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CCEMC: Final Outcomes Report for GPHH Integrated Bio Refinery™ Project

Growing Power Hairy Hill Integrated Bio Refinery™ Project

WEB VERSION
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Prepared by Growing Power Hairy Hill in accordance with final reporting requirements for **CCEMC Project G100394**

Abstract

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The Growing Power Hairy Hill Integrated Bio Refinery™[2] is located near the community of Hairy Hill, Alberta, approximately 20km from the Town of Vegreville, Alberta. It is the home of the world's first IMUS™[3] facility. The Integrated Bio Refinery™ is made up of two integrated processes – IMUS™ (expanded and upgraded over the years since it was first commissioned in 2005) and the newly commissioned 10 million US Gallon/year Ethanol Production Facility. These two processes are co-located and tightly integrated with Highland Feeders Ltd., a beef cattle feedlot.

Manure produced by the feedlot, along with other waste is used in the IMUS™ to produce bioGas. This bioGas generates sufficient electricity to power the Ethanol Production Facility, the IMUS™ the co-located feedlot and export about 900kW to the Alberta grid. The Ethanol Production Facility consumes high-starch (low-value) grain and produces both fuel ethanol and Wet Distillers Grains – a high quality cattle feed. Cattle at the feedlot consume the Wet Distillers Grains to close the loop on the most efficient bioFuel production process currently in commercial operation.

Current operational data indicate that the Carbon Intensity of the Ethanol Produced at GPHH will be an astounding -10.14gCO_2eq/MJ, meaning that each liter of ethanol produced at GPHH and consumed as vehicle fuel results in a **net carbon reduction.**

Based on the operational data now in hand, GPHH predicts that facility **GHG reductions from items in the life cycle up to but not including ethanol consumption (gasoline offset) will be 9,439 tonnes CO_2eq/year and an additional 88,496 tonnes CO_2eq/year[4] from the ethanol consumption portion of the lifecycle.**

[1] The "Fuel Plant Logo" and the wordmark "Growing Power" are registered trademarks of Himark BioGas Inc., used under license by GPHH

[2] "Integrated Bio Refinery" is a registered trademark of Himark bioGas Inc., used under license by GPHH

[3] "IMUS" is a is a registered trademark of Himark bioGas Inc., used under license by GPHH

[4] Assuming that production of ethanol is continuous at the guaranteed production level

Keywords

Greenhouse Gas

Carbon Intensity

Energy Efficiency

bioFuels

bioGas

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Introduction

January 9, 2013 was a banner day for GPHH LP, with the first shipment of ethanol from the facility to a customer. With this shipment, the facility is producing both Fuel Ethanol and Wet Distillers Grains. While the shake-out of start-up continues and production rates increase, the facility is operating using electricity produced at GPHH, and natural gas provided from the natural gas distribution infrastructure.

In the coming weeks, repairs will be completed on the biogas-producing portion of the facility and we anticipate that the full electrical load of the facility (biogas, ethanol, and co-located feedlot) will be produced on site from renewable energy.

The GPHH facility has progressed over the years from a commercial demonstration of the IMUS™ anaerobic digestion technology platform, first put into service in 2005, through several upgrades and expansions, the penultimate expansion in 2010 saw the biogas facility increase its capacity to process organic material and biogas output by nearly 300%. With the integration of the ethanol production process that started on October 27, 2011 the facility is now a true Integrated Bio Refinery™.

Construction of the final phase of the facility (the completion of the ethanol plant and Integration of the Ethanol and BioGas facilities) was initiated in December 2011. At the peak of construction activity more than 90 people were working on the project in addition to GPHH's staff complement of 21. In all, over 90 person years were required to carry out construction activities for the project to date.

Original Project Goals

The original goal of this CCEMC supported project was to complete construction of the GPHH Ethanol Production Facility ("EPF") in full integration with the existing biogas facility.

The CCEMC assisted project, to complete and integrate the EPF was targeted to cost $40MM, and would demonstrate production of the lowest Carbon Intensity commercially-produced ethanol worldwide, as well as the ability to reduce GHG by 9,439 tonnes of CO_2eq annually from the portion of the life cycle up to but not including ethanol consumption (gasoline offset) with an additional 88,496 tonnes of CO_2eq annually from the ethanol consumption portion of the lifecycle. This required both an EPF that was very energy efficient as well as full integration with the co-located IMUS™ facility along with the co-located beef cattle feedlot to use renewable energy and save energy and water for plant cooling by warming the cattle drinking water, which in turn makes for more comfortable, productive cattle.

The Integrated Bio Refinery™ goals are to produce sufficient daily ethanol to match the 37,800,000L/year nameplate capacity, with a nominal conversion efficiency of 390L per tonne of high-starch wheat and an energy efficiency of 0.0053 GJ/L of thermal energy (from natural gas or bioGas) and 0.20 kWh/L of electrical energy (from bioGas). Due to the excess electrical generation capacity installed on site, this would result in the GPHH plant exporting approximately 900kW or more of renewable electricity to the Alberta power grid. Given that the Alberta grid baseload is coal-fired, and GPHH's biogas fired electricity becomes baseload at 900kW, the calculated offset against the weighted average grid carbon intensity is actually

understating the significant impact of GPHH's contribution to lowering the carbon intensity of the Alberta electrical grid[5].

[5] In addition to this, GPHH connects to the distribution grid at 25KV and is a point-source of voltage in an area of the distribution grid that is far from other generation. The "voltage propping" effect of GPHH saves considerable amounts of electricity that would otherwise have been lost due to voltage sagging ("line losses"). This impact is not currently quantified, but could be equal to the amount of electricity that GPHH exports to the grid.

Project Final Outcomes

GPHH Construction Highlights and Commissioning Results

Plant Construction Activities

At the time of this report, plant construction activities were sufficiently advanced to attempt operations.

Figure 1 - GPHH near the end of Construction. This is a view from the north end of the Integrated Bio Refinery with the ethanol plant in the foreground and the IMUS™ facility in the background

Plant Feed Forward Dec 22, 2012

The first grain (high-starch wheat) was processed in the hammer mill on December 22, 2012. Once processed, this grain was transferred into the mashing, cooking and fermenting systems for an initial slow fermentation.

First Ethanol Produced Dec 25, 2012

The distillation column was commissioned on December 25, 2012 and 190-proof ethanol was first produced that day. Rectifier commissioning was subsequently completed and 200-proof ethanol was produced and quality verified, then stored prior to shipping.

First Ethanol Shipped Jan 9, 2013

Upon verification that the ethanol met ASTM/CGSB specifications, as well as customer specifications, the first load of ethanol was shipped from GPHH by tanker on January 9, 2013.

Figure 2 - First Ethanol Shipment from GPHH, January 9, 2013

Production Levels

On February 5, 2013, ethanol production levels of 110,000L/day were achieved during a test run using corn as feedstock. This level of production was maintained for three days prior to throttling of the plant in order to make some identified process changes. During the test run, plant efficiencies were verified and it was noted that:

- **Electricity consumption 81% of target (below target, but above guaranteed level)**[6]
- **Natural Gas consumption 20% above target and guaranteed level**[7]

The low electricity consumption level is a welcome development as electricity in Alberta is both expensive and has a high Carbon Intensity. It is especially positive that this is observed in mid-winter, when plant electricity consumption is expected to be at its highest due to use of heat-tracing for piping freeze-protection. Higher than predicted Natural Gas consumption levels are disappointing and are being aggressively worked on by plant staff. There is a guarantee in place at the target level, but meeting this guarantee will require significant plant changes. The net result of lower electricity and higher natural gas loading is a slight increase in overall carbon intensity of about 0.54gCO_2(eq)/MJ, and an increase in operating costs.

Carbon Intensity of Ethanol Produced at GPHH will initially be slightly higher than modeled values of 2.25gCO_2(eq)/MJ[8]:

- Natural Gas consumption increase from 5.3MJ/L to 6.36MJ/L adds 40,280GJ/year, at 0.049MTCO_2(eq)/GJ, this is 1,973.72 Tonnes CO_2(eq)/year (which adds a cost of $201,000/year)
- Electricity savings from 0.2kWh/L to 0.162kWh/L reduces power usage by 1,444 MWh/year, at 0.65MTCO_2(eq)/MWh, this is 938.6 Tonnes CO_2(eq)/year (this also allows for an additional $173,000/year in revenue from exported power)
- Net of 1,035.12 Tonnes per year additional CO_2(eq)
  - 1,035.12 Tonnes CO_2(eq) * 1,000,000g/Tonne = 1,035,120,000g CO_2(eq)
  - 38,000,000L * 23.5MJ/L for ethanol = 1,083,000,000MJ
  - Additional 0.956gCO_2(eq)/MJ
  - Moves from 2.25gCO_2(eq)/MJ to **3.21gCO_2(eq)/MJ**. This change is nearly insignificant, and still results in real carbon offsets of more than 78,000 tonnes of CO_2(eq)/year
  - Net cost differential is ~$28,000/year
- **Note that electricity use in winter (data was collected in January and February 2013) is expected to be higher than in summer as freeze-**

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[6] Target for Carbon Intensity to match models is 0.2kWh/L, ICM guarantee is 0.162kWh/L – production electricity use matches guarantee exactly.

[7] Target for Carbon Intensity to match models is 5.3MJ/L, ICM guarantee is 5.3MJ/L – production natural gas use currently measures at 6.36MJ/L

[8] (S&T)² Consultants GHGenius Report dated June 18, 2012 give -1.64gCO2(ea)/MJ This report is attached as Appendix C. Adjusted calculation to account for Alberta regulated 0.65MTCO2eq/MWh yields a CI of 2.25gCO2(eq)/MJ. While the numbers used here were calculated using High Starch Wheat as the feedstock, operational data was gathered with wheat/corn mixes and all-corn feedstock and as such may slightly understate the energy needs of the facility on wheat feedstock.

protection of pipes uses considerable electricity.

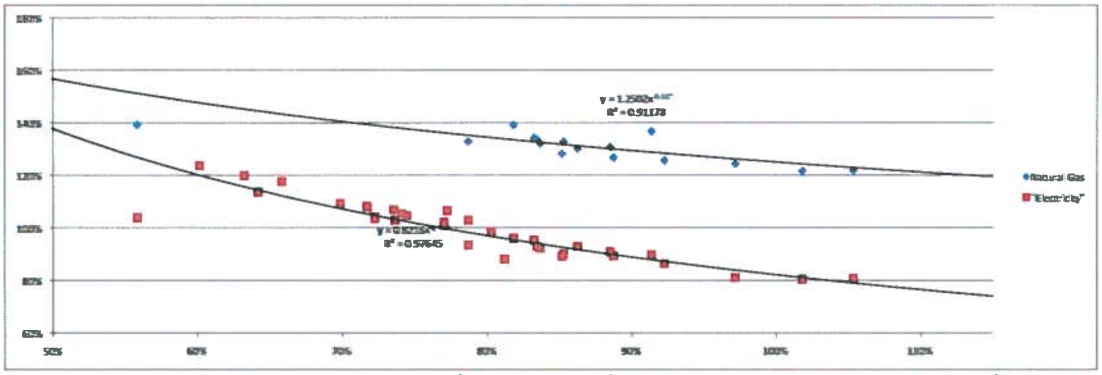

Figure 3 - Energy usage at GPHH, expressed as percent of target usage rate against percent of target ethanol output. This chart incorporates data from plant operating meters from January and February 2013, a larger number of data points exist for electricity meters as Natural Gas data prior to boiler fuel-air curve recalibration was excluded.

Additional Near Term Carbon Intensity Reduction

GPHH has also recently secured contracts to provide waste disposal services for Source Separated Organics to Strathcona County (at least 12,000 tonnes/year previously included in GPHH's Carbon Intensity calculation), and for Leduc Regional Waste Management Authority (at least an additional 12,000 tonnes/year previously serviced by landfill)

- Additional Carbon benefit from service of Leduc Regional Waste Management Authority is 14,458 tonnes of $CO_2(eq)$/year
- Net of 14,458 tonnes per year less $CO_2(eq)$
  - 14,458.05 tonnes $CO_2(eq)$ * 1,000,0000g/tonne = 14,458,000,000g $CO_2(eq)$
  - 1,083,000,000MJ of ethanol produced per year
  - Additional benefit of 13.35 $gCO_2(eq)$/MJ
  - Moves from 3.21 to **-10.14 $gCO_2(eq)$/MJ**
  - **Results in real carbon offsets of 9,439 tonnes of CO_2eq annually from the portion of the life cycle up to but not including ethanol consumption (gasoline offset) with an additional 88,496 tonnes of CO_2eq annually from the ethanol consumption portion of the lifecycle.**

GPHH is set to produce the lowest Carbon Intensity ethanol currently commercially available around the world. The production of ethanol from surplus grain at this low a Carbon Intensity is made possible through the technology integration that links the newly constructed EPF with the existing IMUS™ and pervades both facilities as well as the adjacent 36,000 head beef cattle feedlot.

Without the integration, the ethanol plant would produce ethanol at a much higher C.I., between 40$gCO_2(eq)$/MJ and 63$gCO_2(eq)$/MJ depending on the feedstock that it

employs. The consumption of waste material in the IMUS™ portion of the facility, and the production of electricity from this waste material for use directly in the ethanol production portion of the facility, as well as the trading of heat and water through all-three co-located units allows for the production of ethanol with this low a Carbon Intensity.

Discussion

The project did have its share of successes, and also its share of challenges. The discussion that follows presents both some significant successes and some key challenges that face the GPHH facility.

Successes

From the time of final project sanction to beginning of operations – the GPHH Integrated Bio Refinery Project was managed for GPHH by Project Manager George Caraganis. The Project Manager was instrumental in bringing the project in on budget, and for averting a major additional extension (the initial start date was missed by the construction company) to the construction timeline that would have cost GPHH dearly. The Owner's Engineer/Project Manager function can be seen as a success from this perspective.

It is notable that in Alberta in recent years, it is increasingly rare to see major capital projects come in on budget. Part of the ability to perform this task came from the contracting arrangement with the constructors – a Guaranteed Maximum Price (GMP) contract was employed between GPHH and ICM, and part of the cost management can be directly attributed to diligent project management. In all GMP type construction arrangements, there remains a possibility for a project to go over budget on non-contained items. In GPHH's case, the items that were considered "schedule B" items (i.e. not covered by the GMP) were managed on a day-to-day basis by GPHH's Project Manager and GPHH's executive. Change orders were held to a minimum and in many cases the change-orders that were approved by the Project Manager allowed for considerable savings against the budget.

In North America in 2012, there were very few, if any, other ethanol plants constructed, and GPHH managed to execute on a very tight timeline a relatively large and complicated project with tight budget constraints. This is a major success.

GPHH was also able to execute a Human Resources Strategy that saw the large majority of operational staff brought on board relatively early, several months prior to the planned start-up of the facility. This allowed for very solid training of the operations team and also allowed both time and resources to carry out the search and hiring activities required to bring in excellent, well-qualified, and well-motivated personnel. GPHH's 21 employees are an excellent team of very well trained operators. Building this team was also a major success.

Setbacks/Issues and Identified Solutions

Digester C Roof Sub-Structure Failure

In late October 2012, operators performing regular maintenance at the IMUS™ Facility noticed that the sub-structure of Digester C's[9] roof, (a wood and stainless steel dome that underlies the iconic flexible EPDM membrane) was deformed. Subsequent inspection determined that the sub-structure had collapsed. Shortly thereafter it became impossible to operate the digester.

Due to the piping arrangement, loss of operability of the primary digester (Digester C) necessitated a full shut-down of the facility[10].

Diagnosis

Since the failure appeared structural in nature, an investigation was initiated at the behest of the insurers of the facility. This meant that instead of a quick salvage operation, the structure needed to be dismantled section by section and inspected for damage. This process took more than 60 days. The substructure was completely removed from Digester C on February 10, 2013

Solution

Replacement of the wood and stainless steel sub-structure will take several months, however operations will resume in late March or early April, 2013 - with digesters A and B taking on the role of Primary Digesters and production of sufficient bioGas to fuel the electrical demands of the GPHH Integrated Bio Refinery™. As digester C becomes available the biogas production will increase significantly and export of electricity will be possible.

SSO Contamination

In October 2012 GPHH began receiving loads of Source Separated Organics ("SSO") from Strathcona County. While considerable work had been done to determine the suitability of the IMUS™ infeed system for processing SSO, a level of contamination much higher than anticipated was encountered.

The contamination included a large percentage – upwards of 7% by mass – of items that were listed as non-acceptable in communication with residents of Strathcona

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[9] Digester C was constructed in the GPHH expansion project of 2010-2011

[10] Piping has since been modified to allow for independent operation of Primary and Secondary digesters, which should enable partial operations in very short order

County. It appears to be a fact of human behavior that it is impossible to convince residents to completely adhere to a list of acceptable and non-acceptable items either through education or enforcement. This necessitated a temporary suspension of processing this material and a solution was investigated. It was determined that size reduction and removal of large inorganic contaminants and rope-like materials was necessary. The preferred combination of additional equipment has been selected and a partnership between GPHH and Evergreen Ecological Services (the company contracted to collect organics in Strathcona County and deliver to GPHH) has been struck to finance, install and operate the equipment.

Figure 4 - SSO as recieved at GPHH - this level of contamination requires additional pre-processing prior to digestion in IMUS

Solution – Permanently Installed Grinder and Trammel

A grinder and trammel combination is being specified and is in the process of being purchased, providing a permanent solution to SSO at GPHH and a much-increased capacity to process organic materials. Expect operational system in fall 2013.

GE 320 Overhaul - Extended Repair Timeline

For over a year GPHH has been hobbled by an extended repair cycle on the original GE Jenbacher 320 1MW engine. Originally planned to take 60 days or less, the overhaul on this engine has now taken 14 months and is reportedly 99% complete. At the time of this report the generator has been re-delivered to site and re-installation is imminent. This long delay has reduced the IMUS™ Facility's output capacity to 1.4MW during this time (net of outages on the new 1.4MW GE 420 engine). While we expect this to be resolved shortly, the limitations in service-ability of the GE reseller have caused more than considerable loss of revenue and functionality to GPHH. Due to this it is likely that at the end of the service life of the two GE Jenbacher engines they will be replaced with engines that have better support and lower life-cycle costs.

Boiler Loading

The 20% above-target Natural Gas consumption at the GPHH ethanol facility appears to be extra load on the boiler and is due to a number of factors stemming from design error:

Boiler Fuel-Air Mixture Settings

Initial set-up of the boiler fuel-air curve was carried out using readings from the DCS system on the plant that were not calibrated with the actual flow of natural gas. This error on the part of the boiler installer and the ethanol plant constructors resulted in the boiler being set to burn much richer than it needed to, and subsequently consumed larger amounts of Natural Gas than planned. This was resolved at the end of February and the boiler fuel-air curve is now set for much more efficient combustion.

Wheat Mash Viscosity and Number of Passes Through Heat Exchangers

The ethanol plant designers have great experience (more than 100 ethanol plants) with corn fermentation, however this facility is their first wheat-based plant. Calculations they used on mash viscosity resulted in sizing of heat-exchangers with smaller gaps than would be ideal for wheat, resulting in near-inability to pump material through the heat exchangers. While this issue will be certainly high on the list of plant upgrades for a later time, the plant was made fully operational in this respect by reducing the number of passes that the mash makes through each heat exchanger from 5 to 4. This results in a slightly less efficient heat transfer into the mash requiring more steam to get it to the appropriate temperature and a higher load on the boiler. As discussed above, this increase in boiler load does not generate a significant impact in terms of Carbon Intensity.

HHV vs. LHV

Boilers and other equipment can only extract a certain amount of the maximum theoretical combustion energy from a fuel. The amount of energy that equipment can extract is called the Lower Heating Value ("LHV"). Fuel, however, especially natural gas, is sold on the basis of the maximum theoretical combustion energy, called the Higher Heating Value ("HHV"). This results in a mismatch in expected efficiencies when a certain number of Gigajoules of Natural Gas is passed through the boiler, GPHH purchases that amount based on the HHV, but the boiler can only extract energy from approximately 90% of that amount. The discount between LHV and HHV has complicated the efficiency calculation: in the preceding discussion HHV was used as the measure of energy content in natural gas due to that being the economic measure on which GPHH pays, however the ethanol plant designers make the argument that they are only 5% to 10% less efficient than they guaranteed rather than 20% if they use the LHV of Natural Gas.

In either case, the thermal efficiency of this plant is good, but lower than the guarantee.

Grain to Ethanol Conversion

The conversion rate of Grain to ethanol at GPHH is currently under scrutiny. There is poor consistency in the rate of conversion, and there have been many days where the conversion rate is well below the guaranteed level.

Lower grain conversion is leading to higher production of stillage, and thus to excess loads on evaporation and centrifugation systems, this design error is under investigation at this time.

Type of Meter

Part of the uncertainty in the grain conversion rate calculation stems from the system emplaced to meter grain from the grain elevators into the hammer mills. This system depends on a measure of the indicated level in the grain inventory bins, and calculates the change in level as the amount of grain input into the system. This is subject to some significant error as grain does not lie flat at level in a grain-bin, nor does it have a perfectly consistent slump angle.

The type of meter that would be most useful for this application is a mass flow meter installed directly after the hammer mill. GPHH is investigating the best, most robust and most accurate equipment to put in place in this service and anticipate better ability to calculate – and therefore manage – grain conversion rates in the near future.

Ethanol Load-Out Logistics

Load out of ethanol onto trucks must legally be carried out from isolated tanks in order to ensure that all loads meet the quality parameters tested. At the moment GPHH has only one load-out tank, which creates logistical challenges, if trucks do not arrive on time, meaning there is residual ethanol in the load-out tank when the next batch of Quality Assured ethanol is ready to transfer. While the issue is largely one of accounting and paperwork, in order to satisfy the requirements of various regulators and customers, it is a very real issue.

Solution

In the short term, the plant Operations Manager is managing the logistics of the load-out tank closely – in the longer term, addition of a second load-out tank is a project that would enhance operations significantly. This second load-out tank has been included in the GPHH Phase III Expansion Project Plans.

Ethanol Carbon Intensity Qualification

The Carbon Intensity of GPHH-produced ethanol promises to be the lowest of all commercially available sources of ethanol. Once the GPHH IMUS™ facility is restored to full operations GPHH will be in a position to service Low-Carbon ethanol markets in the US (where, with certain conditions met, GPHH ethanol can qualify as an Advanced BioFuel and generate D-Code 5 RINS, generating a price premium that is expected to average about $0.20/gallon) as well as British Columbia, where Low-Carbon Fuel Standards are in place requiring lower Carbon Intensity of Fuels (Generating a price premium of up to $0.40/L).

GPHH Phase III Expansion Project

To further enhance GPHH's competitive advantage in low-carbon fuel, the GPHH Phase III Expansion Project is planned. This project will see the completion of another very large primary digester and associated piping and pumping equipment. This would raise the working capacity of GPHH from 10,200m^3 to 17,400m^3, and increase the biogas output by as much as double. Effectively, this would allow GPHH to reduce its consumption of Natural Gas to essentially zero, while still producing more than sufficient electricity to service the plant and export to the grid. The Carbon Intensity of GPHH Ethanol would subsequently drop another 15 to 17gCO_2(eq)/MJ, bringing the Intensity as low as –30gCO_2(eq)/MJ. This would equal an additional 30-40,000 tonnes per year in real GHG offsets.

The GPHH Phase III Expansion Project is currently estimated at $8-15MM, which

could be staged in two or three sub phases in order to manage cash outlay for CAPEX.

This project will be initiated when the Carbon Intensity market signals are of sufficient strength to justify the return on investment required by GPHH's investors.

Conclusions and Recommendations

The GPHH Integrated Bio Refinery™ Project is a qualified success. While the full GHG value of the project will only be realized once the IMUS™ portion of the facility is operational, and the EPF shows itself to be as efficient as designed it will assist the overall Integrated Bio Refinery™ in generation of very low Carbon Intensity Ethanol (currently estimated at -10.14gCO_2eq/MJ, by far the lowest of any commercially available Ethanol worldwide). The integration of ethanol production with IMUS™ and a co-located feedlot has been demonstrated to the satisfaction of additional clients for the technology.

At this time, GPHH recommends to its investors to consider leading the target on the Phase III expansion project, and prepare the facility through this expansion to meet the demand for low-carbon ethanol that is being signaled by both British Columbia and California.

GPHH also has a number of recommendations for both of its technology providers – Himark BioGas Inc and ICM, with these confidential discussions surrounding the energy efficiency of ethanol production, conversion rates of grain to ethanol, and the mechanical reliability of both processes. GPHH's recommendations will enhance the reliability and operability of both processes, which is part of a successful technology demonstration.

Now that extremely low Carbon Intensity ethanol can be produced in Alberta, GPHH recommends that additional investment, both public and private, be made in replicating this model on both the larger and smaller scales in order to both improve Alberta's GHG performance and the general perception of Alberta as a poor performer in the area of climate change management. The current cap of $15/tonne CO_2eq imposed by the same legislation that enables CCEMC has allowed for some behavioural change in the industry, but appears to have made all the difference that can be made at that level – increasing the cap to $30/tonne CO_2eq would almost certainly move Integrated Bio Refinery™ projects like GPHH into a realm where investors would find these very attractive.

The GPHH Integrated BioRefinery is a world first, demonstrating the successful integration of proven bioconversion technologies for extreme efficiency. The technology was born in Alberta and is ready to be fully commercial around the world.

CCEMC has assisted greatly in reducing the risks that investors will ascribe to this type of facility – it may yet take some additional assistance to bring the risks and returns in line with investor expectations, however the GPHH Integrated Bio Refinery™ will stand as a shining example of the type of technology that is both economic and environmentally sound.

Preliminary GHG impacts expected from the project, projected over a five-year period

The GPHH Integrated Bio Refinery™ Project will generate considerable carbon benefits both in its inaugural year and going forward as it continues to operate. Given the measured energy consumption data from GPHH since it first began EPF operations in late 2012, as well as the closing of new contracts for GPHH to process organic waste materials, we have adjusted the carbon intensity projections slightly from the original. These projections now show an annual benefit of 102,000 tonnes per year of CO_2eq. A breakdown of the projection calculation is shown in the table below.

Table 1 – Five-Year Carbon Offset Projections for GPHH Integrated Bio Refinery

	Year 1	Year 2	Year 3	Year 4	Year 5
Project Element Emissions Estimates					
Co-Substrate Transport	678	678	678	678	678
Co-Substrate Land Filling Avoidance	- 25,260	- 25,260	- 25,260	- 25,260	- 25,260
Manure Transport	212	212	212	212	212
Manure Land Application Avoidance	- 8,950	- 8,950	- 8,950	- 8,950	- 8,950
Natural Gas P&D	1,275	1,275	1,275	1,275	1,275
Diesel Fuel P&D	35	35	35	35	35
Venting/Flaring	56	56	56	56	56
Cogeneration Unit Operation	2,721	2,721	2,721	2,721	2,721
Boiler Operation	12,961	12,961	12,961	12,961	12,961
Grid Electricity Generation	- 8,187	- 8,187	- 8,187	- 8,187	- 8,187
Liquid Biofertilizer Storage	805	805	805	805	805
Solid Biofertilizer Transport	47	47	47	47	47
Conventional Fertilizer Production Avoidance	- 756	- 756	- 756	- 756	- 756
Wheat Production	21,351	21,351	21,351	21,351	21,351
Wheat Transport	1,065	1,065	1,065	1,065	1,065
WDGS Transport	16	16	16	16	16
WDGS Feed Credit	- 10,484	- 10,484	- 10,484	- 10,484	- 10,484
Ethanol Transport	2,974	2,974	2,974	2,974	2,974
Total Project Emissions	- 9,439	- 9,439	- 9,439	- 9,439	- 9,439
Ethanol Use as Gasoline Offset	- 88,496	- 88,496	- 88,496	- 88,496	- 88,496
Total Emissions	- 97,935	- 97,935	- 97,935	- 97,935	- 97,935
Ethanol Carbon Intensity					
Annual Ethanol Production (L/yr)	39,792,300	39,792,300	39,792,300	39,792,300	39,792,300
Ethanol Energy Content (MJ/L)	23.4	23.4	23.4	23.4	23.4
g CO_2e/MJ	-10.14	-10.14	-10.14	-10.14	-10.14

The reduction in offsets from increased energy usage by the Ethanol Production Facility is more than made up for from the increase in offsets from increased processing of landfill-destined organics.

The project above assumes that the Ethanol plant operates at its guaranteed output rate of 10,000,000 gallons/year (38,700,000L/year). Initial operations have been somewhat challenging, and while that level has been reached has been reached

briefly using corn-only feedstock, the Ethanol Production Facility technology provider and constructor will need to make some upgrades to reach the guaranteed level on a long-term basis.

Once this level is reached it will be considered the baseline operating level and production exceeding this baseline is possible. Any production in excess of the baseline operating level will see an increased carbon offset benefit accumulate to the project.

The GPHH Integrated Bio Refinery does not merely low-carbon ethanol, or even carbon-neutral ethanol, but instead it produces bioFuel that is actually is carbon-negative! Every liter of ethanol from GPHH that is consumed in vehicles pushes the energy equivalent of that liter of fossil fuels out of the market during this time period – both conserving valuable natural resources for a later time *and* reducing Alberta's GHG footprint.

Overall Conclusions and Next Steps

Overall the GPHH Integrated Bio Refinery project was a qualified success. The project sees the full integration of a fuel ethanol plant with a waste-to-energy facility and a large-scale feedlot. The waste produced by the feedlot and other sources becomes renewable electricity used in the ethanol plant that in turn produces both ethanol and wet distillers grains, the latter being consumed by the feedlot. With all the operations working at full speed will result in significant economic and environmental benefits.

Next steps for GPHH are to secure financing to expand the biogas production process both on the front end to increase the scope of materials that can be processed in the facility to include not only SSO, potentially raw Municipal Solid Waste, and complete construction of a second very large digester allowing for production of sufficient additional biogas to fuel the ethanol plant's boilers.

The above-mentioned next steps are referred to as the Phase III expansion of GPHH and would have additional economic and environmental benefits. With a budget of approximately $8-15MM, this project can be completed within one year and could start immediately upon successful financing. CCEMC has recently declined to consider funding for this project as funding was already provided to GPHH for the EPF and Integrated Bio Refinery™ project; therefore other outside sources of funding are being investigated. It is estimated that the Phase III expansion would increase the GHG reductions on site by an additional 40,000-60,000 tonnes of CO_2eq per year.

Himark BioGas, the company who's technology enables both the production of bioGas from waste at GPHH and the integration of the bioGas facility with other facilities is actively promoting the Integrated Bio Refinery™ model both in Canada and particularly in the US. Himark is in the process of starting up a much larger scale version of the GPHH facility at Western Plains Energy in Kansas, where the bioGas plant will be the largest waste-to-energy bioGas facility in the Americas, providing fuel for a 50 million gallon per year (5 times the scale of GPHH) drought-resistant-sorghum based ethanol plant. Other ethanol plants are certain to follow suit, as the economic benefits of integration are considerable, once the perceived risk of implementing such a large scale facility based on "new" technology is reduced due to successful demonstrations at the very large scale.

GPHH is proud to be the first Integrated Bio Refinery™ and to act as a risk-reducing demonstration of this excellent technology.

Appendix A – GHGenius Report

The following 16 pages include a report from (S&T)² Consultants on a GHGenius modeling run for the GPHH Integrated Bio Refinery™

CARBON INTENSITY OF GROWING POWER HAIRY HILL INTEGRATED BIOREFINERY WHEAT ETHANOL

Prepared For:

GROWING POWER HAIRY HILL
AFDP Building, University Farm
6004-118 Street
Edmonton, AB
T6G 2E1

Prepared By

(S&T)[2] Consultants Inc.
11657 Summit Crescent
Delta, BC
Canada, V4E 2Z2

Date: June 18, 2012

Executive Summary

The Government of British Columbia has introduced the Renewable and Low Carbon Fuel Requirements Regulation (RLCFRR) to reduce British Columbia's reliance on non-renewable fuels, help reduce the environmental impact of transportation fuels and contribute to a new, low-carbon economy.

The RLCFRR provides a regulatory framework that enables the Province to set benchmarks for the amount of renewable fuel in B.C.'s transportation fuel blends, reduce the carbon intensity (CI) of transportation fuels, and meet its commitment to adopt a low-carbon fuel standard.

The RLCFRR is designed to reduce the carbon intensity of transportation fuels through two major requirements:

- The Renewable Fuel Requirement (RFR) (5 percent renewable content in gasoline beginning in 2010 and 3 percent renewable content in diesel in 2010, 4 percent in 2011, and 5 percent for 2012 onward); and
- The Low Carbon Fuel Requirement (LCFR) (10 percent reduction in carbon intensity by 2020).

The RFR requirement has no direct GHG emission performance requirement but the LCFR does require the obligated parties to determine the carbon intensity of the pool of products that they produce or import into BC. In order to do this, the carbon intensity of each unique fuel used in BC must be determined and reported on annually. Over time, the regulation will require a reduction in the GHG emissions of each primary suppliers pool of transportation fuels. 2011 is a reporting only year and as noted above the reduction expected in 2020 is 10% below the established baseline.

The modelling of GHG emissions for the production of ethanol produced at the Growing Power Hairy Hill Integrated biorefinery facility has been undertaken using the version of the GHGenius model (3.16c) that has been specified in the BC LCFS regulations.

The lifecycle emissions for the ethanol fuel produced from wheat at the Growing Power Hairy Hill plant near Hairy Hill, Alberta are shown in the following table. The fuel dispensing and fuel use emissions are from running the model for the BC region and the other emissions are from a model run set to Alberta with the Growing Power Hairy Hill operating data.

Figure ES- 1 CI Growing Power Hairy Hill Wheat Ethanol

Source	Growing Power Hairy Hill
	g CO_2eq/GJ
Fuel dispensing	30
Fuel distribution and storage	2,543
Fuel production	24,544
Feedstock transmission	1,621
Feedstock recovery	5,740
Land-use changes, cultivation	7,155
Fertilizer manufacture	10,173
Gas leaks and flares	0
CO_2, H_2S removed from NG	0
Emissions displaced (Power and WDG)	-35,727
Emissions displaced (AD system)	-19,590
Total	-3,511
Fuel Use	2,052
Grand Total	-1,459
CI Grand Total, g CO_2eq/MJ	**-1.46**

The BC Government has published the CI of US corn ethanol produced from a natural gas plant and a coal fired plant, and a western Canadian gas fired wheat ethanol plant as part of their Information Bulletin RLCF-002 (2010). The values are compared to Growing Power Hairy Hill's value in the following table.

Figure ES- 2 Comparison to Baseline CI Values

		CI, g CO_2eq/MJ
W Canadian Wheat Ethanol	Natural Gas Fuelled	40.85
US Corn Ethanol	Natural Gas Fuelled	61.94
US Corn Ethanol	Coal Fuelled	73.82
Growing Power Hairy Hill	Natural Gas Fuelled	-1.46

The CI of the Growing Power Hairy Hill product is more than 100% less than the CI for a typical corn natural gas plant.

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1. INTRODUCTION

The Government of British Columbia has introduced the Renewable and Low Carbon Fuel Requirements Regulation (RLCFRR) to reduce British Columbia's reliance on non-renewable fuels, help reduce the environmental impact of transportation fuels and contribute to a new, low-carbon economy.

The RLCFRR provides a regulatory framework that enables the Province to set benchmarks for the amount of renewable fuel in B.C.'s transportation fuel blends, reduce the carbon intensity (CI) of transportation fuels, and meet its commitment to adopt a low-carbon fuel standard.

The RLCFRR is designed to help diversify B.C.'s transportation fuel supply, decrease GHG emissions and establish a market for low-carbon fuels by:

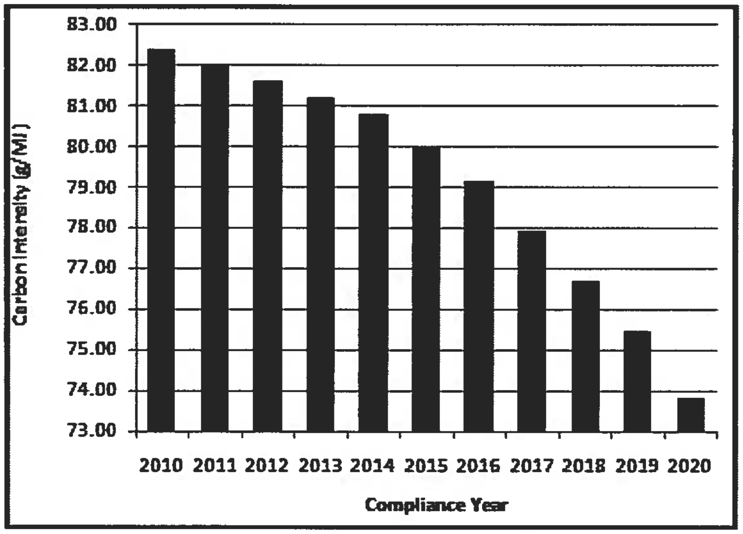
- Encouraging suppliers to determine how best to meet the requirements in accordance with consumer demand and market forces;
- Reducing reliance on non-renewable fuels; and
- Enabling requirements that encourage emerging cleaner fuel technologies.

The RLCFRR is designed to reduce the carbon intensity of transportation fuels through two major requirements:

- The Renewable Fuel Requirement (RFR) (5 percent renewable content in gasoline beginning in 2010 and 3 percent renewable content in diesel in 2010, 4 percent in 2011, and 5 percent for 2012 onward); and
- The Low Carbon Fuel Requirement (LCFR) (10 percent reduction in carbon intensity by 2020).

The RFR requirement has no direct GHG emission performance requirement but the LCFR does require the obligated parties to determine the carbon intensity of the pool of products that they produce or import into BC. In order to do this, the carbon intensity of each unique fuel used in BC must be determined and reported on annually. Over time, the regulation will require a reduction in the GHG emissions of each primary supplier's pool of transportation fuels. 2011 is a reporting only year and as noted above the reduction expected in 2020 is 10% below the established baseline as shown in the following figure.

Figure 1-1 BC LCFS Carbon Intensity Profile



The primary suppliers have begun to ask their renewable fuel providers for the carbon intensities of their products. Under the regulations, this CI must currently be calculated using version 3.16c of GHGenius. GHGenius is a spreadsheet tool that implements lifecycle assessment for transportation fuels. It is used to calculate the amount of greenhouse gases generated from the time a fuel is extracted or grown to the time that it is combusted in a motive energy vehicle to produce power. GHGenius has been developed by $(S\&T)^2$ Consultants Inc. and is supported by Natural Resources Canada.

At this time, the expectation of the BC Government is that suppliers will calculate their CI using GHGenius and only make changes to the input cells in the model (identified by a yellow background) and suppliers will document the changes so that an independent party can duplicate the results.

1.1 Scope of Work

The ethanol produced by Growing Power Hairy Hill (GPHH) is produced from wheat in a 38,000,000 litre/year plant in Hairy Hill, Alberta. This plant is quite unique in that it is an integrated bioRefinery powered by Himark's IMUS technology. The ethanol facility is integrated with other co-facilities to produce a more comprehensive and enclosed production process. All WDGS are consumed at a co-located feedlot, from which manure and other wastes produce biogas sufficient enough to generate more than 100% of the electricity consumed at the ethanol facility. The excess electricity is then sold to the grid, offsetting coal-dominated Alberta power. Because of the lack of drying of the ethanol plant co-product and the use of self generated electric power, life cycle emissions of this facility are expected to be quite low.

Since the wheat ethanol lifecycle is undertaken in several regions (production in Alberta and use in BC), the model must be run twice for the results.

1.2 GHGenius

The GHGenius model has been developed for Natural Resources Canada over the past eleven years. It is based on the 1998 version of Dr. Mark Delucchi's Lifecycle Emissions Model (LEM). GHGenius is capable of analyzing the energy balance and emissions of many contaminants associated with the production and use of traditional and alternative transportation fuels.

GHGenius is capable of estimating life cycle emissions of the primary greenhouse gases and the criteria pollutants from combustion and process sources. The specific gases that are included in the model include:

- Carbon dioxide (CO_2),
- Methane (CH_4),
- Nitrous oxide (N_2O),
- Chlorofluorocarbons (CFC-12),
- Hydro fluorocarbons (HFC-134a),
- The CO_2-equivalent of all of the contaminants above.
- Carbon monoxide (CO),
- Nitrogen oxides (NOx),
- Non-methane organic compounds (NMOCs), weighted by their ozone forming potential,
- Sulphur dioxide (SO_2),
- Total particulate matter.

The model is capable of analyzing the emissions from conventional and alternative fuelled internal combustion engines or fuel cells for light duty vehicles, for class 3-7 medium-duty trucks, for class 8 heavy-duty trucks, for urban buses and for a combination of buses and trucks, for light duty battery powered electric vehicles, and for marine vessels. There are over 200 vehicle and fuel combinations possible with the model.

GHGenius can predict emissions for past, present and future years through to 2050 using historical data or correlations for changes in energy and process parameters with time that are stored in the model. The fuel cycle segments considered in the model are as follows:

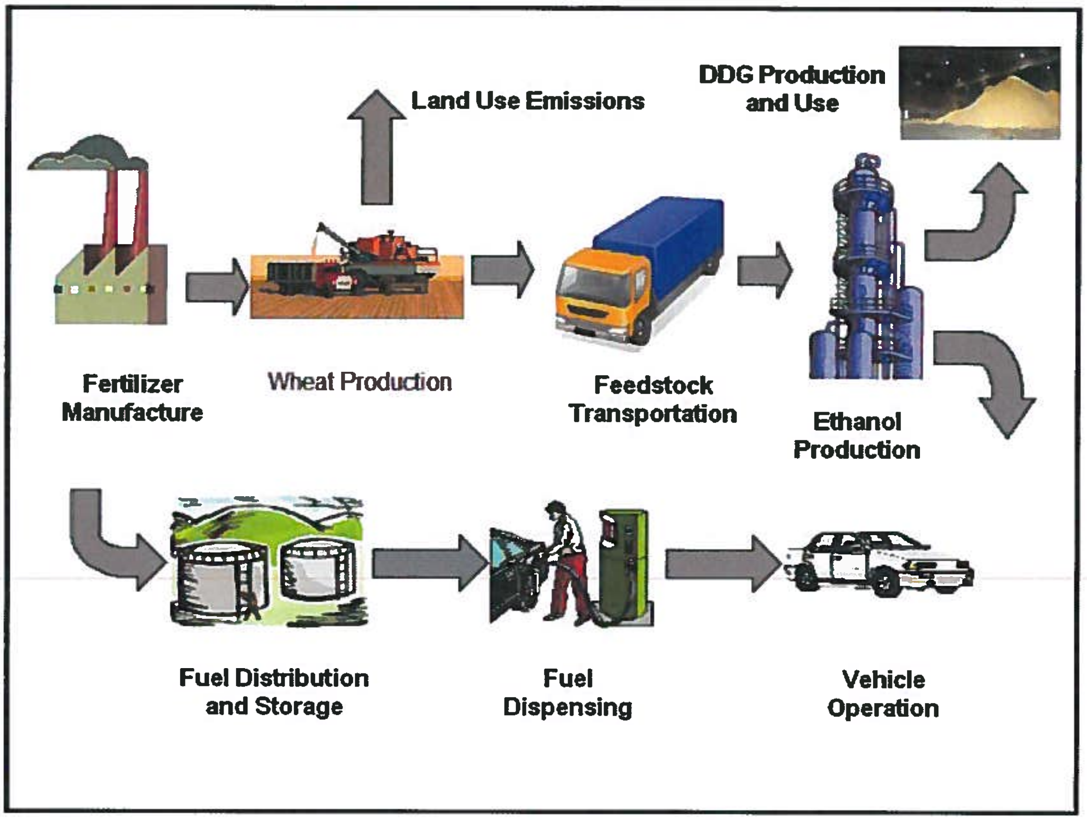
- Vehicle Operation
  Emissions associated with the use of the fuel in the vehicle. Includes all greenhouse gases.
- Fuel Dispensing at the Retail Level
  Emissions associated with the transfer of the fuel at a service station from storage into the vehicles. Includes electricity for pumping, fugitive emissions and spills.
- Fuel Storage and Distribution at all Stages
  Emissions associated with storage and handling of fuel products at terminals, bulk plants and service stations. Includes storage emissions, electricity for pumping, space heating and lighting.
- Fuel Production (as in production from raw materials)
  Direct and indirect emissions associated with conversion of the feedstock into a saleable fuel product. Includes process emissions, combustion emissions for process heat/steam, electricity generation, fugitive emissions and emissions from the life cycle of chemicals used for fuel production cycles.
- Feedstock Transport

Direct and indirect emissions from transport of feedstock, including pumping, compression, leaks, fugitive emissions, and transportation from point of origin to the fuel refining plant. Import/export, transport distances and the modes of transport are considered. Includes energy and emissions associated with the transportation infrastructure construction and maintenance (trucks, trains, ships, pipelines, etc.)

- Feedstock Production and Recovery
  Direct and indirect emissions from recovery and processing of the raw feedstock, including fugitive emissions from storage, handling, upstream processing prior to transmission, and mining.
- Fertilizer Manufacture
  Direct and indirect life cycle emissions from fertilizers, and pesticides used for feedstock production, including raw material recovery, transport and manufacturing of chemicals. This is not included if there is no fertilizer associated with the fuel pathway.
- Land use changes and cultivation associated with biomass derived fuels
  Emissions associated with the change in the land use in cultivation of crops, including N_2O from application of fertilizer, changes in soil carbon and biomass, methane emissions from soil and energy used for land cultivation.
- Carbon in Fuel from Air
  Carbon dioxide emissions credit arising from use of a renewable carbon source that obtains carbon from the air.
- Leaks and flaring of greenhouse gases associated with production of oil and gas
  Fugitive hydrocarbon emissions and flaring emissions associated with oil and gas production.
- Emissions displaced by co-products of alternative fuels
  Emissions displaced by co-products of various pathways. System expansion is used to determine displacement ratios for co-products from biomass pathways.
- Vehicle assembly and transport
  Emissions associated with the manufacture and transport of the vehicle to the point of sale, amortized over the life of the vehicle.
- Materials used in the vehicles
  Emissions from the manufacture of the materials used to manufacture the vehicle, amortized over the life of the vehicle. Includes lube oil production and losses from air conditioning systems.

The main lifecycle stages for a traditional wheat ethanol system are shown in the following figure.

Figure 1-2 Lifecycle Stages – Wheat Ethanol



The GHGenius model version 3.16c has been set to 2012 and the 1995 IPCC GWPs in accordance with the BC Regulations. The modelling data has been supplied by GPHH and is estimated based on the design data. The GPHH ethanol production data supplied for this analysis is consistent with energy consumption data collected and published for the US corn ethanol industry (Mueller, 2010).

In version 3.16c, the production of biogas is not fully integrated with the ethanol plant so the modelling of the biogas production and use is carried out within the GHGenius framework but as a manual calculation for the full lifecycle.

2. Feedstock Supply

Growing Power Hairy Hill is a purchaser of wheat and has little influence over the GHG emissions associated with growing or producing the feedstocks. Accordingly, the default input values in GHGenius are mostly maintained for these stages of the lifecycle. The exception is the transportation distances described in the following section.

2.1 Transportation

The GPHH plant receives wheat by truck. The fraction supplied by and the distances shipped are shown in the following table. The average transportation distance is relatively short.

Table 2-1 Wheat Distribution Scenarios

Processing Location	Hairy Hill, Alberta	
	Input Sheet Cell	Value
Average km shipped		
Truck	Z79	100
Tonnes-shipped/tonne-produced		
Truck	Z85	1.0

A portion of the feedstock for the anaerobic digester is also trucked to the site. The digester inputs are shown in the following table.

Table 2-2 Digester Feedstock

Ingredient	Mass, wet tonnes/day	Mass, dry tonnes/day
Manure	280	77.84
Peptone	5	1.09
DAF Sludge	15	3.74
Municipal organics	20	15.26
Deadstock	4	1.12
Total	324	105.60

The digester process 105.6 tonnes (dry) of material per day to produce 637 GJ/day of gas. Forty tonnes of wet feedstock are transported from Red Deer to the site by truck. The distance is 280 km. The material is waste produced by the meat industry.

Version 3.17 of GHGenius added the emissions for freight movement, all other aspects of the model are identical to GHGenius 3.16c. The GHG freight emissions are 210.6 g CO_2/tonne-km for Alberta. The feedstock freight emissions are therefore 3,703 g CO_2/GJ of gas produced (40*280*210.6/637).

3. Ethanol Production

Ethanol production information has been supplied by GPHH and is based on data collected prior to operations in 2012. The base year for wheat ethanol in the model has been set to 2012 (cell W6 on sheet X) to be consistent with the data collection period.

3.1 Mass and Energy Inputs

The process data used for modelling the ethanol production in GHGenius is summarized in the following table.

Table 3-1 Mass and Energy Inputs

	Growing Power Hairy Hill	
	Input Sheet cell	Value
Net Electricity (kWh)	P229	0.00
Diesel (litres/litre ethanol)	P230	0.00037
Natural Gas (litres)	P231	201.00
Coal (kg)	P232	0.00
Wheat (kg/litre ethanol)	P234	2.72

The anaerobic digester produces 637 GJ of biogas per day. This is equivalent to 0.25 GJ of biogas per GJ of ethanol produced.

Some aspects of the biogas system can be modelled within GHGenius and other aspects must be modelled outside of the model at this time.

Within the GHGenius modelling framework there is a credit for reduced methane emissions from the storage of the manure. The assumption is a methane emissions saving of 0.015 kg methane/kg of solids fed to the digester. At the same time there are methane losses from the system, these have been assumed to be 1% of the gas generated.

The methane production rate from the GPHH system is low compared to the default values in GHGenius. The GPHH system produces 1 GJ of methane for every 165 kg of feedstock whereas the GHGenius input is 67 kg/ GJ of methane. The difference is caused by differences in the composition of the manure, with the GPHH manure having higher quantities of materials that are slower to breakdown.

3.2 Co-products

The GPHH plant produces several co-products, which it both uses in its own facility and sells to a third party. GPHH produces wet distillers grains, which it uses in a co-located feedlot in order to produce manure and animal waste, which in turn gets converted to biogas. The biogas enters a co-gen system where it is converted to electricity, enough to both run the facility in full and export excess to the grid. GPHH also produces bio-based fertilizer from the anaerobic digester.

The quantity of power exported to the grid is 0.276 kWh/litre of ethanol.

There are also other emissions avoided from the production system. In most feedlots the manure that is produced is trucked from the feedlot to a nearby field and spread on the land. In the GPHH system the mass of the material spread on the land is greatly reduced and there is therefore a reduction in the trucking emissions, which should be credited to the system. In addition, some of the feedstock that is used in the biogas system would otherwise be landfilled and created methane emissions in the landfill. In Alberta landfills do not have methane capture systems so a credit is produced from the reduction in landfill emissions.

For the avoided transportation of manure it will be assumed that the net avoidance is 90% of the manure input into the digester, since there is still some biosolids from the system that are landspread. It will be assumed that the average transportation distance is 35 km. The avoided emissions are therefore 2,083 g CO_2/GJ of gas (0.90*200*35*210.6/637).

Methane emissions from uncontrolled landfills can range from 64 to 87 kg CH_4/tonne of waste as reported by Environment Canada in the National GHG Emission Inventory (2008). Municipal waste is reported on an as received basis and contains some non-biodegradable waste. It is assumed that the average moisture content is 25%. A value of 115 kg CH_4/dry tonne of biodegradable waste is used in later versions of GHGenius (75 kg/wet tonne/0.75 dry matter/0.87 biodegradable). The avoided emissions are therefore 76,165 g CO_2/GJ (20.09*115,000*21/637).

The emissions and avoided emissions that are calculated outside of the model are summarized in the following table.

Table 3-2 Emissions Calculated Outside of the Model

Item	Value, g CO2eq/GJ
Feedstock transportation	3,703
Manure transportation	-2,083
Landfill emissions	-76,165
Total	-74,545

3.3 Distribution

The ethanol is shipped directly from the plant to Red Deer by truck and then to Vancouver by rail. The truck distance is 280 km and the rail distance is 1,105 km. In Vancouver the ethanol is trucked 80 km, the distribution distance in BC from the blending facility to the dispensing point. It is the same distance as used for gasoline.

Table 3-3 Ethanol Distribution Scenario

Processing Location	Hairy Hill (Growing Power Hairy Hill), Alberta	
	Input Sheet Cell	Value
Average km shipped		
By Rail	P89	1,105
Domestic water	P90	0
International water	P91	0
Pipeline, tram, conveyor	P92	0
Truck	P93	280+80
Tonnes-shipped/tonne-produced		
By Rail	P95	1.00
Domestic water	P96	0.00
International water	P97	0.00
Pipeline, tram, conveyor	P98	0.00
Truck	P99	1.00

4. Results

The results for the various stages of the lifecycle are presented below along with a description of the modelling framework for each stage.

4.1 Lifecycle Emissions Growing Power Hairy Hill Ethanol

There are two emission sources at GPHH, the electric power system and the ethanol plant and the results for each must be combined to get the ethanol CI.

4.1.1 Anaerobic Digestion

The emissions from the anaerobic digestion system include the methane emissions from the system, the non CO_2 emissions from the combustion of the gas to produce electricity, the methane emissions avoided from the utilization of the manure in the system and then the emissions and avoidances of emissions outside of the GHGenius system.

The quantity of feedstock determines the avoided methane emissions from not landfilling the manure but if the feedstock doesn't produce methane in the AD system it wouldn't produce methane when land applied. The avoided emissions are therefore calculated based on the default feedstock rates in GHGenius rather than the GPHH federates. The table below shows the GHGenius results using the default feedstock value from GHGenius.

Table 4-1 Emissions from AD System

Source	Growing Power Hairy Hill
	g CO_2eq/GJ Biogas
Fuel dispensing	0
Fuel distribution and storage	0
Fuel production (methane leaks)	5,195
Feedstock transmission	0
Feedstock recovery	0
Land-use changes, cultivation	0
Fertilizer manufacture	0
Gas leaks and flares	0
CO_2, H_2S removed from NG	0
Emissions displaced (avoided methane from manure)	-21,105
Total	-15,910
Feedstock transportation	3,703
Manure transportation avoided	-2,083
Landfill emissions avoided	-76,165
Fuel Use	12,094
Grand Total	-78,361

This does not include the emissions avoided from the exported power, as this will be accounted for as part of the ethanol emissions. This assumes that the N_2O emissions from the application of the manure and the digestate are the same. At one time the IPCC had different emission factors for manure from other sources of nitrogen but in the latest guidelines these are now the same. It also assumes that the nitrogen in manure is the same quantity as used in the digestate. Given that there could be more nitrogen in the digestate (from the other substrates) this is a conservative assumption. Note that there are offsetting factors here as the N_2O emissions would be higher but a credit for the fertilizer displaced would have to be provided.

Finally when this emission credit is provided for the ethanol, it must be multiplied by 0.25 to get the emissions per GJ of ethanol produced (-19,590).

4.1.2 Ethanol

The lifecycle emissions for the ethanol fuel produced from wheat at the GPHH plant in Hairy Hill, Alberta are shown in the following table. The fuel dispensing and fuel use emissions are from running the model for the BC region and the other emissions are from a model run set to Alberta with the GPHH inputs that have been described in the previous sections.

Table 4-2 CI Growing Power Hairy Hill Ethanol

Source	Growing Power Hairy Hill
	g CO_2eq/GJ
Fuel dispensing	30
Fuel distribution and storage	2,543
Fuel production	24,544
Feedstock transmission	1,621
Feedstock recovery	5,740
Land-use changes, cultivation	7,155
Fertilizer manufacture	10,173
Gas leaks and flares	0
CO_2, H_2S removed from NG	0
Emissions displaced (Power and WDG)	-35,727
Emissions displaced (AD system)	-19,590
Total	-3,511
Fuel Use	2,052
Grand Total	-1,459
CI Grand Total, g CO_2eq/MJ	**-1.46**

4.2 Comparison to Other Ethanol CI Values

The BC Government has published the CI of US corn ethanol produced from a natural gas plant and a coal fired plant, and a western Canadian gas fired wheat ethanol plant as part of their Information Bulletin RLCF-002 (2010). The values are compared to Growing Power Hairy Hill's value in the following table.

Table 4-3 Comparison to Baseline CI Values

		CI, g CO_2eq/MJ
W Canadian Wheat Ethanol	Natural Gas Fuelled	40.85
US Corn Ethanol	Natural Gas Fuelled	61.94
US Corn Ethanol	Coal Fuelled	73.82
Growing Power Hairy Hill	Natural Gas Fuelled	-1.46

The CI of the Growing Power Hairy Hill product is more than 100% less than the CI for the default corn ethanol natural gas plant.

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