | | \$78,000 |
| Project Development (7%) | 7% | \$83,195 | | \$124,880 | | \$83,195 | | \$124,880 |
| Engineering & Project Management (10%) | 10% | \$118,850 | | \$178,400 | | \$118,850 | | \$178,400 |
| Risk Management (20%) | 20% | \$278,109 | | \$417,456 | | \$278,109 | | \$417,456 |
| Total Capital Expenditure | | \$1,668,654 | | \$2,504,736 | | \$1,668,654 | | \$2,504,736 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.430 | \$406,814 | 0.262 | \$599,026 | 0.100 | \$94,608 | 0.100 | \$228,636 |
| Tipping Fees (SSO) | \$30 | \$25,500 | | \$76,500 | | \$25,500 | | \$76,500 |
| Tipping Fees (FOG) | \$15 | \$12,750 | | \$38,250 | | \$12,750 | | \$38,250 |
| Total Revenue | | \$445,064 | | \$713,776 | | \$132,858 | | \$343,386 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$18,922 | | \$45,727 | | \$18,922 | | \$45,727 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$4,730 | | \$11,432 | | \$4,730 | | \$11,432 |
| Labour for System Operation (h/day; \$50/h, 1hr/100kW) | 1 | \$21,900 | 3 | \$52,925 | 1 | \$21,900 | 3 | \$52,925 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$3,974 | | \$9,603 | | \$3,974 | | \$9,603 |
| Reinvestments | 1% | \$16,687 | | \$25,047 | | \$16,687 | | \$25,047 |
| Total Operating Cost | | \$66,212 | | \$144,734 | | \$66,212 | | \$144,734 |
| Net Operational Income | | \$378,852 | | \$569,042 | | \$66,646 | | \$198,652 |
| Financing | | | | | | | | |
| Total Investment | | \$1,668,654 | | \$2,504,736 | | \$1,668,654 | | \$2,504,736 |
| Grant(s) | | \$0 | | \$0 | 100% | \$1,668,654 | 80% | \$2,003,789 |
| Loan | 100% | \$1,668,654 | 100% | \$2,504,736 | 0% | \$0 | 20% | \$500,947 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 4.0% | | 5.3% |
| Average Income Before Tax | | \$166,135 | | \$250,641 | | \$66,498 | | \$132,778 |

28.0 FARM D PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary - FARM D | | | | | | | | |
|---|-----------------------|--------------------|-----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| Biogas Upgrading | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 500 | 1 | 1,000 | 1 | 500 | 1 | 1,000 |
| Dairy & Beef Manure @ 30% TS (m3 annual) | | 1,700 | | 1,700 | | 1,700 | | 1,700 |
| Hog Manure or other on-farm @ 5% TS (m3 annual) | | 3,400 | | 3,400 | | 3,400 | | 3,400 |
| Source Separated Organics <15% TS (SSO) (tonnes annual) | | 850 | | 2,550 | | 850 | | 2,550 |
| Fats, Oils and Grease <15% TS (FOG) (m3 annual) | | 850 | | 2,550 | | 850 | | 2,550 |
| Total Feedstock Volume (m3 annual) | | 6,800 | | 10,200 | | 6,800 | | 10,200 |
| Biogas Production (m3/hr) | | 49 | | 118 | | 49 | | 118 |
| Biogas Production (m3/yr) | | 429,240 | | 1,033,680 | | 429,240 | | 1,033,680 |
| Energy Production (GJ/hr) | | 1.029 | | 2.478 | | 1.029 | | 2.478 |
| Energy Production (GJ/yr) | | 9,014 | | 21,707 | | 9,014 | | 21,707 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$300,000 | | \$400,000 | | \$300,000 | | \$400,000 |
| Biogas Upgrading System | | \$1,000,000 | | \$1,000,000 | | \$1,000,000 | | \$1,000,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| Off-Farm Reception | | \$125,000 | | \$125,000 | | \$125,000 | | \$125,000 |
| FortisBC Interconnection | | \$250,000 | | \$350,000 | | \$250,000 | | \$350,000 |
| Low Voltage Electrical | | \$85,000 | | \$170,000 | | \$85,000 | | \$170,000 |
| System Controls and Automation (inc. hydraulics) | | \$39,000 | | \$78,000 | | \$39,000 | | \$78,000 |
| Project Development (7%) | 7% | \$129,430 | | \$152,110 | | \$129,430 | | \$152,110 |
| Engineering & Project Management (10%) | 10% | \$184,900 | | \$217,300 | | \$184,900 | | \$217,300 |
| Risk Management (20%) | 20% | \$432,666 | | \$508,482 | | \$432,666 | | \$508,482 |
| Total Capital Expenditure | | \$2,595,996 | | \$3,050,892 | | \$2,595,996 | | \$3,050,892 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 71.00 | \$639,997 | 32.30 | \$701,145 | 15.28 | \$137,735 | 15.28 | \$331,687 |
| Tipping Fees (SSO) | \$30 | \$25,500 | | \$76,500 | | \$25,500 | | \$76,500 |
| Tipping Fees (FOG) | \$15 | \$12,750 | | \$38,250 | | \$12,750 | | \$38,250 |
| Total Revenue | | \$678,247 | | \$815,895 | | \$175,985 | | \$446,437 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$4,292 | | \$10,337 | \$0.01 | \$4,292 | | \$10,337 |
| Labour for System Op. (h/day, \$35/h, 1hr/50m3 biogas) | 1 | \$12,520 | 2 | \$30,149 | 1 | \$12,520 | 2 | \$30,149 |
| AD Elec. Consumption (7% of Prod. Equiv. @ \$0.06/kWh) | 7% | \$3,606 | | \$8,683 | | \$3,606 | | \$8,683 |
| Upgrading System Electricity Consumption | | \$18,000 | | \$18,000 | | \$18,000 | | \$18,000 |
| Reinvestments | 1% | \$25,960 | | \$30,509 | | \$25,960 | | \$30,509 |
| Total Operating Cost | | \$87,977 | | \$121,278 | | \$87,977 | | \$121,278 |
| Net Operational Income | | \$590,269 | | \$694,618 | | \$88,007 | | \$325,160 |
| Financing | | | | | | | | |
| Total Investment | | \$2,595,996 | | \$3,050,892 | | \$2,595,996 | | \$3,050,892 |
| Grant(s) | | \$0 | | \$0 | 100% | \$2,595,996 | 60% | \$1,830,535 |
| Loan | 100% | \$2,595,996 | 100% | \$3,050,892 | 0% | \$0 | 40% | \$1,220,357 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 3.4% | | 5.2% |
| Average Income Before Tax | | \$260,263 | | \$306,311 | | \$88,007 | | \$159,360 |

Farm E

Anaerobic Digestion Feasibility Study

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29.0 FARM E EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm E” in Black Creek. The system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm E would process dairy manure and non-agricultural feedstocks to produce renewable energy and other beneficial co-products.

This study concludes that the proposed AD system on Farm E would be economically viable with 49% non-agricultural feedstock, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.309/kWh;
- Electricity tariff of \$0.10/kWh and funding of 90% (\$2,101,367); or
- Biomethane tariff of \$41.70/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 80% (\$2,412,634).

If Farm E were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions*:

- Electricity tariff of \$0.550/kWh;
- Electricity tariff of \$0.10/kWh and funding of 100% (\$1,618,110); or
- Biomethane tariff of \$94.50/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 100% (\$2,595,996).

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

30.0 FARM E PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure the information presented herein is understood in the proper context and with all necessary supporting information.

30.1 Site Description

Farm E is a dairy operation in Black Creek, B.C. that milks 100 cows. The farm uses alley scrapers for manure collection.

30.2 Project-Specific Considerations

30.2.1 Electrical Interconnection

B.C. Hydro estimates that less than 250m of single-phase line requires upgrading to three-phase service. According to preliminary estimates, there is availability for up to 180kW at Farm E, but for the purposes of this study a standard AD model has been used. Interconnection costs have been estimated at \$425,000. In order for a project to proceed for electrical production, BC Hydro would have to agree to take the produced energy.

30.2.2 Natural Gas Interconnection

Farm E does not have natural gas available on-site. FortisBC estimates that the closest natural gas line is 500m – 1,000m away. Interconnection costs have been estimated at \$250,000 – \$350,000.

30.2.3 Availability of Feedstocks

Based on information provided by Farm E, the following feedstocks have been identified as currently available:

- Dairy Manure:
 - Available from 100 milkers. However, Farm E has expressed an interest in expanding to 250 milkers in the near future.

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG)
 - Considered a high-energy non-agricultural feedstock; and
 - Sourced from food processing facilities.
- Source Separated Organics (SSO)
 - Considered a low-energy non-agricultural feedstock; and
 - Consisting of organic compostable materials, such as spoiled produce and plate scrapings.

30.3 Co-Products

AD systems enable production of a number of beneficial co-products. The following section discusses Farm E's co-product opportunities.

30.3.1 Thermal Energy

Thermal energy could be available for use at Farm E through the integration of a co-generation unit or biogas boiler. While the farm operation does not have any significant heat loads, minor heating requirements could be met.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm E could range from 250,000btu – 1,000,000btu using a co-generation unit, or 600,000btu – 3,000,000btu using high-efficiency, direct combustion.

30.3.2 Livestock Bedding

Farm E spends approximately \$12,000/year on sawdust for livestock bedding. If the farm expands to 250 milkers, this cost would rise to approximately \$30,000/year. Similarly, if bedding were supplied to the neighbouring farm in exchange for the use of manure, additional savings could also be realized. Digestate material from the AD system would be a suitable replacement for livestock bedding if properly managed after the digestion process. Depending on the separation technology selected and desired moisture content, livestock bedding production post-AD typically involves a solid separator and optional drying.

30.3.3 Tipping Fees

Farm E has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

30.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export, or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP. These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of any excess nutrients.

31.0 FARM E PROJECT OPTIONS

31.1 Option 1: 25% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|--------------------------|--------------------------|----------------------------|
| <i>Dairy manure</i> | <i>11 m³</i> | <i>77 m³</i> | <i>4,000 m³</i> |
| <i>FOG</i> | <i>1.5 m³</i> | <i>12 m³</i> | <i>650 m³</i> |
| <i>SSO</i> | <i>1.5 m³</i> | <i>12 m³</i> | <i>650 m³</i> |
| TOTAL | 14 m³ | 101 m³ | 5,300 m³ |

| | |
|--|------------------------------|
| <i>Minimal required digester volume:</i> | <i>500 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>888 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.2 kg VS/day</i> |
| <i>HRT:</i> | <i>27 days</i> |
| <i>CHP unit:</i> | <i>100 kW</i> |
| <i>Upgrading unit capacity:</i> | <i>150 m³/hr</i> |

Option 1 uses a mixture of available manure and 25% non-agricultural feedstock. The proposed AD system includes a 500m³ digester and a 100kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 37m³/hour.

31.2 Option 2: 49% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|-------------------------|--------------------------|----------------------------|
| <i>Dairy manure</i> | <i>11 m³</i> | <i>77m³</i> | <i>4,000 m³</i> |
| <i>FOG</i> | <i>5 m³</i> | <i>38 m³</i> | <i>2,000 m³</i> |
| <i>SSO</i> | <i>5 m³</i> | <i>38 m³</i> | <i>2,000 m³</i> |
| TOTAL | 21 m³ | 153 m³ | 8,000 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>750 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>2,208 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.6 kg VS/day</i> |
| <i>HRT:</i> | <i>27 days</i> |
| <i>CHP unit:</i> | <i>230 kW</i> |
| <i>Upgrading unit capacity:</i> | <i>150 m³/hr</i> |

Option 2 uses a mixture of available manure and 49% non-agricultural feedstocks. The proposed AD system includes a 750m³ digester and a 230kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 92m³/hour.

32.0 FARM E REQUIRED TARIFFS

32.1 Energy Tariff and Funding Requirements

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--|-------------------------------------|---|--|
| 1: 25% | \$0.550 | 100% | \$94.50 | 100% |
| 2: 49% | \$0.309 | 90% | \$41.70 | 80% |

32.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to capital input, this AD system would require high energy tariffs of \$0.550/kWh or \$94.50/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 100% funding if it produces electricity for sale to the SOP or 100% if it produces biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is not considered economically viable.

Option 2: Despite the higher energy output proportionate to the capital input, this AD system would still require high energy tariffs of \$0.309/kWh or \$41.70/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 90% funding if it produces electricity for sale to the SOP or 80% if it produces biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is also not considered economically viable.

33.0 FARM E CONCLUSION

While installation of an AD system at Farm E is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amount, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities.

Based on the information provided and used in this study, none of the AD system options are considered economically viable for Farm E.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

34.0 FARM E PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary -FARM E | | | | | | | | |
|---|-----------------------|--------------------|-----------------------|--------------------|------------------------------------|--------------------|------------------------------------|--------------------|
| Electricity Production | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/grant money under SOP | | Option 2 - w/grant money under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 500 | 1 | 750 | 1 | 500 | 1 | 750 |
| Dairy Manure (m3/yr) | | 4,000 | | 4,000 | | 4,000 | | 4,000 |
| Source Separated Organics (SSO) (m3/yr) | | 650 | | 2,000 | | 650 | | 2,000 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 650 | | 2,000 | | 650 | | 2,000 |
| Total Feedstock Volume (m3/yr) | | 5,300 | | 8,000 | | 5,300 | | 8,000 |
| Engine operating time (hr/day) | | 19.9 | | 21.9 | | 19.9 | | 21.9 |
| Engine Size kW | | 100 | | 230 | | 100 | | 230 |
| Electricity Production (kWh/yr) | | 716,400 | | 1,813,320 | | 716,400 | | 1,813,320 |
| Electricity Production (kWh/day) | | 1,990 | | 5,037 | | 1,990 | | 5,037 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$300,000 | | \$375,000 | | \$300,000 | | \$375,000 |
| Co-Gen Plant (non-containerized) | | \$180,000 | | \$368,000 | | \$180,000 | | \$368,000 |
| Off-Farm Reception | | \$125,000 | | \$125,000 | | \$125,000 | | \$125,000 |
| Powerhouse & Plumbing | | \$68,500 | | \$137,000 | | \$68,500 | | \$137,000 |
| High Voltage Connection (BC Hydro) | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (non-BC Hydro) | | \$55,000 | | \$110,000 | | \$55,000 | | \$110,000 |
| Low Voltage Electrical Distribution | | \$85,000 | | \$170,000 | | \$85,000 | | \$170,000 |
| System Controls and Automation (inc. hydraulics) | | \$39,000 | | \$78,000 | | \$39,000 | | \$78,000 |
| Project Development (7%) | 7% | \$80,675 | | \$116,410 | | \$80,675 | | \$116,410 |
| Engineering & Project Management (10%) | 10% | \$115,250 | | \$166,300 | | \$115,250 | | \$166,300 |
| Risk Management (20%) | 20% | \$269,685 | | \$389,142 | | \$269,685 | | \$389,142 |
| Total Capital Expenditure | | \$1,618,110 | | \$2,334,852 | | \$1,618,110 | | \$2,334,852 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.550 | \$394,020 | 0.309 | \$560,316 | 0.100 | \$71,640 | 0.100 | \$181,332 |
| Tipping Fees (SSO) | \$30 | \$19,500 | | \$60,000 | | \$19,500 | | \$60,000 |
| Tipping Fees (FOG) | \$15 | \$9,750 | | \$30,000 | | \$9,750 | | \$30,000 |
| Total Revenue | | \$423,270 | | \$650,316 | | \$100,890 | | \$271,332 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$14,328 | | \$36,266 | | \$14,328 | | \$36,266 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$3,582 | | \$9,067 | | \$3,582 | | \$9,067 |
| Labour for System Operation (h/day, \$50/h, 1hr/100kW) | 1 | \$18,250 | 2 | \$41,975 | 1 | \$18,250 | 2 | \$41,975 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$3,009 | | \$7,616 | | \$3,009 | | \$7,616 |
| Reinvestments | 1% | \$16,181 | | \$23,349 | | \$16,181 | | \$23,349 |
| Total Operating Cost | | \$55,350 | | \$118,272 | | \$55,350 | | \$118,272 |
| Net Operational Income | | \$367,920 | | \$532,043 | | \$45,540 | | \$153,060 |
| Financing | | | | | | | | |
| Total Investment | | \$1,618,110 | | \$2,334,852 | | \$1,618,110 | | \$2,334,852 |
| Grant(s) | | \$0 | | \$0 | 100% | \$1,618,110 | 90% | \$2,101,367 |
| Loan | 100% | \$1,618,110 | 100% | \$2,334,852 | 0% | \$0 | 10% | \$233,485 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI before tax | | 10.0% | | 10.0% | | 2.8% | | 5.2% |
| Average Income Before Tax | | \$162,227 | | \$233,639 | | \$45,540 | | \$122,368 |

35.0 FARM E PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary -FARM E | | | | | | | | |
|--|-----------------------|--------------------|-----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| Biogas Upgrading | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 500 | 1 | 750 | 1 | 500 | 1 | 750 |
| Dairy Manure (m3/yr) | | 4,000 | | 4,000 | | 4,000 | | 4,000 |
| Source Separated Organics (SSO) (m3/yr) | | 650 | | 2,000 | | 650 | | 2,000 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 650 | | 2,000 | | 650 | | 2,000 |
| Total Feedstock Volume (m3/yr) | | 5,300 | | 8,000 | | 5,300 | | 8,000 |
| Biogas Production (m3/hr) | | 37 | | 92 | | 37 | | 92 |
| Biogas Production (m3/yr) | | 324,120 | | 805,920 | | 324,120 | | 805,920 |
| Energy Production (GJ/hr) | | 0.777 | | 1.932 | | 0.777 | | 1.932 |
| Energy Production (GJ/yr) | | 6,807 | | 16,924 | | 6,807 | | 16,924 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$300,000 | | \$375,000 | | \$300,000 | | \$375,000 |
| Biogas Upgrading System | | \$1,000,000 | | \$1,000,000 | | \$1,000,000 | | \$1,000,000 |
| Off-Farm Reception | | \$125,000 | | \$125,000 | | \$125,000 | | \$125,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| FortisBC Interconnection | | \$250,000 | | \$350,000 | | \$250,000 | | \$350,000 |
| Low Voltage Electrical | | \$85,000 | | \$170,000 | | \$85,000 | | \$170,000 |
| System Controls and Automation (inc. hydraulics) | | \$39,000 | | \$78,000 | | \$39,000 | | \$78,000 |
| Project Development (7%) | 7% | \$129,430 | | \$150,360 | | \$129,430 | | \$150,360 |
| Engineering & Project Management (10%) | 10% | \$184,900 | | \$214,800 | | \$184,900 | | \$214,800 |
| Risk Management (20%) | 20% | \$432,666 | | \$502,632 | | \$432,666 | | \$502,632 |
| Total Capital Expenditure | | \$2,595,996 | | \$3,015,792 | | \$2,595,996 | | \$3,015,792 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 94.50 | \$643,216 | 41.70 | \$705,744 | 15.28 | \$104,004 | 15.28 | \$258,604 |
| Tipping Fees (SSO) | \$30 | \$19,500 | | \$60,000 | | \$19,500 | | \$60,000 |
| Tipping Fees (FOG) | \$15 | \$9,750 | | \$30,000 | | \$9,750 | | \$30,000 |
| Total Revenue | | \$672,466 | | \$795,744 | | \$133,254 | | \$348,604 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$3,241 | | \$8,059 | \$0.01 | \$3,241 | | \$8,059 |
| Labour for System Op. (h/day; \$35/h, 1hr/50m3 biogas) | 1 | \$9,454 | 2 | \$23,506 | 1 | \$9,454 | 2 | \$23,506 |
| AD Elec. Consumption (7% of Prod. Equiv. @ \$0.06/kWh) | 7% | \$2,723 | | \$6,770 | | \$2,723 | | \$6,770 |
| Upgrading System Electricity Consumption | | \$18,000 | | \$18,000 | | \$18,000 | | \$18,000 |
| Reinvestments | 1% | \$25,960 | | \$30,158 | | \$25,960 | | \$30,158 |
| Total Operating Cost | | \$82,977 | | \$110,093 | | \$82,977 | | \$110,093 |
| Net Operational Income | | \$589,489 | | \$685,651 | | \$50,276 | | \$238,511 |
| Financing | | | | | | | | |
| Total Investment | | \$2,595,996 | | \$3,015,792 | | \$2,595,996 | | \$3,015,792 |
| Grant(s) | | \$0 | | \$0 | 100% | \$2,595,996 | 80% | \$2,412,634 |
| Loan | 100% | \$2,595,996 | 100% | \$3,015,792 | 0% | \$0 | 20% | \$603,158 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before tax | | 10.0% | | 10.0% | | 1.9% | | 5.2% |
| Average Income Before Tax | | \$259,991 | | \$301,976 | | \$50,276 | | \$156,511 |

Farm F

Anaerobic Digestion Feasibility Study

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36.0 FARM F EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm F” in Armstrong. The system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm F would process dairy manure and non-agricultural feedstocks to produce renewable energy and other beneficial co-products. It should be noted that the proposed system has a limit of 999kW at this time.

This study concludes that the proposed AD system on Farm F would be economically viable with 30% non-agricultural feedstock creating a system size of 999kW or equivalent biomethane output, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.260/kWh;
- Electricity tariff of \$0.10/kWh and funding of 80% (\$6,638,000); or
- Biomethane tariff of \$24.40/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 35% (\$2,761,668).

If Farm F were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions*:

- Electricity tariff of \$0.266/kWh;
- Electricity tariff of \$0.10/kWh and funding of 83% (\$6,157,551); or
- Biomethane tariff of \$26.50/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 40% (\$3,016,915).

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

37.0 FARM F PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure the information presented herein is understood in the proper context and with all necessary supporting information.

37.1 Site Description

Farm F is a dairy operation in Armstrong, B.C. that milks 1,000 cows. All barns at the farm use automated alley scrapers for manure collection.

37.2 Project-Specific Considerations

37.2.1 Electrical Interconnection

B.C. Hydro estimates that approximately 4km of single-phase line requires upgrading to three-phase service. According to preliminary estimates, there is availability for up to 999kW at Farm F, and interconnection costs have been estimated at \$2,000,000.

37.2.2 Natural Gas Interconnection

Farm F does not have natural gas available on-site. FortisBC estimates that the closest natural gas line is 2km – 4km away. Interconnection costs have been estimated to be in excess of \$2,000,000.

37.2.3 Availability of Feedstocks

Based on information provided by Farm F, the following feedstocks have been identified as currently available:

- Dairy Manure:
 - Available from 1,000 milkers.

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG):
 - Considered a high-energy non-agricultural feedstock; and
 - Sourced from food processing facilities.
- Source Separated Organics (SSO):
 - Considered a low-energy non-agricultural feedstock; and
 - Consisting of organic compostable materials, such as spoiled produce and plate scrapings.

37.3 Co-Products

AD systems enable production of a number of beneficial co-products. The following section discusses Farm F's co-product opportunities.

37.3.1 Thermal Energy

Thermal energy could be available for use at Farm F through the integration of a co-generation unit or biogas boiler. While the farm operation does not have any significant heat loads, minor heating requirements could be met.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm F could range from 1,000,000btu – 5,000,000btu using a co-generation unit, or 2,000,000btu – 8,000,000btu using high-efficiency, direct combustion.

37.3.2 Livestock Bedding

Farm F spends approximately \$200,000/year on sawdust for livestock bedding. Digestate material from the AD system would be a suitable replacement for livestock bedding if properly managed after the digestion process. Depending on the separation technology selected and desired moisture content, livestock bedding production post-AD typically involves a solid separator and optional drying.

Farm F also spends approximately \$190,000/year hauling manure for land application. The use of a solid separator would isolate the nutrient-rich liquid portion of digestate, likely achieving a significant reduction in hauling costs.

37.3.3 Tipping Fees

Farm F has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

37.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export, or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP. These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of any excess nutrients.

Farm F spends approximately \$80,000/year on synthetic fertilizers, the majority of which is urea.

38.0 FARM F PROJECT OPTIONS

38.1 Option 1: 25% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|---------------------------------|---------------------------------|------------------------------------|
| <i>Dairy manure</i> | <i>104 m³</i> | <i>728 m³</i> | <i>37,850 m³</i> |
| <i>FOG</i> | <i>17 m³</i> | <i>121 m³</i> | <i>6,300 m³</i> |
| <i>SSO</i> | <i>17 m³</i> | <i>121 m³</i> | <i>6,300 m³</i> |
| <i>TOTAL</i> | <i>138 m³</i> | <i>970 m³</i> | <i>50,450 m³</i> |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,500 m³</i> |
| <i>No of digesters:</i> | <i>2</i> |
| <i>Biogas production:</i> | <i>8,544 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.4 kg VS/day</i> |
| <i>HRT:</i> | <i>27 days</i> |
| <i>CHP unit:</i> | <i>880 kW</i> |
| <i>Upgrading unit capacity:</i> | <i>800 m³/hr</i> |

Option 1 uses a mixture of available manure and 25% non-agricultural feedstock. The proposed AD system includes 2 x 1,500m³ digesters and a 880kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 356m³/hour.

38.2 Option 2: 49% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|---------------------------------|-----------------------------------|------------------------------------|
| <i>Dairy manure</i> | <i>104 m³</i> | <i>728 m³</i> | <i>37,850 m³</i> |
| <i>FOG</i> | <i>20 m³</i> | <i>144 m³</i> | <i>7,500 m³</i> |
| <i>SSO</i> | <i>20 m³</i> | <i>144 m³</i> | <i>7,500 m³</i> |
| <i>TOTAL</i> | <i>144 m³</i> | <i>1,016 m³</i> | <i>50,450 m³</i> |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,500 m³</i> |
| <i>No of digesters:</i> | <i>2</i> |
| <i>Biogas production:</i> | <i>9,720 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.6 kg VS/day</i> |
| <i>HRT:</i> | <i>22 days</i> |
| <i>CHP unit:</i> | <i>999 kW</i> |
| <i>Upgrading unit capacity:</i> | <i>800 m³/hr</i> |

Option 2 uses a mixture of available manure and 30% non-agricultural feedstocks. The proposed AD system includes 2 x 1,500m³ digesters and a 999kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 405m³/hour.

39.0 FARM F REQUIRED TARIFFS

39.1 Energy Tariff and Funding Requirements

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--|-------------------------------------|---|--|
| 1: 25% | \$0.266 | 83% | \$26.50 | 40% |
| 2: 49% | \$0.260 | 80% | \$24.40 | 35% |

39.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to capital input, this AD system would require high energy tariffs of \$0.266/kWh or \$26.50/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 83% funding if it produces electricity for sale to the SOP or 40% if it produces biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is not considered economically viable.

Option 2: As a result of the higher energy output proportionate to the capital input, this AD system would require energy tariffs of \$0.260/kWh or \$24.40/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 80% funding if it produces electricity for sale to the SOP or 35% if it produces biomethane for sale to FortisBC. As such, there is a low probability that this option will be economically viable for biomethane production. However, this will depend upon interconnection costs, FortisBC's ability to accept the biomethane into their grid, and the ability to generate economic value from co-products.

There is also a low probability that this option will be economically viable for electricity production. However, this will depend upon interconnection costs, the ability to generate economic value from co-products, and at least a \$0.03/kWh – \$0.07/kWh higher electricity tariff or the availability of some funding. While the required electricity tariff or funding amount for Farm F's AD system are within reason when compared to other jurisdictions, they are currently unavailable in B.C.

40.0 FARM F CONCLUSION

While installation of an AD system at Farm F is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amount, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities.

Option 2 is potentially economically viable for Farm F based on the information provided and used in this study and if favourable feedstocks are available and higher energy tariffs become available in the future.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

41.0 FARM F PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary - FARM F | | | | | | | | |
|---|-----------------------|--------------------|------------------------|--------------------|---------------------------------|--------------------|---------------------------------|--------------------|
| Electricity Production | Option 1 - 25% Non-Ag | | Option 2 - <30% Non-Ag | | Option 1 - w/ funding under SOP | | Option 2 - w/ funding under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 2 | 1,500 | 2 | 1,500 | 2 | 1,500 | 2 | 1,500 |
| Dairy Manure (m3/yr) | | 37,850 | | 37,850 | | 37,850 | | 37,850 |
| Source Separated Organics (SSO) (m3/yr) | | 6,300 | | 7,500 | | 6,300 | | 7,500 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 6,300 | | 7,500 | | 6,300 | | 7,500 |
| Total Feedstock Volume (m3/yr) | | 50,450 | | 52,850 | | 50,450 | | 52,850 |
| Engine operating time (hr/day) | | 21.9 | | 21.9 | | 21.9 | | 21.9 |
| Engine Size kW | | 880 | | 999 | | 880 | | 999 |
| Electricity Production (kWh/yr) | | 6,937,920 | | 7,876,116 | | 6,937,920 | | 7,876,116 |
| Electricity Production (kWh/day) | | 19,272 | | 21,878 | | 19,272 | | 21,878 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$1,026,000 | | \$1,026,000 | | \$1,026,000 | | \$1,026,000 |
| Co-Gen Plant (non-containerized) | | \$968,000 | | \$1,098,900 | | \$968,000 | | \$1,098,900 |
| Powerhouse & Plumbing | | \$274,000 | | \$411,000 | | \$274,000 | | \$411,000 |
| Off-Farm Reception | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (BC Hydro) | | \$2,000,000 | | \$2,000,000 | | \$2,000,000 | | \$2,000,000 |
| High Voltage Connection (non-BC Hydro) | | \$220,000 | | \$330,000 | | \$220,000 | | \$330,000 |
| Low Voltage Electrical Distribution | | \$340,000 | | \$510,000 | | \$340,000 | | \$510,000 |
| System Controls and Automation (inc. hydraulics) | | \$156,000 | | \$234,000 | | \$156,000 | | \$234,000 |
| Project Development (7%) | 7% | \$369,880 | | \$413,693 | | \$369,880 | | \$413,693 |
| Engineering & Project Management (10%) | 10% | \$528,400 | | \$590,990 | | \$528,400 | | \$590,990 |
| Risk Management (20%) | 20% | \$1,236,456 | | \$1,382,917 | | \$1,236,456 | | \$1,382,917 |
| Total Capital Expenditure | | \$7,418,736 | | \$8,297,500 | | \$7,418,736 | | \$8,297,500 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.266 | \$1,845,487 | 0.260 | \$2,047,790 | 0.100 | \$693,792 | 0.100 | \$787,612 |
| Tipping Fees (SSO) | \$30 | \$189,000 | | \$225,000 | | \$189,000 | | \$225,000 |
| Tipping Fees (FOG) | \$15 | \$94,500 | | \$112,500 | | \$94,500 | | \$112,500 |
| Total Revenue | | \$2,128,987 | | \$2,385,290 | | \$977,292 | | \$1,125,112 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$138,758 | | \$157,522 | | \$138,758 | | \$157,522 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$34,690 | | \$39,381 | | \$34,690 | | \$39,381 |
| Labour for System Operation (h/day; \$50/h, 1hr/100kW) | 9 | \$160,600 | 10 | \$182,318 | 9 | \$160,600 | 10 | \$182,318 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$29,139 | | \$33,080 | | \$29,139 | | \$33,080 |
| Reinvestments | 1% | \$74,187 | | \$82,975 | | \$74,187 | | \$82,975 |
| Total Operating Cost | | \$437,375 | | \$495,275 | | \$437,375 | | \$495,275 |
| Net Operational Income | | \$1,691,612 | | \$1,890,015 | | \$539,917 | | \$629,837 |
| Financing | | | | | | | | |
| Total Investment | | \$7,418,736 | | \$8,297,500 | | \$7,418,736 | | \$8,297,500 |
| Grant(s) | | \$0 | | \$0 | 83% | \$6,157,551 | 80% | \$6,638,000 |
| Loan | 100% | \$7,418,736 | 100% | \$8,297,500 | 17% | \$1,261,185 | 20% | \$1,659,500 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.0% | | 4.9% |
| Average Income Before Tax | | \$740,478 | | \$826,229 | | \$372,201 | | \$409,303 |

42.0 FARM F PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary - FARM F | | | | | | | | |
|---|----------------------|--------------------|------------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| Biogas Upgrading | Option 1 -25% Non-Ag | | Option 2 - <30% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 2 | 1,500 | 2 | 1,500 | 2 | 1,500 | 2 | 1,500 |
| Dairy Manure (m3/yr) | | 37,850 | | 37,850 | | 37,850 | | 37,850 |
| Source Separated Organics (SSO) (m3/yr) | | 6,300 | | 7,500 | | 6,300 | | 7,500 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 6,300 | | 7,500 | | 6,300 | | 7,500 |
| Total Feedstock Volume (m3/yr) | | 50,450 | | 52,850 | | 50,450 | | 52,850 |
| Biogas Production (m3/hr) | | 356 | | 405 | | 356 | | 405 |
| Biogas Production (m3/yr) | | 3,118,560 | | 3,547,800 | | 3,118,560 | | 3,547,800 |
| Energy Production (GJ/hr) | | 7,476 | | 8,505 | | 7,476 | | 8,505 |
| Energy Production (GJ/yr) | | 65,490 | | 74,504 | | 65,490 | | 74,504 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$1,026,000 | | \$1,026,000 | | \$1,026,000 | | \$1,026,000 |
| Biogas Upgrading System | | \$1,500,000 | | \$1,500,000 | | \$1,500,000 | | \$1,500,000 |
| Off-Farm Reception | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| FortisBC Interconnection | | \$2,000,000 | | \$2,000,000 | | \$2,000,000 | | \$2,000,000 |
| Low Voltage Electrical | | \$340,000 | | \$510,000 | | \$340,000 | | \$510,000 |
| System Controls and Automation (inc. hydraulics) | | \$156,000 | | \$234,000 | | \$156,000 | | \$234,000 |
| Project Development (7%) | 7% | \$376,040 | | \$393,400 | | \$376,040 | | \$393,400 |
| Engineering & Project Management (10%) | 10% | \$537,200 | | \$562,000 | | \$537,200 | | \$562,000 |
| Risk Management (20%) | 20% | \$1,257,048 | | \$1,315,080 | | \$1,257,048 | | \$1,315,080 |
| Total Capital Expenditure | | \$7,542,288 | | \$7,890,480 | | \$7,542,288 | | \$7,890,480 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 26.50 | \$1,735,479 | 24.40 | \$1,817,893 | 15.28 | \$1,000,684 | 15.28 | \$1,138,418 |
| Tipping Fees (SSO) | \$30 | \$189,000 | | \$225,000 | | \$189,000 | | \$225,000 |
| Tipping Fees (FOG) | \$15 | \$94,500 | | \$112,500 | | \$94,500 | | \$112,500 |
| Total Revenue | | \$2,018,979 | | \$2,155,393 | | \$1,284,184 | | \$1,475,918 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$31,186 | | \$35,478 | \$0.01 | \$31,186 | | \$35,478 |
| Labour for System Op. (h/day; \$35/h, 1 hr/50m3 biogas) | 7 | \$90,958 | 8 | \$103,478 | 7 | \$90,958 | 8 | \$103,478 |
| AD Elec. Consumption (7% of Prod. Equiv. @ \$0.06/kWh) | 7% | \$26,196 | | \$29,802 | | \$26,196 | | \$29,802 |
| Upgrading System Electricity Consumption | | \$55,000 | | \$88,000 | | \$55,000 | | \$88,000 |
| Reinvestments | 1% | \$75,423 | | \$78,905 | | \$75,423 | | \$78,905 |
| Total Operating Cost | | \$302,362 | | \$359,262 | | \$302,362 | | \$359,262 |
| Net Operational Income | | \$1,716,616 | | \$1,796,131 | | \$981,821 | | \$1,116,656 |
| Financing | | | | | | | | |
| Total Investment | | \$7,542,288 | | \$7,890,480 | | \$7,542,288 | | \$7,890,480 |
| Grant(s) | | \$0 | | \$0 | 40% | \$3,016,915 | 35% | \$2,761,668 |
| Loan | 100% | \$7,542,288 | 100% | \$7,890,480 | 60% | \$4,525,373 | 60% | \$5,128,812 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 4.9% | | 5.3% |
| Average Income Before Tax | | \$756,220 | | \$789,636 | | \$366,821 | | \$419,656 |

Farm G

Anaerobic Digestion Feasibility Study

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43.0 FARM G EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm G” in Dawson Creek. The system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm G would process combination of livestock manure and non-agricultural feedstocks to produce renewable energy and other beneficial co-products.

This study concludes that the proposed AD system on Farm G would be economically viable with 49% non-agricultural feedstock, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.324/kWh;
- Electricity tariff of \$0.10/kWh and funding of 92.5% (\$2,171,426); or
- Biomethane tariff of \$44.20/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 85% (\$2,593,258).

If Farm G were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions:

- Electricity tariff of \$0.544/kWh;
- Electricity tariff of \$0.10/kWh and funding of 100% (\$1,592,838); or
- Biomethane tariff of \$97.00/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 100% (\$2,595,996).

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

44.0 FARM G PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure the information presented herein is understood in the proper context and with all necessary supporting information.

Farm G has expressed an interest in developing a “bio-energy cluster”. As such, the AD system would be part of this cluster and would support educational initiatives and serve as a demonstration system for the region. As a result, Farm G has expressed separate motives in provision of educational services to students and the local agriculture.

44.1 Site Description

Farm G is an academic institution in Dawson Creek, B.C. that operates an agricultural facility housing approximately 100 beef cattle. Within a kilometre of the farm location, there is a cattle auction house with an unknown quantity of livestock manure production, as well as a horse-showing complex in which there are 130 horses housed on-site at any given time. Manure from these operations has been included in considerations for the development of this AD system.

Farm G has also identified a local abattoir within a kilometre of the farm. This abattoir could supply viscera and washwater, if deemed favourable and feasible. Quantities are unknown at this time. Furthermore, management at Farm G has expressed interest in using purpose-grown energy crops in the AD system. However, because the economics of energy crops are not favourable in B.C. or Canada, and because energy crops require significant dilution to anaerobically digest them in completely-mixed systems, this feedstock was not included in system options discussed in this study.

44.2 Project-Specific Considerations

44.2.1 Electrical Interconnection

Farm G has three-phase service on site. According to preliminary estimates, there is availability for up to 999kW at Farm G, and interconnection costs have been estimated at \$375,000 – \$450,000.

44.2.2 Natural Gas Interconnection

Farm G has natural gas available on-site. Interconnection costs have been estimated at \$250,000-\$350,000. FortisBC can accept all of the biomethane from this system into their grid.

44.2.3 Availability of Feedstocks

Based on information provided by Farm G, the following feedstocks have been identified as currently available:

- Beef Cattle Manure:
 - Available from 100 head of beef as well as additional available from local cattle auction house.
- Horse Manure:
 - 130 horses in nearby stables.
- Process Water and Viscera:
 - Available from local abattoir.
- Hog Manure or other on-farm feedstock @ less than 5% TS:
 - Need to source an existing on-farm feedstock to achieve the necessary dilution for AD.

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG):
 - Considered a high-energy non-agricultural feedstock;
 - To stay within the normal operating parameters of the AD system, this FOG must contain <15% TS; and
 - Sourced from food processing facilities.
- Source Separated Organics (SSO):
 - Considered a low-energy non-agricultural feedstock;
 - To stay within the normal operating parameters of the AD system, this must be <15% TS when mixed with agricultural sources; and
 - Consisting of organic compostable material such as spoiled produce and plate scrapings.

The City of Dawson Creek has indicated that it wishes to divert all organic waste from its local landfill within the coming years. This policy would likely facilitate an increased availability of organic feedstocks for the proposed AD system.

If Farm G cannot source a low TS agricultural feedstock, than low-TS, non-agricultural feedstock would be required. This would result in the AD system's regulatory capacity for non-agricultural waste being used to satisfy the operational requirements of the system, as opposed to maximizing energy output and economic viability.

44.3 Co-Products

AD systems enable the production of a number of beneficial co-products. The following section discusses Farm G's co-product opportunities.

44.3.1 Thermal Energy

Thermal energy could be available for use at Farm G through the integration of a co-generation unit or biogas boiler. While the current farm operation does not have any significant heat loads, minor heating requirements could be met, and there are plans to build greenhouses if an affordable source of heat is available.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm G could range from 350,000btu – 1,000,000btu using a co-generation unit, or 450,000btu – 2,500,000btu using high-efficiency, direct combustion.

44.3.2 Livestock Bedding

Digestate material from the AD system would be a suitable replacement for livestock bedding if properly managed after the digestion process. Depending on the separation technology selected and desired moisture content, livestock bedding production post-AD typically involves a solid separator and optional drying.

44.3.3 Tipping Fees

Farm G has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

44.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export, or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP. These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of any excess nutrients.

45.0 FARM G PROJECT OPTIONS

45.1 Option 1: 25% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|-------------------|-------------------------|-------------------------|----------------------------|
| Total manure | 10 m ³ | 74 m ³ | 3,850 m ³ |
| FOG | 1.5 m ³ | 12 m ³ | 640 m ³ |
| SSO | 1.5 m ³ | 12 m ³ | 640 m ³ |
| TOTAL | 13 m³ | 98 m³ | 5,130 m³ |

| | |
|--|-------------------------|
| <i>Minimal required digester volume:</i> | 500 m ³ |
| <i>No of digesters:</i> | 1 |
| <i>Biogas production:</i> | 864 m ³ /day |
| <i>Organic loading rate:</i> | 3.1 kg VS/day |
| <i>HRT:</i> | 27 days |
| <i>CHP unit:</i> | 90 kW |
| <i>Upgrading unit capacity:</i> | 150 m ³ /hr |

Option 1 uses a mixture of available manure and 25% non-agricultural feedstock. The proposed AD system includes a 500m³ digester and a 90kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 36m³/hour.

45.2 Option 2: 49% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|-------------------|-------------------------|--------------------------|----------------------------|
| Total manure | 10 m ³ | 74 m ³ | 3,850 m ³ |
| FOG | 5 m ³ | 37 m ³ | 1,925 m ³ |
| SSO | 5 m ³ | 37 m ³ | 1,925 m ³ |
| TOTAL | 20 m³ | 148 m³ | 7,700 m³ |

| | |
|--|---------------------------|
| <i>Minimal required digester volume:</i> | 750 m ³ |
| <i>No of digesters:</i> | 1 |
| <i>Biogas production:</i> | 2,112 m ³ /day |
| <i>Organic loading rate:</i> | 3.4 kg VS/day |
| <i>HRT:</i> | 28 days |
| <i>CHP unit:</i> | 220 kW |
| <i>Upgrading unit capacity:</i> | 150 m ³ /hr |

Option 2 uses a mixture of available manure and 49% non-agricultural feedstocks. The proposed AD system includes a 750m³ digester and a 220kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 88m³/hour.

46.0 FARM G REQUIRED TARIFFS

46.1 Energy Tariff and Funding Requirement

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--|-------------------------------------|---|--|
| 1: 25% | \$0.544 | 100% | \$97.00 | 100% |
| 2: 49% | \$0.324 | 92.5% | \$44.20 | 85% |

46.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to capital input, this AD system would require high energy tariffs of \$0.544/kWh or \$97.00/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 100% funding if it produces electricity for sale to the SOP or 100% if it produces biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is not considered economically viable.

Option 2: Despite the higher energy output proportionate to the capital input, this AD system would still require high energy tariffs of \$0.324/kWh or \$44.20/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 92.5% funding if it produces electricity for sale to the SOP or 85% if it produces biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is also not considered economically viable.

47.0 FARM G CONCLUSION

While installation of an AD system at Farm G is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amount, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities and characteristics. Furthermore, addition of a significant quantity of low TS feedstock is also vital to enable the AD system to operate.

Based on the information provided and used in this study, none of the AD system options are considered economically viable for Farm G. However, because Farm G is part of an academic institution, the desire to support educational initiatives and serve as a demonstration system for the region may mean that the AD system is built, regardless of economic viability.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

48.0 FARM G PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary - FARM G | | | | | | | | |
|---|-----------------------|--------------------|-----------------------|--------------------|------------------------------------|--------------------|------------------------------------|--------------------|
| Electricity Production | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/grant money under SOP | | Option 2 - w/grant money under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 500 | 1 | 750 | 1 | 500 | 1 | 750 |
| Horse, Dairy & Beef Manure @ 30% TS (m3/yr) | | 1,500 | | 1,500 | | 1,500 | | 1,500 |
| Hog Manure or other on-farm @ 5% TS (m3/yr) | | 2,350 | | 2,350 | | 2,350 | | 2,350 |
| Source Separated Organics <15% TS (SSO) (m3/yr) | | 640 | | 1,925 | | 640 | | 1,925 |
| Fats, Oils and Grease <15% TS (FOG) (m3/yr) | | 640 | | 1,925 | | 640 | | 1,925 |
| Total Feedstock Volume (m3/yr) | | 5,130 | | 7,700 | | 5,130 | | 7,700 |
| Engine operating time (hr/day) | | 21.9 | | 21.9 | | 21.9 | | 21.9 |
| Engine Size kW | | 90 | | 220 | | 90 | | 220 |
| Electricity Production (kWh/yr) | | 709,560 | | 1,734,480 | | 709,560 | | 1,734,480 |
| Electricity Production (kWh/day) | | 1,971 | | 4,818 | | 1,971 | | 4,818 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$300,000 | | \$400,000 | | \$300,000 | | \$400,000 |
| Co-Gen Plant (non-containerized) | | \$162,000 | | \$352,000 | | \$162,000 | | \$352,000 |
| Off-Farm Reception | | \$125,000 | | \$125,000 | | \$125,000 | | \$125,000 |
| Powerhouse & Plumbing | | \$68,500 | | \$137,000 | | \$68,500 | | \$137,000 |
| High Voltage Connection (BC Hydro) | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (non-BC Hydro) | | \$55,000 | | \$110,000 | | \$55,000 | | \$110,000 |
| Low Voltage Electrical Distribution | | \$85,000 | | \$170,000 | | \$85,000 | | \$170,000 |
| System Controls and Automation (inc. hydraulics) | | \$39,000 | | \$78,000 | | \$39,000 | | \$78,000 |
| Project Development (7%) | 7% | \$79,415 | | \$117,040 | | \$79,415 | | \$117,040 |
| Engineering & Project Management (10%) | 10% | \$113,450 | | \$167,200 | | \$113,450 | | \$167,200 |
| Risk Management (20%) | 20% | \$265,473 | | \$391,248 | | \$265,473 | | \$391,248 |
| Total Capital Expenditure | | \$1,592,838 | | \$2,347,488 | | \$1,592,838 | | \$2,347,488 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.544 | \$386,001 | 0.324 | \$561,972 | 0.100 | \$70,956 | 0.100 | \$173,448 |
| Tipping Fees (SSO) | \$30 | \$19,200 | | \$57,750 | | \$19,200 | | \$57,750 |
| Tipping Fees (FOG) | \$15 | \$9,600 | | \$28,875 | | \$9,600 | | \$28,875 |
| Total Revenue | | \$414,801 | | \$648,597 | | \$99,756 | | \$260,073 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$14,191 | | \$34,690 | | \$14,191 | | \$34,690 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$3,548 | | \$8,672 | | \$3,548 | | \$8,672 |
| Labour for System Operation (h/day; \$50/h, 1hr/100kW) | 1 | \$16,425 | 2 | \$40,150 | 1 | \$16,425 | 2 | \$40,150 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$2,980 | | \$7,285 | | \$2,980 | | \$7,285 |
| Reinvestments | 1% | \$15,928 | | \$23,475 | | \$15,928 | | \$23,475 |
| Total Operating Cost | | \$53,073 | | \$114,272 | | \$53,073 | | \$114,272 |
| Net Operational Income | | \$361,728 | | \$534,325 | | \$46,683 | | \$145,801 |
| Financing | | | | | | | | |
| Total Investment | | \$1,592,838 | | \$2,347,488 | | \$1,592,838 | | \$2,347,488 |
| Grant(s) | | \$0 | | \$0 | 100% | \$1,592,838 | 92.5% | \$2,171,426 |
| Loan | 100% | \$1,592,838 | 100% | \$2,347,488 | 0% | \$0 | 7.5% | \$176,062 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI Before tax | | 10.0% | | 10.0% | | 2.9% | | 5.2% |
| Average Income Before Tax | | \$159,460 | | \$234,451 | | \$46,254 | | \$122,970 |

49.0 FARM G PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary - FARM G | | | | | | | | |
|--|-----------------------|--------------------|-----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| Biogas Upgrading | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 500 | 1 | 750 | 1 | 500 | 1 | 750 |
| Horse, Dairy & Beef Manure @ 30% TS (m3/yr) | | 1,500 | | 1,500 | | 1,500 | | 1,500 |
| Hog Manure or other on-farm @ 5% TS (m3/yr) | | 2,350 | | 2,350 | | 2,350 | | 2,350 |
| Source Separated Organics <15% TS (SSO) (m3/yr) | | 640 | | 1,925 | | 640 | | 1,925 |
| Fats, Oils and Grease <15% TS (FOG) (m3/yr) | | 640 | | 1,925 | | 640 | | 1,925 |
| Total Feedstock Volume (m3/yr) | | 5,130 | | 7,700 | | 5,130 | | 7,700 |
| Biogas Production (m3/hr) | | 36 | | 88 | | 36 | | 88 |
| Biogas Production (m3/yr) | | 315,360 | | 770,880 | | 315,360 | | 770,880 |
| Energy Production (GJ/hr) | | 0.756 | | 1.848 | | 0.756 | | 1.848 |
| Energy Production (GJ/yr) | | 6,623 | | 16,188 | | 6,623 | | 16,188 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$300,000 | | \$400,000 | | \$300,000 | | \$400,000 |
| Biogas Upgrading System | | \$1,000,000 | | \$1,000,000 | | \$1,000,000 | | \$1,000,000 |
| Off-Farm Reception | | \$125,000 | | \$125,000 | | \$125,000 | | \$125,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| FortisBC Interconnection | | \$250,000 | | \$350,000 | | \$250,000 | | \$350,000 |
| Low Voltage Electrical | | \$85,000 | | \$170,000 | | \$85,000 | | \$170,000 |
| System Controls and Automation (inc. hydraulics) | | \$39,000 | | \$78,000 | | \$39,000 | | \$78,000 |
| Project Development (7%) | 7% | \$129,430 | | \$152,110 | | \$129,430 | | \$152,110 |
| Engineering & Project Management (10%) | 10% | \$184,900 | | \$217,300 | | \$184,900 | | \$217,300 |
| Risk Management (20%) | 20% | \$432,666 | | \$508,482 | | \$432,666 | | \$508,482 |
| Total Capital Expenditure | | \$2,595,996 | | \$3,050,892 | | \$2,595,996 | | \$3,050,892 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 97.00 | \$642,388 | 44.20 | \$715,531 | 15.28 | \$101,193 | 15.28 | \$247,360 |
| Tipping Fees (SSO) | \$30 | \$19,200 | | \$57,750 | | \$19,200 | | \$57,750 |
| Tipping Fees (FOG) | \$15 | \$9,600 | | \$28,875 | | \$9,600 | | \$28,875 |
| Total Revenue | | \$671,188 | | \$802,156 | | \$129,993 | | \$333,985 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$3,154 | | \$7,709 | \$0.01 | \$3,154 | | \$7,709 |
| Labour for System Op. (h/day; \$35/h, 1hr/50m3 biogas) | 1 | \$9,198 | 2 | \$22,484 | 1 | \$9,198 | 2 | \$22,484 |
| AD Elec. Consumption (7% of Prod. Equip. @ \$0.06/kWh) | 7% | \$2,649 | | \$6,475 | 7% | \$2,649 | | \$6,475 |
| Upgrading System Electricity Consumption | | \$18,000 | | \$18,000 | | \$18,000 | | \$18,000 |
| Reinvestments | 1% | \$25,960 | | \$30,509 | 1% | \$25,960 | | \$30,509 |
| Total Operating Cost | | \$82,561 | | \$108,777 | | \$82,561 | | \$108,777 |
| Net Operational Income | | \$588,628 | | \$693,379 | | \$47,432 | | \$225,208 |
| Financing | | | | | | | | |
| Total Investment | | \$2,595,996 | | \$3,050,892 | | \$2,595,996 | | \$3,050,892 |
| Grant(s) | | \$0 | | \$0 | 100% | \$2,595,996 | 85% | \$2,593,258 |
| Loan | 100% | \$2,595,996 | 100% | \$3,050,892 | 0% | \$0 | 15% | \$457,634 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 1.8% | | 5.3% |
| Average Income Before Tax | | \$258,810 | | \$305,625 | | \$47,432 | | \$163,008 |

Farm H

Anaerobic Digestion Feasibility Study

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50.0 FARM H EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm H” in North Saanich. The system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm H would process dairy manure and non-agricultural feedstocks to produce renewable energy and other beneficial co-products.

This study concludes that the proposed AD system on Farm H would be economically viable with 49% non-agricultural feedstock, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.202/kWh;
- Electricity tariff of \$0.10/kWh and funding of 60% (\$2,048,296); or
- Biomethane tariff of \$20.90/GJ;
- Biomethane tariff of \$15.28 will produce 6.7% ROI without funding.

If Farm H were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions*:

- Electricity tariff of \$0.360/kWh;
- Electricity tariff of \$0.10/kWh and funding of 100% (\$2,430,324); or
- Biomethane tariff of \$46.40/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 90% (\$2,714,213).

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

51.0 FARM H PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure the information presented herein is understood in the proper context and with all necessary supporting information.

51.1 Site Description

Farm H is a dairy operation in North Saanich, B.C. that milks 210 cows. With the inclusion of young stock and dry cows, total herd size is approximately 480 cows. All barns use alley scrapers to collect the manure, which is piped to a final storage lagoon via an intermediary covered storage tank. Manure collection is done by automated alley scrapers.

51.2 Project-Specific Considerations

51.2.1 Electrical Interconnection

Farm H has three-phase service on-site. Interconnection costs have been estimated at \$500,000.

51.2.2 Natural Gas Interconnection

Farm H does not have natural available on-site. FortisBC estimates that the closest natural gas line is less than 250m away. Interconnection costs have been estimated at \$250,000 – \$350,000.

51.2.3 Availability of Feedstocks

Based on information provided by Farm H, the following feedstocks have been identified as currently available:

- Dairy Manure:
 - Available from 210 milkers and 270 young stock mixed with dry cows.

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG):
 - Considered a high-energy non-agricultural feedstock; and
 - Sourced from food processing facilities.
- Source Separated Organics (SSO):
 - Considered a low-energy non-agricultural feedstock; and
 - Consisting of organic compostable materials, such as spoiled produce and plate scrapings.

51.3 Co-Products

AD systems enable the production of a number of beneficial co-products. The following section discusses Farm H's co-product opportunities.

51.3.1 Thermal Energy

Thermal energy could be available for use at Farm H through the integration of a co-generation unit or biogas boiler. Approximately 500 metres north of Farm H is a greenhouse operation that is presumed to have high heat loads. As such, thermal energy produced by the AD system could be used by the greenhouse operation.

The use of raw biogas at the greenhouse operation could also be an option. However, as this would directly offset low-cost natural gas, it is unlikely that the economics of this option would be

favourable. Furthermore, management of condensation formed in biogas transfer pipes could pose technical challenges and/or additional capital costs.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm H could range from 350,000btu – 1,200,000btu using a co-generation unit, or 750,000btu – 3,500,000btu using high-efficiency, direct combustion.

51.3.2 Livestock Bedding

Farm H spends approximately \$60,000/year on sawdust for livestock bedding. Digestate material from the AD system would be a suitable replacement for livestock bedding if properly managed after the digestion process. Depending on the separation technology selected and desired moisture content, livestock bedding production post-AD typically involves a solid separator and optional drying.

51.3.3 Tipping Fees

Farm H has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

51.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export, or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP. These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of any excess nutrients.

Farm H spends approximately \$25,000 - \$30,000/year on urea.

52.0 FARM H PROJECT OPTIONS

52.1 Option 1: 25% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|-------------------------|--------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>25 m³</i> | <i>173 m³</i> | <i>9,000 m³</i> |
| <i>FOG</i> | <i>4 m³</i> | <i>29 m³</i> | <i>1,500 m³</i> |
| <i>SSO</i> | <i>4 m³</i> | <i>29 m³</i> | <i>1,500 m³</i> |
| TOTAL | 33 m³ | 231 m³ | 12,000 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,000 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>2,040 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.5kgVS/day</i> |
| <i>HRT:</i> | <i>28 days</i> |
| <i>CHP unit:</i> | <i>210 kW</i> |
| <i>Upgrading unit capacity</i> | <i>150 m³/hr</i> |

Option 1 uses a mixture of available manure and 25% non-agricultural feedstocks. The proposed AD system includes a 1,000m³ digester and a 210kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 85m³/hour.

52.2 Option 2: 49% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|-------------------------|--------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>25 m³</i> | <i>173 m³</i> | <i>9,000 m³</i> |
| <i>FOG</i> | <i>12 m³</i> | <i>86 m³</i> | <i>4,500 m³</i> |
| <i>SSO</i> | <i>12 m³</i> | <i>86 m³</i> | <i>4,500 m³</i> |
| TOTAL | 49 m³ | 345 m³ | 18,000 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,500 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>4,944 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.2kgVS/day</i> |
| <i>HRT:</i> | <i>29 days</i> |
| <i>CHP unit:</i> | <i>520 kW</i> |
| <i>Upgrading unit capacity</i> | <i>300 m³/hr</i> |

Option 2 uses a mixture of available manure and 49% non-agricultural feedstocks. The proposed AD system includes a 1,500m³ digester and a 520kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 220m³/hour.

53.0 FARM H REQUIRED TARIFFS

53.1 Energy Tariff and Funding Requirements

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--|-------------------------------------|---|--|
| 1: 25% | \$0.360 | 100% | \$46.40 | 90% |
| 2: 49% | \$0.202 | 60% | \$20.90 | 0%* |

Note*: 0% indicates the AD system is able to make greater than 5% ROI using \$15.28/GJ

53.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to capital input, this AD system would require high energy tariffs of \$0.360/kWh or \$46.40/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 100% funding if it produces electricity for sale to the SOP or 90% if it produces biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is not considered economically viable.

Option 2: As a result of the higher energy output proportionate to the capital input, this AD system would require energy tariffs of \$0.202/kWh or \$20.90/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 60% funding if it produces electricity for sale to the SOP. As such, there is a high probability that this option will be economically viable for biomethane production. However, this will depend upon interconnection costs, FortisBC's ability to accept the biomethane into their grid, and the ability to generate economic value from co-products.

There is also a low probability that this option will be economically viable for electricity production. However, this will depend upon interconnection costs, the ability to generate economic value from co-products, and at least a \$0.04/kWh – \$0.09/kWh higher electricity tariff or the availability of some funding. While the required electricity tariff or funding amount for Farm H's AD system are within reason when compared to other jurisdictions, they are currently unavailable in B.C.

54.0 FARM H CONCLUSION

While installation of an AD system at Farm H is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amount, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities.

Option 2, biomethane production, is considered economically viable for Farm H based on the information provided and used in this study. Option 2, electricity production, may also be economically viable for Farm H if a slightly higher electricity tariff or funding becomes available.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

55.0 FARM H PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary - FARM H | | | | | | | | |
|---|-----------------------|--------------------|-----------------------|--------------------|------------------------------------|--------------------|------------------------------------|--------------------|
| Electricity Production | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/grant money under SOP | | Option 2 - w/grant money under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,000 | 1 | 1,500 | 1 | 1,000 | 1 | 1,500 |
| Dairy Manure (m3/yr) | | 9,000 | | 9,000 | | 9,000 | | 9,000 |
| Source Separated Organics (SSO) (m3/yr) | | 1,500 | | 4,500 | | 1,500 | | 4,500 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 1,500 | | 4,500 | | 1,500 | | 4,500 |
| Total Feedstock Volume (m3/yr) | | 12,000 | | 18,000 | | 12,000 | | 18,000 |
| Engine operating time (hr/day) | | 21.9 | | 21.9 | | 21.9 | | 21.9 |
| Engine Size kW | | 210 | | 520 | | 210 | | 520 |
| Electricity Production (kWh/yr) | | 1,655,640 | | 4,099,680 | | 1,655,640 | | 4,099,680 |
| Electricity Production (kWh/day) | | 4,599 | | 11,388 | | 4,599 | | 11,388 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$475,000 | | \$513,000 | | \$475,000 | | \$513,000 |
| Co-Gen Plant (non-containerized) | | \$336,000 | | \$676,000 | | \$336,000 | | \$676,000 |
| Off-Farm Reception | | \$125,000 | | \$200,000 | | \$125,000 | | \$200,000 |
| Powerhouse & Plumbing | | \$137,000 | | \$205,500 | | \$137,000 | | \$205,500 |
| High Voltage Connection (BC Hydro) | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (non-BC Hydro) | | \$110,000 | | \$165,000 | | \$110,000 | | \$165,000 |
| Low Voltage Electrical Distribution | | \$170,000 | | \$255,000 | | \$170,000 | | \$255,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$117,000 | | \$78,000 | | \$117,000 |
| Project Development (7%) | 7% | \$121,170 | | \$170,205 | | \$121,170 | | \$170,205 |
| Engineering & Project Management (10%) | 10% | \$173,100 | | \$243,150 | | \$173,100 | | \$243,150 |
| Risk Management (20%) | 20% | \$405,054 | | \$568,971 | | \$405,054 | | \$568,971 |
| Total Capital Expenditure | | \$2,430,324 | | \$3,413,826 | | \$2,430,324 | | \$3,413,826 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.360 | \$596,030 | 0.202 | \$828,135 | 0.100 | \$165,564 | 0.100 | \$409,968 |
| Tipping Fees (SSO) | \$30 | \$45,000 | | \$135,000 | | \$45,000 | | \$135,000 |
| Tipping Fees (FOG) | \$15 | \$22,500 | | \$67,500 | | \$22,500 | | \$67,500 |
| Total Revenue | | \$663,530 | | \$1,030,635 | | \$233,064 | | \$612,468 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$33,113 | | \$81,994 | | \$33,113 | | \$81,994 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$8,278 | | \$20,498 | | \$8,278 | | \$20,498 |
| Labour for System Operation (h/day; \$50/h, 1hr/100kW) | 2 | \$38,325 | 5 | \$94,900 | 2 | \$38,325 | 5 | \$94,900 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$6,954 | | \$17,219 | | \$6,954 | | \$17,219 |
| Reinvestments | 1% | \$24,303 | | \$34,138 | | \$24,303 | | \$34,138 |
| Total Operating Cost | | \$110,973 | | \$248,749 | | \$110,973 | | \$248,749 |
| Net Operational Income | | \$552,557 | | \$781,886 | | \$122,091 | | \$363,719 |
| Financing | | | | | | | | |
| Total Investment | | \$2,430,324 | | \$3,413,826 | | \$2,430,324 | | \$3,413,826 |
| Grant(s) | | \$0 | | \$0 | 100% | \$2,430,324 | 60% | \$2,048,296 |
| Loan | 100% | \$2,430,324 | 100% | \$3,413,826 | 0% | \$0 | 40% | \$1,365,530 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.0% | | 5.4% |
| Average Income Before Tax | | \$242,487 | | \$341,899 | | \$122,324 | | \$182,904 |

56.0 FARM H PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary - FARM H | | | | | | | | |
|--|-----------------------|--------------------|-----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| Biogas Upgrading | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,000 | 1 | 1,500 | 1 | 1,000 | 1 | 1,500 |
| Dairy Manure (m3/yr) | | 9,000 | | 9,000 | | 9,000 | | 9,000 |
| Source Separated Organics (SSO) (m3/yr) | | 1,500 | | 4,500 | | 1,500 | | 4,500 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 1,500 | | 4,500 | | 1,500 | | 4,500 |
| Total Feedstock Volume (m3/yr) | | 12,000 | | 18,000 | | 12,000 | | 18,000 |
| Biogas Production (m3/hr) | | 85 | | 220 | | 85 | | 220 |
| Biogas Production (m3/yr) | | 744,600 | | 1,927,200 | | 744,600 | | 1,927,200 |
| Energy Production (GJ/hr) | | 1.785 | | 4.620 | | 1.785 | | 4.620 |
| Energy Production (GJ/yr) | | 15,637 | | 40,471 | | 15,637 | | 40,471 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$475,000 | | \$513,000 | | \$475,000 | | \$513,000 |
| Biogas Upgrading System | | \$1,000,000 | | \$1,200,000 | | \$1,000,000 | | \$1,200,000 |
| Off-Farm Reception | | \$125,000 | | \$200,000 | | \$125,000 | | \$200,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| FortisBC Interconnection | | \$250,000 | | \$350,000 | | \$250,000 | | \$350,000 |
| Low Voltage Electrical | | \$170,000 | | \$255,000 | | \$170,000 | | \$255,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$117,000 | | \$78,000 | | \$117,000 |
| Project Development (7%) | 7% | \$150,360 | | \$187,950 | | \$150,360 | | \$187,950 |
| Engineering & Project Management (10%) | 10% | \$214,800 | | \$268,500 | | \$214,800 | | \$268,500 |
| Risk Management (20%) | 20% | \$502,632 | | \$628,290 | | \$502,632 | | \$628,290 |
| Total Capital Expenditure | | \$3,015,792 | | \$3,769,740 | | \$3,015,792 | | \$3,769,740 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 46.40 | \$725,538 | 20.90 | \$845,848 | 15.28 | \$238,927 | 15.28 | \$618,400 |
| Tipping Fees (SSO) | \$30 | \$45,000 | | \$135,000 | | \$45,000 | | \$225,000 |
| Tipping Fees (FOG) | \$15 | \$22,500 | | \$67,500 | | \$22,500 | | \$112,500 |
| Total Revenue | | \$793,038 | | \$1,048,348 | | \$306,427 | | \$955,900 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$7,446 | | \$19,272 | | \$7,446 | | \$19,272 |
| Labour for System Op. (h/day; \$35/h, 1hr/50m3 biogas) | 2 | \$21,718 | 4 | \$56,210 | 2 | \$21,718 | 4 | \$56,210 |
| AD Elec. Consumption (7% of Prod. Equiv. @ \$0.06/kWh) | 7% | \$6,255 | | \$16,188 | | \$6,255 | | \$16,188 |
| Upgrading System Electricity Consumption | | \$18,000 | | \$37,000 | | \$18,000 | | \$37,000 |
| Reinvestments | 1% | \$30,158 | | \$37,697 | | \$30,158 | | \$37,697 |
| Total Operating Cost | | \$107,176 | | \$189,968 | | \$107,176 | | \$189,968 |
| Net Operational Income | | \$685,862 | | \$858,380 | | \$199,251 | | \$765,932 |
| Financing | | | | | | | | |
| Total Investment | | \$3,015,792 | | \$3,769,740 | | \$3,015,792 | | \$3,769,740 |
| Grant(s) | | \$0 | | \$0 | 90% | \$2,714,213 | 0% | \$0 |
| Loan | 100% | \$3,015,792 | 100% | \$3,769,740 | 10% | \$301,579 | 100% | \$3,769,740 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.2% | | 6.7% |
| Average Income Before Tax | | \$302,339 | | \$376,795 | | \$158,251 | | \$253,932 |

Farm I

Anaerobic Digestion Feasibility Study

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57.0 FARM I EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm I” in Deroche. The system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm I would process dairy manure and non-agricultural feedstocks to produce renewable energy and other beneficial co-products.

This study concludes that the proposed AD system on Farm I would be economically viable with 49% non-agricultural feedstock, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.161/kWh;
- Electricity tariff of \$0.10/kWh and funding of 35% (\$1,757,246); or
- Biomethane tariff of \$17.20/GJ;
- Biomethane tariff of \$15.28/GJ will produce 6.8% ROI without funding.

If Farm I were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions*:

- Electricity tariff of \$0.244/kWh;
- Electricity tariff of \$0.10/kWh and funding of 80% (\$2,394,662); or
- Biomethane tariff of \$34.80/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 70% (\$2,910,071).

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

58.0 FARM I PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure the information presented herein is understood in the proper context and with all necessary supporting information.

58.1 Site Description

Farm I is a dairy operation in Deroche, B.C. that milks 400 cows. Adjacent to Farm I is a dairy farm that milks 100 certified organic cows. Because the cows at this neighbouring farm are pastured for approximately 6 months of the year, manure quantities used in this study account for the fact that this manure is only available 6 months a year. Manure collection is by automated alley scraper and would be pumped to the AD site from the neighbouring farm as needed.

58.2 Project-Specific Considerations

58.2.1 Electrical Interconnection

Farm I has a three-phase service on-site. According to preliminary estimates, there is availability for up to 500kW at Farm I, and Interconnection costs have been estimated at \$500,000. For the purposes of this study a standard AD model has been used. If a project is to move forward with electrical generation BC Hydro will have to agree to take all the produced energy.

58.2.2 Natural Gas Interconnection

Neither Farm I nor the neighbouring farm have natural gas available on-site. Furthermore, it is understood to be an extremely long distance away. Despite interconnection being unavailable for this site, this study includes biomethane production for the purposes of informing the B.C. Anaerobic Digestion Benchmark Study. Interconnection costs have been generously estimated at \$750,000.

58.2.3 Availability of Feedstocks

Based on information provided by Farm I, the following feedstocks have been identified as currently available:

- Dairy Manure:
 - 400 milkers on-site and neighbours 100 milkers (of which half the manure can be collected and used in the AD system).

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG):
 - Considered a high-energy non-agricultural feedstock; and
 - Sourced from food processing facilities.
- Source Separated Organics (SSO):
 - Considered a low-energy non-agricultural feedstock; and
 - Consisting of organic compostable materials, such as spoiled produce and plate scrapings.

58.3 Co-Products

AD systems enable the production of a number of beneficial co-products. The following section discusses Farm I's co-product opportunities.

58.3.1 Thermal Energy

Thermal energy could be available for use at Farm I through the integration of a co-generation unit or biogas boiler. Farm I's neighbour, who operates a greenhouse with a high heat load, has expressed interest in expanding the greenhouse operation to maximize use of thermal energy.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm I could range from 500,000btu – 2,000,000btu using a co-generation unit, or 1,000,000btu – 6,000,000btu using high-efficiency, direct combustion.

58.3.2 Livestock Bedding

Farm I and its neighbour spend approximately \$90,000/year on sawdust for livestock bedding. Digestate material from the AD system would be a suitable replacement for livestock bedding if properly managed after the digestion process. Depending on the separation technology selected and desired moisture content, livestock bedding production post-AD typically involves a solid separator and optional drying.

58.3.3 Tipping Fees

Farm I has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

58.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export, or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP. These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of any excess nutrients.

59.0 FARM I PROJECT OPTIONS

59.1 Option 1: 25% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|-------------------------|--------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>47 m³</i> | <i>327 m³</i> | <i>17,000 m³</i> |
| <i>FOG</i> | <i>8 m³</i> | <i>54 m³</i> | <i>2,800 m³</i> |
| <i>SSO</i> | <i>8 m³</i> | <i>54 m³</i> | <i>2,800 m³</i> |
| TOTAL | 63 m³ | 435 m³ | 22,600 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,500 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>3,696 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.3kgVS/day</i> |
| <i>HRT:</i> | <i>28 days</i> |
| <i>CHP unit:</i> | <i>390 kW</i> |
| <i>Upgrading unit capacity</i> | <i>300 m³/hr</i> |

Option 1 utilizes a mixture of available manure and 25% non-agricultural feedstocks. The proposed AD system includes a 1,500m³ digester and a 390kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 154m³/hour.

59.2 Option 2: 49% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|-------------------------|--------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>47 m³</i> | <i>327 m³</i> | <i>17,000 m³</i> |
| <i>FOG</i> | <i>23 m³</i> | <i>163 m³</i> | <i>8,500 m³</i> |
| <i>SSO</i> | <i>23 m³</i> | <i>163 m³</i> | <i>8,500 m³</i> |
| TOTAL | 93 m³ | 653 m³ | 34,000 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,500 m³</i> |
| <i>No of digesters:</i> | <i>2</i> |
| <i>Biogas production:</i> | <i>9,630 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.6kgVS/day</i> |
| <i>HRT:</i> | <i>24 days</i> |
| <i>CHP unit:</i> | <i>960 kW</i> |
| <i>Upgrading unit capacity</i> | <i>800 m³/hr</i> |

Option 2 uses a mixture of available manure and 49% non-agricultural feedstocks. The proposed system includes 2 x 1,500m³ digesters and a 960kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 390m³/hour.

60.0 FARM I REQUIRED TARIFFS

60.1 Energy Tariff and Funding Requirements

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--------------------------------------|-------------------------------|------------------------------------|-------------------------------------|
| 1: 25% | \$0.244 | 80% | \$34.80 | 70% |
| 2: 49% | \$0.161 | 35% | \$17.20 | 0%* |

Note*: 0% indicates the AD system is able to make greater than 5% ROI using \$15.28/GJ

60.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to capital input, this AD system would require high energy tariffs of \$0.244/kWh or \$34.80/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 80% funding if it produces electricity for sale to the SOP or 70% if it produces biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is not considered economically viable.

Option 2: As a result of the higher energy output proportionate to the capital input, this AD system would require energy tariffs of \$0.161/kWh or \$17.20/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 35% funding if it produces electricity for sale to the SOP. As such, there is a high probability that this option will be economically viable for biomethane production. However, this will depend upon interconnection costs, FortisBC's ability to accept the biomethane into their grid, and the ability to generate economic value from co-products. For this site the interconnection is severely lacking and would need a major commitment from FortisBC to upgrade and interconnect the AD system.

There is also a low probability that this option will be economically viable for electricity production. However, this will depend upon interconnection costs, the ability to generate economic value from co-products, and at least a \$0.02/kWh – \$0.05/kWh higher electricity tariff or the availability of some funding. While the required electricity tariff or funding amount for Farm I's AD system are within reason when compared to other jurisdictions, they are currently unavailable in B.C.

61.0 FARM I CONCLUSION

While installation of an AD system at Farm I is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amount, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities.

Option 2, biomethane production, may be economically viable for Farm I based on the information provided and used in this study. Option 2, electricity production, may also be economically viable for Farm I if a slightly higher electricity tariff or funding becomes available.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

62.0 FARM I PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary - FARM I | | | | | | | | |
|---|-----------------------|--------------------|-----------------------|--------------------|------------------------------------|--------------------|------------------------------------|--------------------|
| Electricity Production | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/grant money under SOP | | Option 2 - w/grant money under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,500 | 2 | 1,500 | 1 | 1,500 | 2 | 1,500 |
| Dairy Manure (m3/yr) | | 17,000 | | 17,000 | | 17,000 | | 17,000 |
| Source Separated Organics (SSO) (m3/yr) | | 2,800 | | 8,500 | | 2,800 | | 8,500 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 2,800 | | 8,500 | | 2,800 | | 8,500 |
| Total Feedstock Volume (m3/yr) | | 22,600 | | 34,000 | | 22,600 | | 34,000 |
| Engine operating time (hr/day) | | 21.9 | | 21.9 | | 21.9 | | 21.9 |
| Engine Size kW | | 390 | | 960 | | 390 | | 960 |
| Electricity Production (kWh/yr) | | 3,074,760 | | 7,568,640 | | 3,074,760 | | 7,568,640 |
| Electricity Production (kWh/day) | | 8,541 | | 21,024 | | 8,541 | | 21,024 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$513,000 | | \$1,026,000 | | \$513,000 | | \$1,026,000 |
| Co-Gen Plant (non-containerized) | | \$624,000 | | \$960,000 | | \$624,000 | | \$960,000 |
| Powerhouse & Plumbing | | \$137,000 | | \$274,000 | | \$137,000 | | \$274,000 |
| Off-Farm Reception | | \$200,000 | | \$300,000 | | \$200,000 | | \$300,000 |
| High Voltage Connection (BC Hydro) | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (non-BC Hydro) | | \$110,000 | | \$220,000 | | \$110,000 | | \$220,000 |
| Low Voltage Electrical Distribution | | \$170,000 | | \$340,000 | | \$170,000 | | \$340,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$156,000 | | \$78,000 | | \$156,000 |
| Project Development (7%) | 7% | \$149,240 | | \$250,320 | | \$149,240 | | \$250,320 |
| Engineering & Project Management (10%) | 10% | \$213,200 | | \$357,600 | | \$213,200 | | \$357,600 |
| Risk Management (20%) | 20% | \$498,888 | | \$836,784 | | \$498,888 | | \$836,784 |
| Total Capital Expenditure | | \$2,993,328 | | \$5,020,704 | | \$2,993,328 | | \$5,020,704 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.244 | \$750,241 | 0.161 | \$1,218,551 | 0.100 | \$307,476 | 0.100 | \$756,864 |
| Tipping Fees (SSO) | \$30 | \$84,000 | | \$255,000 | | \$84,000 | | \$255,000 |
| Tipping Fees (FOG) | \$15 | \$42,000 | | \$127,500 | | \$42,000 | | \$127,500 |
| Total Revenue | | \$876,241 | | \$1,601,051 | | \$433,476 | | \$1,139,364 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$61,495 | | \$151,373 | | \$61,495 | | \$151,373 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$15,374 | | \$37,843 | | \$15,374 | | \$37,843 |
| Labour for System Operation (h/day; \$50/h, 1hr/100kW) | 4 | \$71,175 | 10 | \$175,200 | 4 | \$71,175 | 10 | \$175,200 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$12,914 | | \$31,788 | | \$12,914 | | \$31,788 |
| Reinvestments | 1% | \$29,933 | | \$50,207 | | \$29,933 | | \$50,207 |
| Total Operating Cost | | \$190,891 | | \$446,411 | | \$190,891 | | \$446,411 |
| Net Operational Income | | \$685,350 | | \$1,154,640 | | \$242,585 | | \$692,953 |
| Financing | | | | | | | | |
| Total Investment | | \$2,993,328 | | \$5,020,704 | | \$2,993,328 | | \$5,020,704 |
| Grant(s) | | \$0 | | \$0 | 80% | \$2,394,662 | 35% | \$1,757,246 |
| Loan | 100% | \$2,993,328 | 100% | \$5,020,704 | 20% | \$598,666 | 65% | \$3,263,458 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.4% | | 5.2% |
| Average Income Before Tax | | \$300,722 | | \$504,246 | | \$162,991 | | \$259,719 |

63.0 FARM I PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary - FARM I | | | | | | | | |
|--|-----------------------|--------------------|-----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| Biogas Upgrading | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,500 | 2 | 1,500 | 1 | 1,500 | 2 | 1,500 |
| Dairy Manure (m3/yr) | | 17,000 | | 17,000 | | 17,000 | | 17,000 |
| Source Separated Organics (SSO) (m3/yr) | | 2,800 | | 8,500 | | 2,800 | | 8,500 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 2,800 | | 8,500 | | 2,800 | | 8,500 |
| Total Feedstock Volume (m3/yr) | | 22,600 | | 34,000 | | 22,600 | | 34,000 |
| Biogas Production (m3/hr) | | 154 | | 390 | | 154 | | 390 |
| Biogas Production (m3/yr) | | 1,349,040 | | 3,416,400 | | 1,349,040 | | 3,416,400 |
| Energy Production (GJ/hr) | | 3,234 | | 8,190 | | 3,234 | | 8,190 |
| Energy Production (GJ/yr) | | 28,330 | | 71,744 | | 28,330 | | 71,744 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$513,000 | | \$1,026,000 | | \$513,000 | | \$1,026,000 |
| Biogas Upgrading System | | \$1,200,000 | | \$1,500,000 | | \$1,200,000 | | \$1,500,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| Off-Farm Reception | | \$200,000 | | \$300,000 | | \$200,000 | | \$300,000 |
| FortisBC Interconnection | | \$750,000 | | \$750,000 | | \$750,000 | | \$750,000 |
| Low Voltage Electrical | | \$170,000 | | \$340,000 | | \$170,000 | | \$340,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$156,000 | | \$78,000 | | \$156,000 |
| Project Development (7%) | 7% | \$207,270 | | \$288,540 | | \$207,270 | | \$288,540 |
| Engineering & Project Management (10%) | 10% | \$296,100 | | \$412,200 | | \$296,100 | | \$412,200 |
| Risk Management (20%) | 20% | \$692,874 | | \$964,548 | | \$692,874 | | \$964,548 |
| Total Capital Expenditure | | \$4,157,244 | | \$5,787,288 | | \$4,157,244 | | \$5,787,288 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 34.80 | \$985,878 | 17.20 | \$1,234,004 | 15.28 | \$432,880 | 15.28 | \$1,096,254 |
| Tipping Fees (SSO) | \$30 | \$84,000 | | \$255,000 | | \$84,000 | | \$255,000 |
| Tipping Fees (FOG) | \$15 | \$42,000 | | \$127,500 | | \$42,000 | | \$127,500 |
| Total Revenue | | \$1,111,878 | | \$1,616,504 | | \$558,880 | | \$1,478,754 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$13,490 | | \$34,164 | | \$13,490 | | \$34,164 |
| Labour for System Op. (h/day; \$35/h, 1hr/50m3 biogas) | 3 | \$39,347 | 8 | \$99,645 | 3 | \$39,347 | 8 | \$99,645 |
| AD Elec. Consumption (7% of Prod. Equip. @ \$0.06/kWh) | 7% | \$11,332 | | \$28,698 | | \$11,332 | | \$28,698 |
| Upgrading System Electricity Consumption | | \$37,000 | | \$55,000 | | \$37,000 | | \$55,000 |
| Reinvestments | 1% | \$41,572 | | \$57,873 | | \$41,572 | | \$57,873 |
| Total Operating Cost | | \$166,342 | | \$298,980 | | \$166,342 | | \$298,980 |
| Net Operational Income | | \$945,537 | | \$1,317,524 | | \$392,538 | | \$1,179,775 |
| Financing | | | | | | | | |
| Total Investment | | \$4,157,244 | | \$5,787,288 | | \$4,157,244 | | \$5,787,288 |
| Grant(s) | | \$0 | | \$0 | 70% | \$2,910,071 | 0% | \$0 |
| Loan | 100% | \$4,157,244 | 100% | \$5,787,288 | 30% | \$1,247,173 | 100% | \$5,787,288 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.4% | | 6.8% |
| Average Income Before Tax | | \$416,131 | | \$577,346 | | \$223,038 | | \$393,275 |

Farm J

Anaerobic Digestion Feasibility Study

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64.0 FARM J EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm J” in Delta. This system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm J would process dairy manure, poultry waste and non-agricultural feedstocks to produce renewable energy and other beneficial co-products.

This study concludes that the proposed AD system on Farm J would be economically viable with 49% non-agricultural feedstock, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.186/kWh;
- Electricity tariff of \$0.10/kWh and funding of 45% (\$1,595,611); or
- Biomethane tariff of \$19.10/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 10% (\$385,679).

If Farm J were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions*:

- Electricity tariff of \$0.328/kWh;
- Electricity tariff of \$0.10/kWh and funding of 97.5% (\$2,435,273); or
- Biomethane tariff of \$40.30/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 80% (\$2,412,634).

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

65.0 FARM J PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure the information presented herein is understood in the proper context and with all necessary supporting information.

65.1 Site Description

Farm J is a dairy operation in Delta, B.C. that milks 250 cows. With the inclusion of young stock and dry cows, total herd size is approximately 500 cows. Farm J also receives approximately 750 tonnes/year of poultry waste from a neighbouring broiler operation. Farm J uses a flush system in their barns with the flush water being separated and reused. This system can be integrated into an AD facility.

65.2 Project-Specific Considerations

65.2.1 Electrical Interconnection

Farm J has three-phase service on-site. Interconnection costs have been estimated at \$375,000 – \$500,000.

65.2.2 Natural Gas Interconnection

Farm J has natural gas available on-site. Interconnection costs have been estimated at \$250,000 – \$350,000. FortisBC can accept all of the biomethane from this system into their grid.

65.2.3 Availability of Feedstocks

Based on information provided by Farm J, the following feedstocks have been identified as currently available:

- Dairy Manure:
 - 250 milkers and 250 young stock mixed with dry cows.
- Poultry Litter:
 - Direct supply available from neighbouring farm.*

**Note that poultry litter is a particularly challenging feedstock as a result of high nitrogen and total solids content. Operational experience and computer simulation indicates an absolute minimum poultry to dairy manure ratio of 5:1 is necessary. However, this ratio is highly dependent on individual feedstock characteristics and should only be used as a rough estimation.*

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG):
 - Considered a high-energy non-agricultural feedstock; and
 - Sourced from food processing facilities.
- Source Separated Organics (SSO):
 - Considered a low-energy non-agricultural feedstock; and
 - Consisting of organic compostable materials, such as spoiled produce and plate scrapings.

65.3 Co-Products

AD systems enable the production of a number of beneficial co-products. The following section discusses Farm J's co-product opportunities.

65.3.1 Thermal Energy

Thermal energy could be available for use at Farm J through the integration of a co-generation unit or biogas boiler. The current farm operation has some greenhouses in use and would like to expand given an affordable heat source.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm J could range from 250,000btu – 1,000,000btu using a co-generation unit, or 600,000btu – 3,000,000btu using high-efficiency, direct combustion.

65.3.2 Livestock Bedding

Farm J spends approximately \$70,000/year on sawdust for livestock bedding. Digestate material from the AD system would be a suitable replacement for livestock bedding if properly managed after the digestion process. Depending on the separation technology selected and desired moisture content, livestock bedding production post-AD typically involves a solid separator and optional drying.

Farm J currently has a Biolyntk system from Daritech, which is used to manage flush manure. This system is specifically designed to integrate with an AD system. As a result, the additional cost and operational consideration normally associated with the use of flush-water in an AD system should be largely, if not entirely avoided.

65.3.3 Tipping Fees

Farm J has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

65.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export, or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP. These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of any excess nutrients.

66.0 FARM J PROJECT OPTIONS

66.1 Option 1: 25% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|-----------------------|--------------------------|--------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>26 m³</i> | <i>183 m³</i> | <i>9,500 m³</i> |
| <i>Poultry Litter</i> | <i>2 m³</i> | <i>14 m³</i> | <i>750 m³</i> |
| <i>FOG</i> | <i>4.5 m³</i> | <i>31 m³</i> | <i>1,600 m³</i> |
| <i>SSO</i> | <i>4.5 m³</i> | <i>31 m³</i> | <i>1,600 m³</i> |
| TOTAL | 37 m³ | 259 m³ | 13,450 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,250 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>2,352 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.5kgVS/day</i> |
| <i>HRT:</i> | <i>23 days</i> |
| <i>CHP unit:</i> | <i>240 kW</i> |
| <i>Upgrading unit capacity:</i> | <i>150 m³/hr</i> |

Option 1 uses a mixture of available manure and 25% non-agricultural feedstocks. The proposed AD system includes a 1,250m³ digester and a 240kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 98m³/hour.

66.2 Option 2: 49% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|-----------------------|-------------------------|--------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>31 m³</i> | <i>220 m³</i> | <i>9,500 m³</i> |
| <i>Poultry litter</i> | <i>2 m³</i> | <i>14 m³</i> | <i>750 m³</i> |
| <i>FOG</i> | <i>16 m³</i> | <i>115 m³</i> | <i>6,000 m³</i> |
| <i>SSO</i> | <i>16 m³</i> | <i>115 m³</i> | <i>6,000 m³</i> |
| TOTAL | 55 m³ | 464 m³ | 22,250 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,750 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>5,664 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.6kgVS/day</i> |
| <i>HRT:</i> | <i>24 days</i> |
| <i>CHP unit:</i> | <i>590 kW</i> |
| <i>Upgrading unit capacity</i> | <i>300 m³/hr</i> |

Option 2 uses a mixture of available manure and 49% non-agricultural feedstocks. The proposed AD system includes a 1,750m³ digester and a 590kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 236m³/hour.

67.0 FARM J REQUIRED TARIFFS

67.1 Energy Tariff and Funding Requirements

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--|-------------------------------------|---|--|
| 1: 25% | \$0.328 | 97.5% | \$40.30 | 80% |
| 2: 49% | \$0.186 | 45% | \$19.10 | 10% |

67.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to the capital input, this AD system would require high energy tariffs of \$0.328/kWh or \$40.30/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 97.5% funding if it produces electricity for sale to the SOP or 80% if it produces biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is not considered economically viable.

Option 2: As a result of the higher energy output proportionate to the capital input, this AD system would require energy tariffs of \$0.186/kWh or \$19.10/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 45% funding if it produces electricity for sale to the SOP or 10% if it produces biomethane for sale to FortisBC. As such, there is a high probability that this option will be economically viable for biomethane production. However, this will depend upon interconnection costs, FortisBC's ability to accept the biomethane into their grid, and the ability to generate economic value from co-products.

There is also a low probability that this option will be economically viable for electricity production. However, this will depend upon interconnection costs, the ability to generate economic value from co-products, and at least a \$0.03/kWh – \$0.08/kWh higher electricity tariff or the availability of some funding. While the required electricity tariff or funding amount for Farm J's AD system are within reason when compared to other jurisdictions, they are currently unavailable in B.C.

68.0 FARM J CONCLUSION

While installation of an AD system at Farm J is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amount, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities and characteristics. Furthermore, addition of a significant quantity of low nitrogen and low TS feedstock is also vital to enable Farm J's AD system to operate effectively.

Option 2, biomethane production, is considered economically viable for Farm J based on the information provided and used in this study. Option 2, electricity production, may also be economically viable for Farm J if a slightly higher electricity tariff or funding becomes available.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

69.0 FARM J PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary -FARM J | | | | | | | | |
|---|--------------------------|--------------------|--------------------------|--------------------|---------------------------------------|--------------------|--|--------------------|
| Electricity Production | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/grant money under SOP | | Option 2 - w/grant money under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,250 | 1 | 1,750 | 1 | 1,250 | 1 | 1,750 |
| Dairy Manure (m3/yr) | | 9,500 | | 9,500 | | 9,500 | | 9,500 |
| Poultry Waste (Broiler - m3/yr) | | 750 | | 750 | | 750 | | 750 |
| Source Separated Organics (SSO) (m3/yr) | | 1,600 | | 5,000 | | 1,600 | | 5,000 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 1,600 | | 5,000 | | 1,600 | | 5,000 |
| Total Feedstock Volume (m3/yr) | | 13,450 | | 20,250 | | 13,450 | | 20,250 |
| Engine operating time (hr/day) | | 21.9 | | 21.9 | | 21.9 | | 21.9 |
| Engine Size kW | | 240 | | 590 | | 240 | | 690 |
| Electricity Production (kWh/yr) | | 1,892,160 | | 4,651,560 | | 1,892,160 | | 5,439,960 |
| Electricity Production (kWh/day) | | 5,256 | | 12,921 | | 5,256 | | 15,111 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$475,000 | | \$575,000 | | \$475,000 | | \$575,000 |
| Co-Gen Plant (non-containerized) | | \$384,000 | | \$708,000 | | \$384,000 | | \$708,000 |
| Powerhouse & Plumbing | | \$137,000 | | \$205,500 | | \$137,000 | | \$205,500 |
| Off-Farm Reception | | \$125,000 | | \$200,000 | | \$125,000 | | \$200,000 |
| High Voltage Connection (BC Hydro) | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (non-BC Hydro) | | \$110,000 | | \$165,000 | | \$110,000 | | \$165,000 |
| Low Voltage Electrical Distribution | | \$170,000 | | \$255,000 | | \$170,000 | | \$255,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$117,000 | | \$78,000 | | \$117,000 |
| Project Development (7%) | 7% | \$124,530 | | \$176,785 | | \$124,530 | | \$176,785 |
| Engineering & Project Management (10%) | 10% | \$177,900 | | \$252,550 | | \$177,900 | | \$252,550 |
| Risk Management (20%) | 20% | \$416,286 | | \$590,967 | | \$416,286 | | \$590,967 |
| Total Capital Expenditure | | \$2,497,716 | | \$3,545,802 | | \$2,497,716 | | \$3,545,802 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.328 | \$620,628 | 0.186 | \$865,190 | 0.100 | \$189,216 | 0.100 | \$543,996 |
| Tipping Fees (SSO) | \$30 | \$48,000 | | \$150,000 | | \$48,000 | | \$150,000 |
| Tipping Fees (FOG) | \$15 | \$24,000 | | \$75,000 | | \$24,000 | | \$75,000 |
| Total Revenue | | \$692,628 | | \$1,090,190 | | \$261,216 | | \$768,996 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$37,843 | | \$93,031 | | \$37,843 | | \$108,799 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$9,461 | | \$23,258 | | \$9,461 | | \$27,200 |
| Labour for System Operation (h/day; \$50/h, 1hr/100kW) | 2 | \$43,800 | 6 | \$107,675 | 2 | \$43,800 | 7 | \$125,925 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$7,947 | | \$19,537 | | \$7,947 | | \$22,848 |
| Reinvestments | 1% | \$24,977 | | \$35,458 | | \$24,977 | | \$35,458 |
| Total Operating Cost | | \$124,028 | | \$278,959 | | \$124,028 | | \$320,230 |
| Net Operational Income | | \$568,600 | | \$811,232 | | \$137,188 | | \$448,766 |
| Financing | | | | | | | | |
| Total Investment | | \$2,497,716 | | \$3,545,802 | | \$2,497,716 | | \$3,545,802 |
| Grant(s) | | \$0 | | \$0 | 97.5% | \$2,435,273 | 45% | \$1,595,611 |
| Loan | 100% | \$2,497,716 | 100% | \$3,545,802 | 2.5% | \$62,443 | 55% | \$1,950,191 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.2% | | 5.3% |
| Average Income Before Tax | | \$249,335 | | \$353,128 | | \$129,482 | | \$188,897 |

70.0 FARM J PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary -FARM J | | | | | | | | |
|--|--------------------------|--------------------|--------------------------|--------------------|-------------------------|--------------------|-------------------------|--------------------|
| Biogas Upgrading | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,250 | 1 | 1,750 | 1 | 1,250 | 1 | 1,750 |
| Dairy Manure (m3/yr) | | 9,500 | | 9,500 | | 9,500 | | 9,500 |
| Poultry Waste (Broiler - m3/yr) | | 750 | | 750 | | 750 | | 750 |
| Source Separated Organics (SSO) (m3/yr) | | 1,600 | | 5,000 | | 1,600 | | 5,000 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 1,600 | | 5,000 | | 1,600 | | 5,000 |
| Total Feedstock Volume (m3/yr) | | 13,450 | | 20,250 | | 13,450 | | 20,250 |
| Biogas Production (m3/hr) | | 98 | | 236 | | 98 | | 236 |
| Biogas Production (m3/yr) | | 858,480 | | 2,067,360 | | 858,480 | | 2,067,360 |
| Energy Production (GJ/hr) | | 2.058 | | 4.956 | | 2.058 | | 4.956 |
| Energy Production (GJ/yr) | | 18,028 | | 43,415 | | 18,028 | | 43,415 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$475,000 | | \$575,000 | | \$475,000 | | \$575,000 |
| Biogas Upgrading System | | \$1,000,000 | | \$1,200,000 | | \$1,000,000 | | \$1,200,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| Off-Farm Reception | | \$125,000 | | \$200,000 | | \$125,000 | | \$200,000 |
| FortisBC Interconnection | | \$250,000 | | \$350,000 | | \$250,000 | | \$350,000 |
| Low Voltage Electrical | | \$170,000 | | \$255,000 | | \$170,000 | | \$255,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$117,000 | | \$78,000 | | \$117,000 |
| Project Development (7%) | 7% | \$150,360 | | \$192,290 | | \$150,360 | | \$192,290 |
| Engineering & Project Management (10%) | 10% | \$214,800 | | \$274,700 | | \$214,800 | | \$274,700 |
| Risk Management (20%) | 20% | \$502,632 | | \$642,798 | | \$502,632 | | \$642,798 |
| Total Capital Expenditure | | \$3,015,792 | | \$3,856,788 | | \$3,015,792 | | \$3,856,788 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 40.30 | \$726,532 | 19.10 | \$829,218 | 15.28 | \$275,469 | 15.28 | \$663,374 |
| Tipping Fees (SSO) | \$30 | \$48,000 | | \$150,000 | | \$48,000 | | \$150,000 |
| Tipping Fees (FOG) | \$15 | \$24,000 | | \$75,000 | | \$24,000 | | \$75,000 |
| Total Revenue | | \$798,532 | | \$1,054,218 | | \$347,469 | | \$888,374 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$8,585 | | \$20,674 | | \$8,585 | | \$20,674 |
| Labour for System Op. (h/day, \$35/h, 1hr/50m3 biogas) | 2 | \$25,039 | 5 | \$60,298 | 2 | \$25,039 | 5 | \$60,298 |
| AD Elec. Consumption (7% of Prod. Equiv. @ \$0.06/kWh) | 7% | \$7,211 | | \$17,366 | | \$7,211 | | \$17,366 |
| Upgrading System Electricity Consumption | | \$18,000 | | \$37,000 | | \$18,000 | | \$37,000 |
| Reinvestments | 1% | \$30,158 | | \$38,568 | | \$30,158 | | \$38,568 |
| Total Operating Cost | | \$112,593 | | \$197,505 | | \$112,593 | | \$197,505 |
| Net Operational Income | | \$685,939 | | \$856,713 | | \$234,876 | | \$690,869 |
| Financing | | | | | | | | |
| Total Investment | | \$3,015,792 | | \$3,856,788 | | \$3,015,792 | | \$3,856,788 |
| Grant(s) | | \$0 | | \$0 | 80% | \$2,412,634 | 10% | \$385,679 |
| Loan | 100% | \$3,015,792 | 100% | \$3,856,788 | 20% | \$603,158 | 90% | \$3,471,109 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.1% | | 5.7% |
| Average Income Before Tax | | \$302,155 | | \$385,864 | | \$152,876 | | \$219,369 |

Farm K

Anaerobic Digestion Feasibility Study

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71.0 FARM K EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm K” in Abbotsford. The system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm K would process hog manure, poultry waste and non-agricultural feedstocks to produce renewable energy and other beneficial co-products.

This study concludes that the proposed AD system on Farm K would be economically viable with 49% non-agricultural feedstock, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.193/kWh;
- Electricity tariff of \$0.10/kWh and funding of 55% (\$1,956,369); or
- Biomethane tariff of \$20.35/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 10% (\$382,169).

If Farm K were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions*:

- Electricity tariff of \$0.330/kWh;
- Electricity tariff of \$0.10/kWh and funding of 97.5% (\$2,435,273); or
- Biomethane tariff of \$41.30/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 82.5% (\$2,488,028).

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

72.0 FARM K PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure the information presented herein is understood in the proper context and with all necessary supporting information.

72.1 Site Description

Farm K is a hog and poultry operation in Abbotsford, B.C. A total of 6,000 hogs are raised at any one time, with approximately 20,000 animals processed each year. The poultry (broiler) operation houses approximately 180,000 broilers 6.5 times over the course of the year, and generates approximately 1,000 tonnes/year of waste. The two operations are approximately 1km apart. The hog manure is collected for storage under the barns and would be pumped to the site with the poultry waste being front loaded.

Hog manure is currently managed predominantly on-site whereas poultry manure is hauled for off-site management. As a result, it is logistically and economically favourable to site the AD system at the hog operation and to import poultry waste, as this waste is already being trucked.

72.2 Project-Specific Considerations

72.2.1 Electrical Interconnection

B.C. Hydro estimates that less than 250m of single-phase line requires upgrading to three-phase service at the hog operation and interconnection costs have been estimated at \$500,000.

72.2.2 Natural Gas Interconnection

Farm K has natural gas available on-site. Interconnection costs have been estimated at \$250,000 – \$350,000. FortisBC may be able to accept all of the biomethane from this system into their grid.

72.2.3 Availability of Feedstocks

Based on information provided by Farm K, the following feedstocks have been identified as currently available:

- Hog Manure:
 - 6,000 hogs on site at any one time.
- Poultry Waste;
 - 180,000 broilers on site 6.5 times over the duration of a year.*

**Note that poultry litter is a particularly challenging feedstock as a result of high nitrogen and total solids content. Operational experience and computer simulation indicates an absolute minimum hog manure to poultry litter ratio of 5:1 is necessary. However, this ratio is highly dependent on individual feedstock characteristics and should only be used as a rough estimation.*

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG):
 - Considered a high-energy non-agricultural feedstock; and
 - Sourced from local food processing facilities.
- Source Separated Organics (SSO):
 - Considered a low-energy non-agricultural feedstock; and

- Consisting of organic compostable materials, such as spoiled produce and plate scrapings.

72.3 Co-Products

AD systems enable the production of a number of beneficial co-products. The following section discusses Farm K's co-product opportunities.

72.3.1 Thermal Energy

Thermal energy could be available for use at Farm K through the integration of a co-generation unit or biogas boiler. While neither the hog nor poultry operation has significant thermal loads, minor requirements for the hog barns could be met.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm K could range from 500,000btu – 2,000,000btu using a co-generation unit, or 1,000,000btu – 6,000,000btu using high-efficiency, direct combustion.

72.3.2 Livestock Bedding

Farm K, as a hog and poultry producer, does not use bedding for livestock. Post digested material could be used as compost and/or fill for on-farm uses. Current manure disposal costs are approximately \$15,000 – \$20,000/year.

72.3.3 Tipping Fees

Farm K has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

72.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export, or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP. These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of any excess nutrients.

73.0 FARM K PROJECT OPTIONS

73.1 Option 1: 25% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|-----------------------|-------------------------|--------------------------|-----------------------------|
| <i>Hog manure</i> | <i>23 m³</i> | <i>163 m³</i> | <i>8,500 m³</i> |
| <i>Poultry litter</i> | <i>3 m³</i> | <i>19 m³</i> | <i>1,000 m³</i> |
| <i>FOG</i> | <i>4 m³</i> | <i>29 m³</i> | <i>1,500 m³</i> |
| <i>SSO</i> | <i>4 m³</i> | <i>29 m³</i> | <i>1,500 m³</i> |
| TOTAL | 34 m³ | 240 m³ | 12,500 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,000 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>2,304 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.5kgVS/day</i> |
| <i>HRT:</i> | <i>28 days</i> |
| <i>CHP unit:</i> | <i>240 kW</i> |
| <i>Upgrading unit capacity</i> | <i>150 m³/hr</i> |

Option 1 uses a mixture of available manure and 25% non-agricultural feedstocks. The proposed AD system includes a 1,000m³ digester and a 240kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 96m³/hour.

73.2 Option 2: 49% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|-----------------------|-------------------------|--------------------------|-----------------------------|
| <i>Dairy manure</i> | <i>23 m³</i> | <i>163 m³</i> | <i>8,500 m³</i> |
| <i>Poultry litter</i> | <i>3 m³</i> | <i>19 m³</i> | <i>1,000 m³</i> |
| <i>FOG</i> | <i>13 m³</i> | <i>91 m³</i> | <i>4,750 m³</i> |
| <i>SSO</i> | <i>13 m³</i> | <i>91 m³</i> | <i>4,750 m³</i> |
| TOTAL | 52 m³ | 364 m³ | 19,000 m³ |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,500 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>5,448 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.6kgVS/day</i> |
| <i>HRT:</i> | <i>24 days</i> |
| <i>CHP unit:</i> | <i>570 kW</i> |
| <i>Upgrading unit capacity</i> | <i>300 m³/hr</i> |

Option 2 uses a mixture of available manure and 49% non-agricultural feedstocks. The proposed AD system includes a 1,500m³ digester and a 570kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 227m³/hour.

74.0 FARM K REQUIRED TARIFFS

74.1 Energy Tariff and Funding Requirements

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--|-------------------------------------|---|--|
| 1: 25% | \$0.330 | 97.5% | \$41.30 | 82.5% |
| 2: 49% | \$0.193 | 55% | \$20.35 | 10% |

74.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to the capital input, this AD system would require high energy tariffs of \$0.330/kWh or \$41.30/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 97.5% funding if it produces electricity for sale to the SOP or 82.5% if it produces biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is not considered economically viable.

Option 2: As a result of the higher energy output proportionate to the capital input, this AD system would require energy tariffs of \$0.193/kWh or \$20.35/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 55% funding if it produces electricity for sale to the SOP or 10% if it produces biomethane for sale to FortisBC. As such, there is a high probability that this option will be economically viable for biomethane production. However, this will depend upon interconnection costs, FortisBC's ability to accept the biomethane into their grid, and the ability to generate economic value from co-products.

There is also a low probability that this option will be economically viable for electricity production. However, this will depend upon interconnection costs, the ability to generate economic value from co-products, and at least a \$0.04/kWh – \$0.08/kWh higher electricity tariff or the availability of some funding. While the required electricity tariff or funding amount for Farm K's AD system are within reason when compared to other jurisdictions, they are currently unavailable in B.C.

75.0 FARM K CONCLUSION

While installation of an AD system at Farm K is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amount, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities and characteristics. Furthermore, addition of a significant quantity of low nitrogen and low TS feedstock is also vital to enable Farm K's AD system to operate effectively.

Option 2, biomethane production, may be economically viable for Farm K based on the information provided and used in this study. Option 2, electricity production, may also be economically viable for Farm K if a slightly higher electricity tariff or funding becomes available.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

76.0 FARM K PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary - FARM K | | | | | | | | |
|---|-----------------------|--------------------|-----------------------|--------------------|------------------------------------|--------------------|------------------------------------|--------------------|
| Electricity Production | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/grant money under SOP | | Option 2 - w/grant money under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,000 | 1 | 1,750 | 1 | 1,000 | 1 | 1,750 |
| Hog Manure (m3/yr) | | 8,500 | | 8,500 | | 8,500 | | 8,500 |
| Poultry Waste (m3/yr) | | 1,000 | | 1,000 | | 1,000 | | 1,000 |
| Source Separated Organics (SSO) (m3/yr) | | 1,500 | | 4,750 | | 1,500 | | 4,750 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 1,500 | | 4,750 | | 1,500 | | 4,750 |
| Total Feedstock Volume (m3/yr) | | 12,500 | | 19,000 | | 12,500 | | 19,000 |
| Engine operating time (hr/day) | | 21.9 | | 21.9 | | 21.9 | | 21.9 |
| Engine Size kW | | 240 | | 570 | | 240 | | 570 |
| Electricity Production (kWh/yr) | | 1,892,160 | | 4,493,880 | | 1,892,160 | | 4,493,880 |
| Electricity Production (kWh/day) | | 5,256 | | 12,483 | | 5,256 | | 12,483 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$475,000 | | \$550,000 | | \$475,000 | | \$550,000 |
| Co-Gen Plant (non-containerized) | | \$384,000 | | \$741,000 | | \$384,000 | | \$741,000 |
| Powerhouse & Plumbing | | \$137,000 | | \$205,500 | | \$137,000 | | \$205,500 |
| Off-Farm Recpetion | | \$125,000 | | \$200,000 | | \$125,000 | | \$200,000 |
| High Voltage Connection (BC Hydro) | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (non-BC Hydro) | | \$110,000 | | \$165,000 | | \$110,000 | | \$165,000 |
| Low Voltage Electrical Distribution | | \$170,000 | | \$255,000 | | \$170,000 | | \$255,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$117,000 | | \$78,000 | | \$117,000 |
| Project Development (7%) | 7% | \$124,530 | | \$177,345 | | \$124,530 | | \$177,345 |
| Engineering & Project Management (10%) | 10% | \$177,900 | | \$253,350 | | \$177,900 | | \$253,350 |
| Risk Management (20%) | 20% | \$416,286 | | \$592,839 | | \$416,286 | | \$592,839 |
| Total Capital Expenditure | | \$2,497,716 | | \$3,557,034 | | \$2,497,716 | | \$3,557,034 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.330 | \$624,413 | 0.193 | \$867,319 | 0.100 | \$189,216 | 0.100 | \$449,388 |
| Tipping Fees (SSO) | \$30 | \$45,000 | | \$142,500 | | \$45,000 | | \$142,500 |
| Tipping Fees (FOG) | \$15 | \$22,500 | | \$71,250 | | \$22,500 | | \$71,250 |
| Total Revenue | | \$691,913 | | \$1,081,069 | | \$256,716 | | \$663,138 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$37,843 | | \$89,878 | | \$37,843 | | \$89,878 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$9,461 | | \$22,469 | | \$9,461 | | \$22,469 |
| Labour for System Operation (h/day; \$50/h, 1hr/100kW) | 2 | \$43,800 | 6 | \$104,025 | 2 | \$43,800 | 6 | \$104,025 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$7,947 | | \$18,874 | | \$7,947 | | \$18,874 |
| Reinvestments | 1% | \$24,977 | | \$35,570 | | \$24,977 | | \$35,570 |
| Total Operating Cost | | \$124,028 | | \$270,817 | | \$124,028 | | \$270,817 |
| Net Operational Income | | \$567,885 | | \$810,252 | | \$132,688 | | \$392,321 |
| Financing | | | | | | | | |
| Total Investment | | \$2,497,716 | | \$3,557,034 | | \$2,497,716 | | \$3,557,034 |
| Grant(s) | | \$0 | | \$0 | 97.5% | \$2,435,273 | 55% | \$1,956,369 |
| Loan | 100% | \$2,497,716 | 100% | \$3,557,034 | 2.5% | \$62,443 | 45% | \$1,600,665 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.0% | | 5.1% |
| Average Income Before Tax | | \$248,586 | | \$355,287 | | \$124,774 | | \$179,752 |

77.0 FARM K PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary - FARM K | | | | | | | | |
|--|-----------------------|--------------------|-----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| Biogas Upgrading | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,000 | 1 | 1,500 | 1 | 1,000 | 1 | 1,500 |
| Hog Manure (m3/yr) | | 8,500 | | 8,500 | | 8,500 | | 8,500 |
| Poultry Waste (m3/yr) | | 1,000 | | 1,000 | | 1,000 | | 1,000 |
| Source Separated Organics (SSO) (m3/yr) | | 1,500 | | 4,750 | | 1,500 | | 4,750 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 1,500 | | 4,750 | | 1,500 | | 4,750 |
| Total Feedstock Volume (m3/yr) | | 12,500 | | 19,000 | | 12,500 | | 19,000 |
| Biogas Production (m3/hr) | | 96 | | 227 | | 96 | | 227 |
| Biogas Production (m3/yr) | | 840,960 | | 1,988,520 | | 840,960 | | 1,988,520 |
| Energy Production (GJ/hr) | | 2.016 | | 4.767 | | 2.016 | | 4.767 |
| Energy Production (GJ/yr) | | 17,660 | | 41,759 | | 17,660 | | 41,759 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$475,000 | | \$550,000 | | \$475,000 | | \$550,000 |
| Biogas Upgrading System | | \$1,000,000 | | \$1,200,000 | | \$1,000,000 | | \$1,200,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| Off-Farm Reception | | \$125,000 | | \$200,000 | | \$125,000 | | \$200,000 |
| FortisBC Interconnection | | \$250,000 | | \$350,000 | | \$250,000 | | \$350,000 |
| Low Voltage Electrical | | \$170,000 | | \$255,000 | | \$170,000 | | \$255,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$117,000 | | \$78,000 | | \$117,000 |
| Project Development (7%) | 7% | \$150,360 | | \$190,540 | | \$150,360 | | \$190,540 |
| Engineering & Project Management (10%) | 10% | \$214,800 | | \$272,200 | | \$214,800 | | \$272,200 |
| Risk Management (20%) | 20% | \$502,632 | | \$636,948 | | \$502,632 | | \$636,948 |
| Total Capital Expenditure | | \$3,015,792 | | \$3,821,688 | | \$3,015,792 | | \$3,821,688 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 41.30 | \$729,365 | 20.35 | \$849,794 | 15.28 | \$269,847 | 15.28 | \$638,076 |
| Tipping Fees (SSO) | \$30 | \$45,000 | | \$142,500 | | \$45,000 | | \$142,500 |
| Tipping Fees (FOG) | \$15 | \$22,500 | | \$71,250 | | \$22,500 | | \$71,250 |
| Total Revenue | | \$796,865 | | \$1,063,544 | | \$337,347 | | \$851,826 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$8,410 | | \$19,885 | | \$8,410 | | \$19,885 |
| Labour for System Op. (h/day, \$35/h, 1hr/50m3 biogas) | 2 | \$24,528 | 5 | \$57,999 | 2 | \$24,528 | 5 | \$57,999 |
| AD Elec. Consumption (7% of Prod. Equip. @ \$0.06/kWh) | 7% | \$7,064 | | \$16,704 | | \$7,064 | | \$16,704 |
| Upgrading System Electricity Consumption | | \$18,000 | | \$37,000 | | \$18,000 | | \$37,000 |
| Reinvestments | 1% | \$30,158 | | \$38,217 | | \$30,158 | | \$38,217 |
| Total Operating Cost | | \$111,760 | | \$193,404 | | \$111,760 | | \$193,404 |
| Net Operational Income | | \$685,105 | | \$870,140 | | \$225,588 | | \$658,422 |
| Financing | | | | | | | | |
| Total Investment | | \$3,015,792 | | \$3,821,688 | | \$3,015,792 | | \$3,821,688 |
| Grant(s) | | \$0 | | \$0 | 82.5% | \$2,488,028 | 10% | \$382,169 |
| Loan | 100% | \$3,015,792 | 100% | \$3,821,688 | 17.5% | \$527,764 | 90% | \$3,439,519 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 0.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.1% | | 5.0% |
| Average Income Before Tax | | \$301,323 | | \$381,930 | | \$153,588 | | \$191,422 |

Farm L

Anaerobic Digestion Feasibility Study

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1.0 FARM L EXECUTIVE SUMMARY

This study assesses the economic viability of installing an AD system on “Farm L” in Agassiz. The system was evaluated in context of the B.C. Anaerobic Digestion Benchmark Study, herein known as *The Study*, and should be referenced as such. The proposed AD system on Farm L would process dairy manure and non-agricultural feedstocks to produce renewable energy and other beneficial co-products.

This study concludes that the proposed AD system on Farm L would be economically viable with 49% non-agricultural feedstock, dependent on the feedstocks used, under the following conditions*:

- Electricity tariff of \$0.190/kWh;
- Electricity tariff of \$0.10/kWh and funding of 55% (\$1,865,249); or
- Biomethane tariff of \$20.50/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 10% (\$376,974).

If Farm L were to use only 25% non-agricultural feedstock, and dependent on the feedstocks used, the proposed AD system would only be economically viable under the following conditions*:

- Electricity tariff of \$0.350/kWh;
- Electricity tariff of \$0.10/kWh and funding of 100% (\$2,452,788); or
- Biomethane tariff of \$41.80/GJ;
- Biomethane tariff of \$15.28/GJ and funding of 85% (\$2,563,423).

**Note that the necessary energy tariffs and funding requirements are directly related to final installed costs for the AD system. Managing development and construction costs can allow systems to be economically viable at lower tariffs or with less funding.*

Budget estimates provided in this study are reflective of generalized costs. True costs are ultimately dependant on firm quotes from local contractors and the amount of work put in by the owner. This budget should be updated to reflect true costs once firm quotes for specific work items are received.

It should also be noted that potential economic value associated with co-products, including the use of residual heat for on-site and neighbouring (less than 500m) needs, and the value of offsetting bedding requirements, are not included in the budget. This is because investments in co-products are considered independently of the AD system, as they should be based on their own economic merit. Through cost management and accounting for additional revenue streams, the required energy tariffs and funding amounts for AD systems to be economically viable can be reduced by as much as 25%.

2.0 FARM L PROJECT SCOPE

This study should be read in conjunction with the British Columbia Anaerobic Digestion Benchmark Study to ensure the information presented herein is understood in the proper context and with all necessary supporting information.

2.1 Site Description

Farm L is a dairy operation in Agassiz, B.C. that milks 250 cows at their location. With the inclusion of young stock and dry cows, total herd size is approximately 500 cows. Manure collection is done by automated alley scrapers.

2.2 Project-Specific Considerations

2.2.1 Electrical Interconnection

Farm L has three-phase service on-site. Interconnection costs have been estimated at \$375,000 – \$500,000.

2.2.2 Natural Gas Interconnection

Farm L has natural gas available on-site. Interconnection costs have been estimated at \$250,000 – \$350,000. FortisBC can accept all of the biomethane from this system into their grid.

2.2.3 Availability of Feedstocks

Based on information provided by Farm L, the following feedstocks have been identified as currently available:

- Dairy Manure:
 - Available from 250 milkers and 250 young stock mixed with dry cows.

To determine potential system scales and parameters, the following non-agricultural feedstocks have been identified as suitable for on-farm AD:

- Fats Oils and Greases (FOG):
 - Considered a high-energy non-agricultural feedstock; and
 - Sourced from food processing facilities.
- Source Separated Organics (SSO):
 - Considered a low-energy non-agricultural feedstock; and
 - Consisting of organic compostable materials, such as spoiled produce and plate scrapings.

2.3 Co-Products

AD systems enable the production of a number of beneficial co-products. The following section discusses Farm L's co-product opportunities.

2.3.1 Thermal Energy

Thermal energy could be available for use at Farm L through the integration of a co-generation unit or biogas boiler. While the farm operation does not have any significant heat loads, minor heating requirements could be met.

The economic viability of using thermal energy should be evaluated as a stand-alone option. Depending on system choice, thermal energy production at Farm L could range from 250,000btu – 1,000,000btu using a co-generation unit, or 600,000btu – 3,000,000btu using high-efficiency, direct combustion.

2.3.2 Livestock Bedding

Farm L spends approximately \$35,000/year on sand for livestock bedding. Digestate material from the AD system would be a suitable replacement for livestock bedding if properly managed after the digestion process. Depending on the separation technology selected and desired moisture content, livestock bedding production post-AD typically involves a solid separator and optional drying.

2.3.3 Tipping Fees

Farm L has the ability to generate tipping fees by accepting non-agricultural feedstocks. The fees will be dependent upon the type and quality of feedstocks delivered. For the purpose of this study, tipping fees of \$30/tonne for SSO and \$15/tonne for FOG have been assumed. For more information on tipping fees, refer to the main body of The Study.

2.3.4 Nutrient Recovery

AD systems have two primary impacts to on-farm nutrient management:

- i. The use of non-agricultural feedstocks results in the import of additional nutrients which need to be managed according to an approved Nutrient Management Plan (NMP); and
- ii. The AD process converts nutrients from long-chain organic compounds into their base molecular form. This results in greater nutrient availability for plant uptake as well as provides the opportunity to isolate nutrients for export, or more efficient land application.

It should be noted that only nominal quantities of nitrogen are lost in the AD process (i.e., 1% – 10% loss). Potash and Phosphorous concentrations are not typically reduced as a result of passing through a digester.

The selection of non-agricultural feedstocks should consider any nutrient deficit or surplus. If a surplus of nutrients proportionate to the land application base is identified, then a nutrient recovery system may be required to ensure compliance with a NMP. These systems are typically capital intensive and should be considered in the context of an independent economic evaluation, whereby capital would be offset by the sale of recovered nutrients and/or the savings for disposal of any excess nutrients.

Farm L has been working with faculty and UBC's Point Grey Campus to install a pilot nutrient recovery system. It is likely that this system will integrate well with the proposed AD system, and that it could serve as a showcase for other on-farm AD systems interested in nutrient recovery.

3.0 FARM L PROJECT OPTIONS

3.1 Option 1: 25% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|--------------------------------|---------------------------------|------------------------------------|
| <i>Dairy manure</i> | <i>26 m³</i> | <i>183 m³</i> | <i>9,500 m³</i> |
| <i>FOG</i> | <i>4 m³</i> | <i>29 m³</i> | <i>1,500 m³</i> |
| <i>SSO</i> | <i>4 m³</i> | <i>29 m³</i> | <i>1,500 m³</i> |
| <i>TOTAL</i> | <i>34 m³</i> | <i>241 m³</i> | <i>12,500 m³</i> |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,250 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>2,280 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.4kgVS/day</i> |
| <i>HRT:</i> | <i>26 days</i> |
| <i>CHP unit:</i> | <i>220 kW</i> |
| <i>Upgrading unit capacity:</i> | <i>150 m³/hr</i> |

Option 1 uses a mixture of available manure and 25% non-agricultural feedstocks. The proposed AD system includes a 1,250m³ digester and a 220kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 95m³/hour.

3.2 Option 2: 49% Non-Agricultural Feedstock

| <i>Substrate:</i> | <i>Daily</i> | <i>Weekly</i> | <i>Yearly</i> |
|---------------------|--------------------------------|---------------------------------|------------------------------------|
| <i>Dairy manure</i> | <i>26 m³</i> | <i>183 m³</i> | <i>9,500 m³</i> |
| <i>FOG</i> | <i>13 m³</i> | <i>91 m³</i> | <i>4,750 m³</i> |
| <i>SSO</i> | <i>13 m³</i> | <i>91 m³</i> | <i>4,750 m³</i> |
| <i>TOTAL</i> | <i>52 m³</i> | <i>365 m³</i> | <i>19,000 m³</i> |

| | |
|--|--------------------------------|
| <i>Minimal required digester volume:</i> | <i>1,750 m³</i> |
| <i>No of digesters:</i> | <i>1</i> |
| <i>Biogas production:</i> | <i>5,400 m³/day</i> |
| <i>Organic loading rate:</i> | <i>3.6kgVS/day</i> |
| <i>HRT:</i> | <i>24 days</i> |
| <i>CHP unit:</i> | <i>550 kW</i> |
| <i>Upgrading unit capacity</i> | <i>300 m³/hr</i> |

Option 2 uses a mixture of available manure and 49% non-agricultural feedstocks. The proposed AD system includes a 1,750m³ digester and a 550kW co-generation unit or equivalent biogas scrubber. Anticipated biogas production is 225m³/hour.

4.0 FARM L REQUIRED TARIFFS

4.1 Energy Tariff and Funding Requirements

| Option # | Electricity Tariff Required (\$/kWh) | % Funding Necessary under SOP | Biomethane Tariff Required (\$/GJ) | % Funding Necessary with \$15.28/GJ |
|----------|--|-------------------------------------|---|--|
| 1: 25% | \$0.350 | 100% | \$41.80 | 85% |
| 2: 49% | \$0.190 | 55% | \$20.50 | 10% |

4.2 Consideration of Options

This study has proposed two options, each intended to provide variable AD system parameters and generation characteristics.

Option 1: As a result of the relatively low energy output proportionate to capital input, this AD system would require high energy tariffs of \$0.350/kWh or \$41.80/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 100% funding if it produces electricity for sale to the SOP or 85% if it produced biomethane for sale to FortisBC. Given the low likelihood of these tariffs or this amount of funding being available in the foreseeable future, this option is not considered economically viable.

Option 2: As a result of the higher energy output proportionate to the capital input, this AD system would require energy tariffs of \$0.190/kWh or \$20.50/GJ for electricity and biomethane, respectively. Alternatively, this AD system would require 55% funding if it produces electricity for sale to the SOP or 10% if it produced biomethane for sale to FortisBC. As such, there is a high probability that this option will be economically viable for biomethane production. However, this will depend upon interconnection costs, FortisBC's ability to accept the biomethane into their grid, and the ability to generate economic value from co-products.

There is also a low probability that this option will be economically viable for electricity production. However, this will depend upon interconnection costs, the ability to generate economic value from co-products, and at least a \$0.04/kWh – \$0.08/kWh higher electricity tariff or the availability of some funding. While the required electricity tariff or funding amount for Farm L's AD system are within reason when compared to other jurisdictions, they are currently unavailable in B.C.

5.0 FARM L CONCLUSION

While installation of an AD system at Farm L is technologically feasible, economic viability is dependent on the necessary energy tariffs or funding amount, interconnection costs and the economic value of co-products. Success of this AD system is also dependent on securing suitable non-agricultural feedstocks in the prescribed quantities.

Option 2, biomethane production, may be economically viable for Farm L based on the information provided and used in this study. Option 2, electricity production, may also be economically viable for Farm L if a slightly higher electricity tariff or funding becomes available.

Consideration of nutrients is important when using non-agricultural feedstocks in an on-farm AD system. As such, it is important to include all additional nutrients associated with the import of this material in a NMP. Regulatory requirements for all AD system options must also be further evaluated to ensure compliance.

6.0 FARM L PROJECT BUDGET – ELECTRICITY PRODUCTION

| Budget Estimate Summary -FARM L | | | | | | | | |
|---|-----------------------|--------------------|-----------------------|--------------------|------------------------------------|--------------------|------------------------------------|--------------------|
| Electricity Production | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/grant money under SOP | | Option 2 - w/grant money under SOP | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,250 | 1 | 1,500 | 1 | 1,250 | 1 | 1,500 |
| Dairy Manure (m3/yr) | | 9,500 | | 9,500 | | 9,500 | | 9,500 |
| Source Separated Organics (SSO) (m3/yr) | | 1,500 | | 4,750 | | 1,500 | | 4,750 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 1,500 | | 4,750 | | 1,500 | | 4,750 |
| Total Feedstock Volume (m3/yr) | | 12,500 | | 19,000 | | 12,500 | | 19,000 |
| Engine operating time (hr/day) | | 21.9 | | 21.9 | | 21.9 | | 21.9 |
| Engine Size kW | | 220 | | 550 | | 220 | | 550 |
| Electricity Production (kWh/yr) | | 1,734,480 | | 4,336,200 | | 1,734,480 | | 4,336,200 |
| Electricity Production (kWh/day) | | 4,818 | | 12,045 | | 4,818 | | 12,045 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$475,000 | | \$513,000 | | \$475,000 | | \$513,000 |
| Co-Gen Plant (non-containerized) | | \$352,000 | | \$660,000 | | \$352,000 | | \$660,000 |
| Powerhouse & Plumbing | | \$137,000 | | \$205,500 | | \$137,000 | | \$205,500 |
| Off-Farm Reception | | \$125,000 | | \$200,000 | | \$125,000 | | \$200,000 |
| High Voltage Connection (BC Hydro) | | \$300,000 | | \$300,000 | | \$300,000 | | \$300,000 |
| High Voltage Connection (non-BC Hydro) | | \$110,000 | | \$165,000 | | \$110,000 | | \$165,000 |
| Low Voltage Electrical Distribution | | \$170,000 | | \$255,000 | | \$170,000 | | \$255,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$117,000 | | \$78,000 | | \$117,000 |
| Project Development (7%) | 7% | \$122,290 | | \$169,085 | | \$122,290 | | \$169,085 |
| Engineering & Project Management (10%) | 10% | \$174,700 | | \$241,550 | | \$174,700 | | \$241,550 |
| Risk Management (20%) | 20% | \$408,798 | | \$565,227 | | \$408,798 | | \$565,227 |
| Total Capital Expenditure | | \$2,452,788 | | \$3,391,362 | | \$2,452,788 | | \$3,391,362 |
| Revenue | | | | | | | | |
| Sale Electricity - Electricity Tariff (Cent/kWh) | 0.350 | \$607,068 | 0.190 | \$823,878 | 0.100 | \$173,448 | 0.100 | \$433,620 |
| Tipping Fees (SSO) | \$30 | \$45,000 | | \$142,500 | | \$45,000 | | \$142,500 |
| Tipping Fees (FOG) | \$15 | \$22,500 | | \$71,250 | | \$22,500 | | \$71,250 |
| Total Revenue | | \$674,568 | | \$1,037,628 | | \$240,948 | | \$647,370 |
| Operating Cost | | | | | | | | |
| CHP Maintenance (2 Cents/kWh) | 0.020 | \$34,690 | | \$86,724 | | \$34,690 | | \$86,724 |
| Digester Maintenance (0.5 Cents/kWh) | 0.005 | \$8,672 | | \$21,681 | | \$8,672 | | \$21,681 |
| Labour for System Operation (h/day; \$50/h, 1hr/100kW) | 2 | \$40,150 | 6 | \$100,375 | 2 | \$40,150 | 6 | \$100,375 |
| Electricity Consumption (7% of Production @ \$0.06/kWh) | 7% | \$7,285 | | \$18,212 | | \$7,285 | | \$18,212 |
| Reinvestments | 1% | \$24,528 | | \$33,914 | | \$24,528 | | \$33,914 |
| Total Operating Cost | | \$115,325 | | \$260,906 | | \$115,325 | | \$260,906 |
| Net Operational Income | | \$559,243 | | \$776,722 | | \$125,623 | | \$386,464 |
| Financing | | | | | | | | |
| Total Investment | | \$2,452,788 | | \$3,391,362 | | \$2,452,788 | | \$3,391,362 |
| Grant(s) | | \$0 | | \$0 | 100% | \$2,452,788 | 55% | \$1,865,249 |
| Loan | 100% | \$2,452,788 | 100% | \$3,391,362 | 0% | \$0 | 45% | \$1,526,113 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI Before Tax | | 10.0% | | 10.0% | | 5.1% | | 5.4% |
| Average Income Before Tax | | \$246,215 | | \$339,127 | | \$125,808 | | \$184,258 |

7.0 FARM L PROJECT BUDGET – BIOMETHANE PRODUCTION

| Budget Estimate Summary -FARM L | | | | | | | | |
|--|--------------------------|--------------------|--------------------------|--------------------|-------------------------|--------------------|-------------------------|--------------------|
| Biogas Upgrading | Option 1 - 25% Non-Ag | | Option 2 - 49% Non-Ag | | Option 1 - w/funding | | Option 2 - w/funding | |
| | Qty | | Qty | | Qty | | Qty | |
| Components | | | | | | | | |
| Digester (No, size m3) | 1 | 1,250 | 1 | 1,500 | 1 | 1,250 | 1 | 1,500 |
| Dairy Manure (m3/yr) | | 9,500 | | 9,500 | | 9,500 | | 9,500 |
| Source Separated Organics (SSO) (m3/yr) | | 1,500 | | 4,750 | | 1,500 | | 4,750 |
| Fats, Oils and Grease (FOG) (m3/yr) | | 1,500 | | 4,750 | | 1,500 | | 4,750 |
| Total Feedstock Volume (m3/yr) | | 12,500 | | 19,000 | | 12,500 | | 19,000 |
| Biogas Production (m3/hr) | | 95 | | 225 | | 95 | | 225 |
| Biogas Production (m3/yr) | | 832,200 | | 1,971,000 | | 832,200 | | 1,971,000 |
| Energy Production (GJ/hr) | | 1.995 | | 4.725 | | 1.995 | | 4.725 |
| Energy Production (GJ/yr) | | 17,476 | | 41,391 | | 17,476 | | 41,391 |
| Budget Estimates | | | | | | | | |
| Anaerobic Digester | | \$475,000 | | \$513,000 | | \$475,000 | | \$513,000 |
| Biogas Upgrading System | | \$1,000,000 | | \$1,200,000 | | \$1,000,000 | | \$1,200,000 |
| Control Building & Office | | \$50,000 | | \$50,000 | | \$50,000 | | \$50,000 |
| Off-Farm Reception | | \$125,000 | | \$200,000 | | \$125,000 | | \$200,000 |
| FortisBC Interconnection | | \$250,000 | | \$350,000 | | \$250,000 | | \$350,000 |
| Low Voltage Electrical | | \$170,000 | | \$255,000 | | \$170,000 | | \$255,000 |
| System Controls and Automation (inc. hydraulics) | | \$78,000 | | \$117,000 | | \$78,000 | | \$117,000 |
| Project Development (7%) | 7% | \$150,360 | | \$187,950 | | \$150,360 | | \$187,950 |
| Engineering & Project Management (10%) | 10% | \$214,800 | | \$268,500 | | \$214,800 | | \$268,500 |
| Risk Management (20%) | 20% | \$502,632 | | \$628,290 | | \$502,632 | | \$628,290 |
| Total Capital Expenditure | | \$3,015,792 | | \$3,769,740 | | \$3,015,792 | | \$3,769,740 |
| Revenue | | | | | | | | |
| Sale of Biogas (\$/GJ) | 41.80 | \$730,505 | 20.50 | \$848,516 | 15.28 | \$267,036 | 15.28 | \$632,454 |
| Tipping Fees (SSO) | \$30 | \$45,000 | | \$142,500 | | \$45,000 | | \$135,000 |
| Tipping Fees (FOG) | \$15 | \$22,500 | | \$71,250 | | \$22,500 | | \$67,500 |
| Total Revenue | | \$798,005 | | \$1,062,266 | | \$334,536 | | \$834,954 |
| Operating Cost | | | | | | | | |
| Upgrading System Maintenance & Monitoring | | \$23,600 | | \$23,600 | | \$23,600 | | \$23,600 |
| Digester Maintenance (\$/m3 raw gas) | \$0.01 | \$8,322 | | \$19,710 | | \$8,322 | | \$19,710 |
| Labour for System Op. (h/day; \$35/h, 1hr/50m3 biogas) | 2 | \$24,273 | 5 | \$57,488 | 2 | \$24,273 | 5 | \$57,488 |
| AD Elec. Consumption (7% of Prod. Equip. @ \$0.06/kWh) | 7% | \$6,990 | | \$16,556 | | \$6,990 | | \$16,556 |
| Upgrading System Electricity Consumption | | \$18,000 | | \$37,000 | | \$18,000 | | \$37,000 |
| Reinvestments | 1% | \$30,158 | | \$37,697 | | \$30,158 | | \$37,697 |
| Total Operating Cost | | \$111,343 | | \$192,051 | | \$111,343 | | \$192,051 |
| Net Operational Income | | \$686,662 | | \$870,214 | | \$223,193 | | \$642,903 |
| Financing | | | | | | | | |
| Total Investment | | \$3,015,792 | | \$3,769,740 | | \$3,015,792 | | \$3,769,740 |
| Grant(s) | | \$0 | | \$0 | 85% | \$2,563,423 | 10% | \$376,974 |
| Loan | 100% | \$3,015,792 | 100% | \$3,769,740 | 15% | \$452,369 | 90% | \$3,392,766 |
| Equity | 0% | \$0 | 0% | \$0 | 0% | \$0 | 0% | \$0 |
| Loan Amortization Years | | 10 | | 10 | | 10 | | 10 |
| Interest Rate | | 6.0% | | 6.0% | | 6.0% | | 6.0% |
| Annual Inflation | | 2.0% | | 2.0% | | 2.0% | | 2.0% |
| Average ROI Before Tax | | 10.1% | | 10.3% | | 5.5% | | 5.7% |
| Average Income Before Tax | | \$303,223 | | \$388,887 | | \$166,619 | | \$214,058 |