Exploring Carbon Offset Opportunities for the Maritime Livestock Industry

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Table of Contents

Executive Summary

The opportunity for the agriculture sector to increase farm gate revenues from the sale of carbon offset credits has been explored since Canada ratified the Kyoto protocol in 2002. Despite much discussion over successive federal governments, no regulatory framework exists for the development of a Canadian carbon market. However, numerous regional markets have been developed and carbon offset credits from viable projects are traded on a regular basis. The Province of Alberta has implemented greenhouse gas emission reduction legislation, making it the only regulated region in Canada.

Despite the lack of a regulatory compliance based carbon market, numerous science based greenhouse gas quantification protocols have been developed for the Canadian agricultural sector. These tools make it possible to determine how many carbon offset credits a farm might generate from a change in management practice or through the adoption of green technologies. The economic return from carbon offset sales can then be factored into the cost-benefit analysis for emission reduction projects.

Opportunities for the Maritime livestock sector to generate carbon offsets were explored by completing a series of on-farm greenhouse gas audits. Greenhouse gas reductions that could be achieved with advanced feeding and manure systems management in the beef, dairy and pork sectors were considered. Energy efficiency and renewable energy generation opportunities for the agriculture sector were also considered.

Each of the beef, dairy and pork sectors have the potential to contribute significantly to the development of a carbon offset package. Based on limited (25%) industry participation, an innovation project focussing on livestock feeding and manure management systems would generate roughly 40,000-tonnes of offset credits annually. Assuming an offset value of $15 per tonne, this equates to $600,000-annually in gross farm gate revenues. Energy efficiency and renewable energy generation projects have the potential to deliver an additional 16,000-tonnes of offsets annually, valued at $240,000.

Apart from the potential for revenue generation from offset sales, increases in production efficiency are inherent for on-farm greenhouse gas reduction projects, resulting in a decreased cost of production and increased farm profitability.

Maritime livestock producers should be encouraged to increase production efficiency by adopting advanced feeding and manure management systems. Energy efficiency projects and the installation of renewable energy generation systems should also be encouraged. Focusing on production efficiency, energy conservation and renewable energy generation will allow projects to be deployed in the near term, and carbon offset generation for individual projects can be quantified and aggregated as they are implemented. Tracking offset development will require that a detailed monitoring and record keeping system be developed to support carbon offset quantification activities.

The Maritime livestock sector has the potential to develop a carbon offset package in excess of 56,000-tonnes per year, an annual value of $840,000. A minimum quantity of 10,000-tonnes is required to attract serious interest from the carbon market, and small projects will have to be aggregated to satisfy the requirements of the marketplace.

Maritime Federations of Agriculture could support the development of a carbon offsets project by providing administrative leadership, communications outreach to the producer community and acting as a liaison between the supply and demand sides of regional carbon markets. Engaging provincial Departments of Agriculture, Environment and Energy will also be necessary to ensure that supporting policy is developed to allow for producer engagement in a carbon offset development project.

Glossary of Terms

Acid Detergent Fiber (ADF)- This value refers to the cell wall portions of the forage that are made up of cellulose and lignin. These values are important because they relate to the ability of an animal to digest the forage. As ADF increases, digestibility of a forage usually decreases. Many of the calculated values appearing on the forage reports are generated using ADF values.

Carbon Dioxide (CO_2) – The most abundant greenhouse gas, carbon dioxide is primarily produced during the combustion of fossil fuels, but is also emitted from soil when intensive tillage is practiced, due to the breakdown of soil organic matter.

Carbon Dioxide Equivalent (CO_2e) - Carbon dioxide equivalent is the standard reporting unit for GHG emissions, and is tied directly to the global warming potential of the various greenhouse gases. 1-kg of methane is equivalent to 21-kg CO_2e, given its GWP. Similarly, 1-kg of nitrous oxide is equivalent to 310-kg CO_2e. Reporting a farms GHG profile in carbon dioxide equivalents saves the reader from having to make conversions and allows for standard GHG reporting between and across sectors.

Carbon Offset – Commonly referred to as a carbon credit, a carbon offset is equal to 1-tonne of greenhouse gas reduced, expressed in tonnes of carbon dioxide equivalents (1-tonne CO_2e)

Carbon Offset Development Project – A single organization, or cluster of small businesses working in aggregate, to build a carbon offset package for sale on the carbon market. A carbon offset project would typically deliver at least 10,000-tonnes CO_2e per year to the client, for the life of the project.

Electricity Grid Greenhouse Gas Intensity – The total GHG emissions associated with each unit of energy output for an electrical utility. The Maritime provinces have varied GHG power grid GHG intensities, due to the variation in generation fuels used. Nova Scotia, with 70% reliance on coal-fired power generation has a grid intensity of 0.92 kg CO_2e kWh^{-1}. New Brunswick and Prince Edward Island have grid intensities of 0.58 and 0.66 kg CO_2e kWh^{-1}, respectively, reflecting the greater proportion of wind and hydro electricity generation capacity in these provinces.

Enteric Fermentation – The digestive process by which carbohydrates are broken down by microorganisms in the rumen (stomach) of ruminant livestock, into simple molecules for absorption into the bloodstream of the animal. Large quantities of methane emissions are produced during this process.

Global Warming Potential (GWP) - Carbon dioxide, methane and nitrous oxide each have varying abilities to trap atmospheric heat energy. Carbon dioxide has a GWP of 1, methane has a GWP of 21 and nitrous oxide a GWP of 310, meaning that methane and nitrous oxide can trap 21 and 310-times more atmospheric heat energy than carbon dioxide, respectively.

Greenhouse Gas (GHG) – A class of gases capable of trapping the suns energy in the earth's atmosphere as it is reflected off the earth's surface. A stable concentration of GHG in the atmosphere is necessary in order to retain enough of the sun's energy to regulate earth's temperature. The addition of man-made greenhouse gas to the atmosphere increases the amount of heat retained leading to global atmospheric warming.

Greenhouse Gas Liability – A regulated requirement to reduce GHG emissions output from a specific facility, or company. Regulatory compliance can be achieved through in-house GHG emissions reductions, investments in technology fund programs, or the purchase of carbon offsets.

Greenhouse Gas Project Baseline Case – The management conditions and GHG profile that existed on the farm prior to the implementation of a GHG reduction project

Greenhouse Gas Project Case – The management conditions and GHG profile that exist on the farm following the implementation of a GHG reduction project

Large Final Emitter – A corporation emitting greenhouse gas emissions in excess of 100,000-tonnes CO_2e annually prior to 2009, 50,000-tonnes CO_2e post 2009.

Methane (CH_4) – Methane is created during the anaerobic (without oxygen) decomposition of organic matter. The two main methane sources for the Canadian agricultural sector are the rumen of ruminant livestock and liquid manure storages, due to the breakdown of fibre under anaerobic conditions in both cases.

Neutral Detergent Fiber (NDF) - The NDF value is the total cell wall, which is comprised of the ADF fraction plus hemicellulose. Neutral detergent fiber values are important in ration formulation because they reflect the amount of forage the animal can consume. As NDF percentages increase, dry matter intake will generally decrease. Many laboratories analyze for ADF but may not include NDF values.

Nitrous Oxide (N_2O) – Nitrous oxide is a highly potent greenhouse gas produced by soil bacteria under anaerobic (without oxygen) soil conditions. In the absence of free oxygen, soil bacteria will use the oxygen contained in nitrate-nitrogen (NO_3^-) to continue their respiration processes. Nitrous oxide is a byproduct of this process.

Quantification Protocol (QP) – The technical document that outlines the proper procedures for quantifying baseline and project case GHG emissions for a farm unit. Quantification protocols outline the data required to complete the necessary calculations, and specifies the monitoring protocol that must be implemented in order to have carbon offsets verified on a regular basis.

Total Digestible Nutrients - The sum of the digestible fiber, protein, lipid, and carbohydrate components of a cattle diet. TDN is directly related to digestible energy and is often calculated based on acid detergent fiber values.

1. On-Farm Greenhouse Gas Management Basics

Greenhouse gas (GHG) emissions associated with the Canadian agriculture industry account for roughly 10% of the Canadian emissions profile. These emissions are comprised of Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O).

Carbon Dioxide emissions from the industry are primarily a byproduct of fossil fuel combustion for heat and electricity generation and diesel fuel for the operation of farm machinery. Primary and secondary tillage of cropland also contribute CO_2 emissions through the breakdown of soil organic matter. Soil carbon sequestration through the widespread adoption of conservation tillage has reversed the CO_2 emissions trend in the prairie ecosystem, which is currently sequestering more soil carbon than is being emitted as CO_2 due to the adoption of zero-till seeding practices.

Agricultural methane emissions are produced primarily by ruminant livestock (cattle, sheep, goats) through the digestion of high fibre feeds (silage, hay, pasture). Methane is also emitted from liquid manure storages through microbial decomposition of organic matter excreted in livestock manure. Dairy and pork production are the two sectors that would generally manage manure in a liquid form, and would therefore account for the majority of manure storage methane emissions. In both cases, methane production is a byproduct of microbial decomposition of organic matter under anaerobic conditions.

Nitrous oxide emissions contribute significantly to the Canadian GHG emissions profile due to its relatively high global warming potential, 320-times greater than carbon dioxide. Nitrous oxide emissions are the result of microbial processes in saturated agricultural soils. When manure and fertilizer applications to cropland are followed by a soil saturation event, such as heavy fall or spring rainfall events, soil bacteria can make use of the oxygen in nitrate-nitrogen (NO_3^-) to maintain respiratory function. Nitrous oxide is a by-product of this process. Soils that are prone to soil saturation, primarily in central, eastern and Atlantic Canada, contribute more significantly to total nitrous oxide emissions than do prairie soils, which are less prone to become saturated due to heavy rainfall and soil saturation.

Table 1 outlines the total agricultural GHG emissions profile for Canada.

Table 1. Canadian Agricultural GHG Emissions: 1990-2005

GHG Source Category		GHG Emissions (1000-Tonnes CO_2e)			
		1990	2004	2005	% of Total (2005)
Agriculture Total		**46,000**	**56,000**	**57,000**	100%
Enteric Fermentation		***18,000***	***24,000***	***25,000***	***44%***
Methane	Dairy Cattle	3,400	3,000	3,000	5%
	Beef Cattle	14,000	20,000	21,000	37%
	Others	610	1,000	1,000	2%
Manure Management		***6,700***	***8,400***	***8,600***	***15%***
Methane	Dairy Cattle	740	660	660	1%
	Beef Cattle	670	830	850	1%
	Swine	1,100	1,500	1,600	3%
	Poultry	70	90	90	0%
	Others	20	40	40	0%
Nitrous Oxide	All Animal Types	4,100	5,300	5,400	9%
Agricultural Soils		***21,000***	***24,000***	***23,000***	***40%***
Direct Sources (N2O)		12,140	13,060	12,690	22%
	Synthetic Nitrogen Fertilizers	5,100	6,300	5,800	10%
	Manure Applied as Fertilizers	1,900	2,200	2,300	4%
	Crop Residue Decomposition	4,100	4,200	4,300	8%
	Cultivation of Organic Soils	60	60	60	0%
	Conservation Tillage[1]	-180	-550	-580	-1%
	Summerfallow	920	570	530	1%
	Irrigation	240	280	280	0%
Pasture, Range, and		3,200	4,300	4,400	8%
Paddock Manure (N2O)					0%
Indirect Sources (N2O)		5,400	6,400	6,300	11%

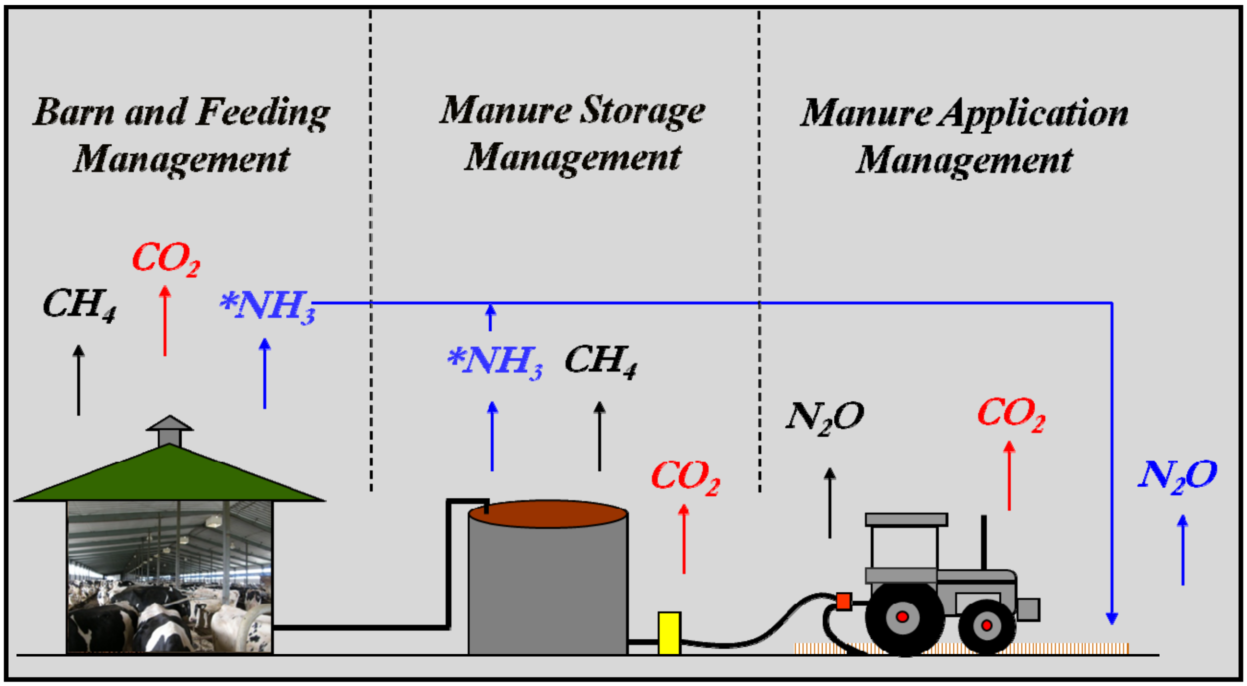
Source: National Inventory Report: Greenhouse Gas Sources and Sinks in Canada: 1990-2005.

[1] The negative values reflect a reduced N_2O emission due to the adoption of conservation tillage. Totals may not add up due to rounding.

Total provincial GHG emissions for the Atlantic Canadian provinces, in relation to agricultural and transportation emissions are outlined in Table 2. Figure 1 contains graphical representation of the typical GHG emissions sources on a Canadian livestock operation.

Table 2. Total, Agricultural and Transportation GHG Emissions Profiles for the Atlantic Provinces

GHG Emissions by Sector (1000-Tonnes CO_2e)					
	PEI	NFLD	NS	NB	Total
Total	2,280	10,500	22,700	21,300	56,780
Transport	910	3,900	6,400	5,500	16,710
Agriculture	530	46	500	490	1,566
% Transport	40%	37%	28%	26%	29%
% Agriculture	23.2%	0.4%	2.2%	2.3%	2.8%



*Denotes indirect GHG emissions through the deposition of ammonia and subsequent conversion to nitrous oxide

Figure 1. Typical GHG Emissions Sources for a Canadian Livestock Operation

GHG emissions are typically the result of a loss of efficiency in agricultural production. Each unit of carbon or nitrogen that is lost from the production system as CO_2, CH_4 or N_2O represents the loss of raw material that will not be converted into milk or meat products, but will rather, contribute to climate change processes.

Forage quality in the cattle sector is an excellent example of how reduced efficiency can contribute to increased GHG emissions. A high fibre, low quality dairy silage will be less digestible by rumen bacteria, and will ultimately increase the enteric fermentation methane emissions for the herd consuming the feed. Low quality forage production may be due to adverse weather conditions during harvest time, however, more often, low quality stored forage is the result of a longer than optimal harvest interval. GHG case studies revealed the importance of cutting early and often as a means of maximizing stored quality forage, and reducing enteric GHG emissions. Cattle offered high quality forages that are relatively low in non-digestible fibre will produce fewer rumen methane emissions, and convert more harvested fibre into meat and milk products.

To concept of GHG emissions intensity, ie. GHG output per unit of production, is important for benchmarking GHG emissions from individual farms, in order to compare them directly with one another. For example, a number of the case studies that make up the results of this project, were completed on farms that had undergone significant growth in herd population numbers between the baseline and project cases. A hog operation that underwent a major expansion will undoubtedly increase in net GHG emissions, however, economies of scale may allow for a significant increase in feed conversion efficiency. In this case, it becomes important to evaluate the farms GHG emissions based on kg-CO_2e per kg pig produced, in order to fully capture how gains in production efficiency have contributed to the farms GHG emissions profile.

With the exception of CO_2 emissions produced during the combustion of fossil fuels for heat, electricity or horsepower production, agricultural GHG emissions are largely a result of naturally occurring microbial processes. Recall that methane is produced through enteric fermentation and manure carbon decomposition in manure storage, and nitrous oxide is produced by soil bacteria under saturated soil conditions. Temperature therefore plays an important role in agricultural GHG emissions, and can introduce considerable variance into the GHG emissions profile between farms located in different Canadian climate zones.

For example, a dairy operation located in the Annapolis Valley region of Nova Scotia will tend to produce more manure storage methane emissions than an identical farm in Northern New Brunswick, due to the higher average temperatures enjoyed in the Annapolis Valley. Nitrous oxide emissions from agricultural soils may also trend higher in warmer regions due to enhanced microbial activity, although N_2O production is more likely dictated by the degree of soil saturation and the availability of soil carbon and nitrogen than soil temperature.

2. Greenhouse Gas Quantification Procedures

The biological nature of agricultural GHG emissions makes the development and use of standardized quantification protocols for estimating GHG emissions from an individual farm unit essential. The Government of Canada as a signatory to the Kyoto protocol is required to develop and submit regular national GHG emissions reports to the United Nations Framework Convention on Climate Change (UNFCCC). The national inventory report, due to the inclusion of all Canadian farms in the assessment calculations, is able to use regional or national default emissions factors to populate the inventory. The vast number of farms included in the calculations results in an average GHG emissions output per farm which is multiplied by the number of farms to derive an agriculture sector emissions estimate. Note in Table 1 that emissions by component of agricultural emissions are rounded to the nearest 1000, a testament to the 'average' nature of the estimate.

Individual on-farm GHG emission calculations, completed for the purposes of moving carbon offsets from the farm into the carbon market, require a much greater level of accuracy than that of the Canadian GHG inventory report. This is due to the fact that firstly, the demand side of the carbon market is likely intending to purchase these offsets, and therefore the boundaries of the offset credit package to be sold must be well defined, and secondly, the offsets are likely being purchased to satisfy regulatory compliance liabilities for CO_2 emissions. Regulated GHG emitters must have a high level of assurance that carbon offsets purchased are validated and verifiable as they risk fines of up to \$200-tonne CO_2e^{-1} for regulatory incompliance.

Quantification protocols (QP) are detailed, science based documents that outline how to go about quantifying GHG emissions from a specific project type. Protocols are developed by first establishing a working group which will generally include members of the scientific research community, industry liaisons, and industry practitioners. Including academia and industry on the working group ensures that protocols are rooted in scientific understanding, yet remain viable for implementation by industry.

QPs across Canada have been built on a number of platforms, with the ISO-14064 platform being the most popular to date. National pork and dairy sector protocols were constructed to be fully ISO-14064 compatible. Alberta has developed a number of QPs pertaining to agriculture, energy, forestry and waste management sectors that were also constructed to be ISO-14064 compliant.

> ISO 14064-2:2006, Greenhouse gases -- Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements
>
> http://www.iso.org/iso/catalogue_detail?csnumber=38381

Early site specific protocols and the quantification procedures used for Intergovernmental Panel on Climate Change (IPCC) Clean Development Mechanism (CDM) project quantifications were based on default emissions factors for most calculations. Generally, the only variables considered in livestock based protocols were the country of origin and livestock population size. Given the importance that small nuances, such as animal diet composition, manure storage emptying scheduling and local temperature regime can have on the actual GHG emissions output for a farm unit, and the possible emissions reductions, more robust protocols have been developed. Recent protocols allow for full farm case studies and scenarios to be analysed using a number of possible input scenarios. This flexibility allows for site specific assessment of a project idea before making significant on-farm practice changes in order to create carbon offsets.

A quantification protocol specifies the following:

1. Project Eligibility - Based on a set of qualifying criteria, a project idea may or may not qualify to develop a GHG reduction project using the QP in question. For example, although the manure storage emissions calculations for pork and dairy manure protocols are similar, the pork protocol clearly states that only pork projects are eligible to use the pork protocol to generate offset projects.

2. Quantification Approach - Based on the most up-to-date and available scientific understanding of GHG production processes, the mathematical equations and emissions factors required to complete a GHG assessment are formulated. Often, country specific emissions factors need to be developed to take into account country specific management practices, production systems, temperature regimes, etc.

   The quantification approach is used to validate a GHG reduction project by calculating the emissions profile for the baseline and project cases. The baseline case is the state of operations at the project site before implementing a management practice change or installing a new GHG reduction technology. The project case is the state of operations after the project concept has been implemented. GHG reductions are calculated by subtracting the project case emissions from the baseline emissions profile.

3. Monitoring Plan - To complete necessary calculations for baseline and project cases in a GHG reduction project, a complete data set for all necessary variables must be available. As such, a GHG QP will specify a set of data to be collected for the project, the level of detail necessary for the data to be considered accurate, and the frequency at which the data must be collected. In some cases, continuous automated data collection may be specified.

2.1. Pork Sector Quantification Protocol

The pork sector GHG quantification protocol was the first of its kind in Canada, developed in response to significant GHG aggregator activity in western Canada, despite a lack of scientific understanding of the processes contributing to a farms GHG emissions or how to evaluate, measure and report these emissions. The pork QP was constructed to allow for site specific estimation of emissions based on the local weather regime, and actual on-farm ration composition and manure management practices. The pork protocol was an important advancement in the quantification of Canadian GHG emissions, building on scientific research results from various sources, including Agriculture and Agri-Food Canada, the United States Environmental Protection Agency, Canadian and US academic research units. The pork protocol largely proved the quantification protocol development process that remains the standard approach for QP development today.

The pork protocol was constructed to allow for the quantification of GHG emissions projects based on advancements in feed conversion efficiency and the implementation of advanced manure management strategies.

2.2. Beef Sector Quantification Protocols

A number of beef sector quantification protocols were developed for use in the regulatory compliance offsets market in Alberta. The beef protocols focus on increased feed conversion efficiency, primarily in the feedlot sectors, and the addition of feed supplements such as edible oils, shown to reduce enteric fermentation emissions by as much as 20% when fed at 4-6% of total ration dry matter intake. As cattle emit methane through enteric fermentation on a continual basis, reducing the cattle days to market results in a net reduction in GHG emissions, which forms the basis of the beef sector QPs.

2.3. Dairy Sector Quantification Protocol

The dairy sector GHG protocol was constructed for use in quantifying dairy GHG emissions from across Canada, although to date the protocol has only been approved for use in the Alberta Offset System, as no new protocols are being reviewed at the Canadian federal level. The dairy sector protocol was largely modelled after the pork protocol allowing for the quantification of GHG reduction projects involving advanced feeding and manure management strategies. This project is the first in-field test of the new Dairy GHG Quantification Protocol.

2.4. Energy Efficiency Quantification Protocols

An energy efficiency protocol was contemplated for the federal offset system and an energy efficiency protocol has been approved for use in the Alberta Offset System. Energy efficiency represents a fairly straight forward GHG reduction project concept with the baseline case being the energy consumed prior to project implementation and the project case considered as the energy usage following project implementation. Utility bills provide much of the necessary data needed to quantify reductions in energy usage, and therefore, the resulting GHG emissions. Quantifying the emissions reductions from electrical energy efficiency projects, requires that the electricity grid intensity (kg CO_2e kWh^{-1}) for the provinces in which the project is operating are known. GHG reductions are calculated by multiplying the energy use reduction by the grid intensity. Similarly for thermal energy projects, reductions in the use of diesel, heavy fuel oil, propane, natural gas, etc., are multiplied by the fuel specific GHG emissions factor (ie. kg-CO_2e L-Heating Oil^{-1}) to derive a GHG emissions reduction estimate.

2.5. Renewable Energy Generation Quantification Protocols

The procedures for quantifying GHG emission reductions achieved through the generation of renewable energies are similar to those for quantifying energy efficiency projects. In the case of electricity generation, the total amount of electricity produced is multiplied by the provincial grid GHG intensity factor to derive the GHG offset achieved. Quantifying renewable thermal energy generation project GHG emissions requires that the quantity of non-renewable fuel being offset by the renewable project be quantified and multiplied by the default fuel GHG emission factor.

Energy efficiency protocols have been approved for use in the Alberta Offset System, and were proposed for use in the Canadian Offset System as well.

3. Carbon Market Engagement

3.1. The North American Carbon Market

The North American carbon market as a whole is a complex and diverse network of provincial, state and regional markets. Despite several attempts under the governments of the Honourable Jean Chretien, Paul Martin and most recently Stephen Harper little federal policy direction regarding the development of a national carbon market has been solidified. US President Barack Obama indicated a desire to increase the prominence and importance of climate change policy in the United States. However, the global economic downturn and difficulties in passing legislation has significantly delayed the implementation of a US climate change bill. Canada, seeking to partner with the United States in a North American wide carbon market initiative, has also largely stalled the development of climate change policy, choosing instead to wait for US policy to develop.

In the absence of federal policy direction, numerous regional GHG markets have developed to service provincial, state and regional demand for carbon offsets, generated through state and provincial regulatory compliance measures largely imposed on heavy industry and fossil-based energy producers.

3.2. Canadian Regulatory Compliance Markets

Currently, the only regulated regional market in Canada is the Alberta carbon offset market. Saskatchewan and Ontario have also signalled their intention to develop domestic compliance based carbon markets and British Columbia is currently soliciting for offsets projects through the Pacific Carbon Trust. The segregated nature of the Canadian market has resulted in the development of carbon offset trade barriers, as regulated jurisdictions seek to limit the flow of capital outside of their borders, as illustrated below in the description of the Alberta carbon market structure.

The Alberta Climate Change Emissions Management Act was amended in 2007 to require companies with annual emissions of more than 100,000-tonnes CO_2e to reduce their emissions by 12% from a 2003-2005 baseline. This created a strong demand for carbon offsets as the affected companies are obligated to reduce their emissions in house, purchase offsets from others, or purchase from a public technology fund in order to reach regulatory compliance. Non-compliant companies face stiff penalties of up to $200-tonne

CO_2e^{-1} and possibly an additional flat fee of $250,000. The financial implications of inaction in Alberta have created a market for 'Gold Standard' credits consistently valued at $12-15 tonne CO_2e^{-1}. This has created a significant opportunity for developing carbon offset projects in Alberta and the demand side of the marketplace has looked favorably towards the agriculture industry as a supplier of offset credits. As in other North American jurisdictions, however, the Alberta offset market rules state that regulatory compliance can only be met with offsets created within Alberta, effectively shutting out any potential non-Albertan offsets created in North America from flowing into the Alberta market.

3.3. Voluntary North American Carbon Markets

The voluntary carbon markets do not tend to place restrictions on where offsets projects are located, and are thus more accessible for projects located outside a regulated market region. The voluntary markets were initially designed to service the anticipated growing need for regulatory compliance offsets. However, with the lack of federal regulations in Canada and the US, voluntary markets have instead evolved to service the growing market for offsets used in marketing and promotion and/or long term carbon liability risk management.

One of the mot well known, and longest operating voluntary carbon markets in North America is the Chicago Climate Exchange, established in 2000 and operational since 2003. The CCX was established as a means for marketing and purchasing carbon offsets in an unregulated carbon constrained economy. As evidence of climate change became more mainstream, governments, environmental groups and corporate board members around the world began to call for more stringent accounting of carbon emissions and increased effort to control the rise in carbon emissions. The CCX and others such as the Montreal Climate Exchange, and the European Climate Exchange provided a means for corporations to purchase carbon offsets, validated and verified by certified third parties, providing a high level of assurance that the offsets that were purchased were real and bankable.

3.4. Marketing Carbon in Regulated Versus Voluntary Markets

The risk associated with regulatory non-compliance is well reflected in the market price of carbon in a regulated market, as in the case of the Alberta Offset System where one tonne of CO_2e can be marketed for $12-15. Voluntary carbon offset markets tend to return a much lower price for carbon, historically in the range of $2-5-tonne CO_2e^{-1}, reflecting the lack of risk of non-compliance and possible fines that may be incurred. It is therefore desirable to market offsets into regulated markets wherever possible, but as is the case in many regional markets, offsets created outside the region are not eligible for trading.

3.5. Marketing Volume and Transaction Costs

The concept of carbon aggregation has proven to be an important component to marketing agricultural based carbon offsets. Due to the relatively small offset packages that can be developed on a per farm basis, it is necessary to aggregate numerous packages in order to engage the market, which typically requires at least 10,000-tonne CO_2e to consider a transaction. Thus, agricultural offsets generally cannot be marketed without aggregation.

Secondly, the transaction costs for moving an offset package are typically 15-30% of the gross value of the offsets. A 10,000-tonne package marketed for $15-tonne CO_2e will gross $150,000 and carry transaction fees of $22,500-$45,000. Transaction fees may include, but are not limited to, the cost of validation, verification, marketing, contract negotiation, financing negotiations, and legal due diligence. Much of the transaction labour will be conducted by members of an accounting and/or legal team, owing to the significant cost of completing a carbon transaction. Aggregation allows these costs to be borne over a large number of projects, making transaction costs more manageable for each individual project participant.

Another important function of aggregation is shared market risk. If the minimum offset package size is 10,000-tonnes CO_2e, and each participating farm is able to contribute 200-tonnes CO_2e, it would be necessary to have 50-farms as part of the aggregation group to satisfy the package size requirement. It is highly likely that a number of farms, despite good intentions, will not meet the criteria of the offset program or the specific scope of the offset project, may change ownership, or encounter financial hardship that will require the farm to be excluded from the project. An aggregated project will allow the risk associated with non-delivery to be spread over the remaining participants, or if possible, the excluded operations can be replaced. Shared risk ensures that a project will not falter completely if a portion of the membership is not able to meet their individual requirements towards the project.

Aggregation of agricultural based projects is, therefore, a necessity for marketing carbon into traditional carbon market systems. Contemporary approaches to carbon marketing may be possible in some cases, depending on the type of offset project, examples of which are described below.

3.6. Direct Carbon Offset Marketing and Embedded Carbon Value

Marketing carbon through a traditional carbon market system, as has been described in detail earlier in this report, requires a significant level of administration to collect and manage data, perform validation and verification tasks and engage the demand side of the carbon market. Capturing the embedded carbon value of renewable energy based projects can tend to be more administratively straight forward for a number of reasons.

First, direct measurement of renewable heat and electricity generation can be achieved with real-time data logging equipment. This reduces the labour requirement for data collection and significantly reduces the potential for human error in data management. For example, a data logging system monitoring the electricity generated by a commercial wind turbine will provide accurate data on the amount of non-renewable energy the project is offsetting on a daily basis. A dairy based GHG reduction project will, however, require the collection of feed ration component quality data, amount of feed offered the heifer, lactation and dry animal herds and the manure application schedule for the farm, before performing detailed calculations on the farms net GHG emissions output. The administrative requirements between the two project concepts is evident.

Second, all three Maritime electric utilities have developed programs to allow on-farm electricity generation systems to be connected to the distribution grid, through net metering or embedded generation as an independent power producer, see side bar for detail on Net Metering and Embedded Generation programs. Renewable electricity exported from an on-farm electricity generator through an embedded generation program will generate carbon by offsetting non-renewable energy on the grid, however, the provincial utility is likely to assume ownership of any carbon offsets created. While this presents an opportunity to market carbon offsets from a renewable energy project with a minimal amount of overhead and administration, it is important that the embedded carbon value of renewable energy be reflected in the Feed-in-Tariff rate. The Nova Scotia Renewable Energy Program has indicated a willingness to address the embedded carbon value for renewable energy generation, while the NB Power Embedded Generation program assigns little to no value to carbon offsets created by renewable

Net Metering

Installing an electricity generation device with a capacity sufficient to meet the demand needs of the net metered facility. Designed to allow ratepayers to become electricity self-sufficient.

Embedded Generation

Installing an electricity generation system with the express intent of exporting power from the generation site to the distribution power grid for sale to ratepayers.

Feed-In-Tariff

A stable renewable energy purchase price established during program development.

energy generation projects collected to the grid through the Embedded Generation program.

Developing innovative carbon marketing approaches that minimize offset sale administration may help to streamline the sale of agricultural carbon offsets and may warrant exploration with regional large final emitters such as provincial power utilities.

3.7. Maritime Large Final Emitter Community Emissions Profile

The total annual GHG emissions profile for the Maritime Large Final Emitter (LFE) community is outlined in Table 3. According to the rules outlined in Section 46 of the *Canadian Environmental Protection Act, 1999* (CEPA 1999), any organization emitting greenhouse gases in excess of 100,000-tonnes CO_2e annually, must report these emissions to Environment Canada, which are published through the Greenhouse Gas Emissions Reporting Program.

The data presented in Tables 4-6 represent emissions for each facility that was required to submit 2008 emissions data according to CEPA 1999, in each of the Maritime provinces. The 2008 data was the most recent, complete data set available from Environment Canada. Note that several emitters who are below the 100,000-tonnes CO_2e threshold reported their emissions voluntarily.

Table #3. Maritime Large Final Emitter Community Emissions Profile

	Total Annual Greenhouse Gas Emissions (Tonnes CO_2e)						
	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
New Brunswick	10,212,407	26,474	44,874	0	0	0	10,283,755
Nova Scotia	10,931,673	54,181	97,727	116	0	20,482	11,104,179
Prince Edward Island	98,589	0	0	0	0	0	98,589
Total	21,242,670	80,655	142,601	116	0	20,482	21,486,523
% of Total	98.87%	0.38%	0.66%	0.00%	0.00%	0.10%	

Table #4. New Brunswick Large Final Emitter Community Emissions Profile

Rank	Facility	Reporting Company	Tonnes CO_2e
1	Belledune Generating Station	NB Power Generation Corporation	3,150,000
2	Refinery	Irving Oil Refining G.P.	2,981,743
3	Dalhousie Generating Station	NB Power Generation Corporation	1,860,000
4	Coleson Cove Generating Station	NB Power Coleson Cove Corporation	976,000
5	Bayside Power	Bayside Power L.P.	443,330
6	Brunswick Smelter	Xstrata Canada Corporation	200,467
7	Grand Lake Generating Station	NB Power Generation Corporation	175,000
8	Irving Paper	Irving Paper Limited	165,137
9	AV Nackawic	AV Nackawic Inc.	157,801
10	Irving Pulp & Paper Ltd.	Irving Pulp & Paper Ltd.	100,948
11	Havelock	Graymont (NB) Inc.	73,325

Table #5. Nova Scotia Large Final Emitter Community Emissions Profile

Rank	Facility	Reporting Company	Tonnes CO_2e
1	Lingan Generating Station	Nova Scotia Power Incorporated	4,138,005
2	Trenton Generating Station	Nova Scotia Power Incorporated	2,171,380
3	Point Aconi Generating Station	Nova Scotia Power Incorporated	1,434,807
4	Point Tupper Generating Station	Nova Scotia Power Incorporated	1,047,105
5	Tufts Cove Generating Station	Nova Scotia Power Incorporated	990,949
6	Dartmouth Refinery	Imperial Oil	727,008
7	Brookfield Plant	Lafarge Canada Inc.	332,782
8	Thebaud Platform	ExxonMobil Canada Properties	151,274
9	Goldboro Gas Plant	ExxonMobil Canada Properties	110,865

Table #6. Prince Edward Island Large Final Emitter Community Emissions Profile

Rank	Facility	Reporting Company	Tonnes CO_2e
1	Cavendish Farms	Cavendish Farms Corporation	98,589

Several important changes to the Greenhouse Gas Emissions Reporting Program came into effect in 2009 including the implementation of a much lower reporting threshold. Facilities emitting more than 50,000-tonnes CO_2e annually must now report their GHG emissions. This is of particular interest to the agricultural sector. Large firms with carbon liabilities in excess of 100,000-tonnes annually (10% reduction target on a 1,000,000-tonne CO_2e emissions profile), will be more inclined to seek partnerships with large GHG emission reduction projects that can deliver verifiable carbon offsets in large package sizes that minimize transaction costs. These project types may include landfill gas capture and destruction projects or large renewable energy projects such as wind farm or biomass fired electricity generation systems.

Smaller large final emitters with an annual emissions profile closer to 50,000-tonnes CO_2e, are likely to be more willing to partner on agricultural based GHG reduction projects, as the desired offsets package size can be more easily delivered through agricultural based projects. This concept is illustrated in Table 7 using the actual emissions profiles for the 2nd and 11th largest final emitters in New Brunswick in 2008.

Table #7. New Brunswick Large Final Emitter Carbon Liability Comparison

Large Final Emitter	Annual Emissions (2008)	Reduction Target	Offset Liability
Irving Oil Refining G.P.	2,981,743.00	10%	298,174.30
Graymont (NB) Inc.	73,325.69	10%	7,332.57

Using a theoretical GHG emissions reduction target 10%, The Irving Oil Refinery with annual GHG emissions close to 3-million tonnes CO_2e, would have a nearly 300,000-tonne CO_2e annual GHG liability. Delivering a carbon offsets package of this size would likely prove to be very difficult for the agricultural industry at this time.

By contrast, Graymont's limestone quarry and processing operations in Havelock, NB has an annual emissions profile of roughly 73,000 tonnes CO_2e. If the same theoretical emissions reduction target of 10% is assumed for this facility as well, the total offset liability would be 7,332 tonnes CO_2e, a value much more in line with the carbon offsets delivery capabilities of the Maritime agricultural sector. The 2009 Greenhouse Gas Emissions Reporting Program datasets, which will include all LFEs with more than 50,000 tonnes CO_2e, is likely to reveal a number of realistic opportunities for the agricultural sector to partner with small LFEs to develop manageable carbon offset projects.

A complete list of Canadian Large Final Emitters is outlined in APPENDIX A.

3.8. Potential Agricultural Carbon Market Share Analysis

In order to put the total carbon market opportunity for the agricultural industry in perspective, Table 8 has been formulated to outline the total carbon liability that would be created with the implementation of a regulated carbon reduction mandate for Maritime large final emitters. While a 100% GHG emissions reduction goal is well out of reach of modern society in 2010, these values have been included for context of the long-term GHG emissions challenge faced by industry and the opportunity that exists for green technology developers, providers and adopters.

Table 8. Potential Carbon Market Volume for Maritime Province Large Final Emitter Community

	Greenhouse Gas (tonnes CO_2e)						
Market Share	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
1%	212,427	807	1,426	1	-	205	214,865
2%	424,853	1,613	2,852	2	-	410	429,730
3%	637,280	2,420	4,278	3	-	614	644,596
4%	849,707	3,226	5,704	5	-	819	859,461
5%	1,062,133	4,033	7,130	6	-	1,024	1,074,326
6%	1,274,560	4,839	8,556	7	-	1,229	1,289,191
7%	1,486,987	5,646	9,982	8	-	1,434	1,504,057
8%	1,699,414	6,452	11,408	9	-	1,639	1,718,922
9%	1,911,840	7,259	12,834	10	-	1,843	1,933,787
10%	2,124,267	8,065	14,260	12	-	2,048	2,148,652
20%	4,248,534	16,131	28,520	23	-	4,096	4,297,305
30%	6,372,801	24,196	42,780	35	-	6,145	6,445,957
40%	8,497,068	32,262	57,040	46	-	8,193	8,594,609
50%	10,621,335	40,327	71,300	58	-	10,241	10,743,261
60%	12,745,602	48,393	85,560	69	-	12,289	12,891,914
70%	14,869,869	56,458	99,820	81	-	14,338	15,040,566
80%	16,994,136	64,524	114,080	93	-	16,386	17,189,218
90%	19,118,403	72,589	128,340	104	-	18,434	19,337,871
100%	21,242,670	80,655	142,601	116	-	20,482	21,486,523

The total GHG emissions for Maritime region CEPA reporting facilities is 21,486,523-tonnes CO_2e annually. A regulated 1% reduction in net GHG output would create a demand for 214, 865-tonnes CO_2e, while a regulated 10% reduction would create a demand for 2,148,652-tonnes CO_2e annually. While the agricultural sector would not be the only industry working to bring carbon offsets to market, the total demand in relation to the opportunity to deliver offsets in the short term is an important consideration.

3.9. Agriculture Sector Carbon Offset Development Opportunity

The following tables 9-11 outline the total identified carbon offset development opportunity for the primary Maritime livestock sectors, energy efficiency measures and select renewable energy technologies.

Table 9 outlines the total number of eligible participant farms, identified using industry and Statistics Canada data, assumed to be available for participation in a carbon offsets development project.

Table 9 also outlines the total carbon offsets package that could theoretically be developed, by individual industry sectors and in aggregate, based on 25, 50, 75 and 100% industry participation. The final assessment was developed using an escalating participation rate to represent the likelihood of limited initial producer engagement in a carbon offset development project. Industry leaders are likely to engage in a development project initially, followed by the less risk adverse members of the livestock producer community.

Table 9. Maritime Livestock Operations Available for Carbon Offset Project Participation

		Participation Level (# Farms)			
	Eligible Farms	**25%**	**50%**	**75%**	**100%**
Dairy Sector	692	173	346	519	692
Beef Feedlot Sector	2458	615	1229	1844	2458
Pork Sector	43	11	22	32	43
Energy Efficiency					
Swine	43	11	22	32	43
Poultry	180	45	90	135	180
Dairy	693	173	347	520	693
Vegetable Storage	515	129	257	386	515
		Participation Level (# Farms)			
		10%	**25%**	**50%**	**100%**
5-kW Wind Turbine	1032	103	258	516	1032
4-Panel Solar Hot Water System Array	2097	210	524	1,049	2,097
Biomass Energy Generation	207	21	52	103	207
		Participation Level (# Farms)			
		17%	**33%**	**67%**	**100%**
Biogas Energy Systems	30	5	10	20	30
		Potential Offset Package (Tonnes CO_2e)			
Dairy Sector		15,980	31,960	47,941	63,921
Beef Feedlot Sector		21,516	43,033	64,549	86,066
Pork Sector		2,471	4,942	7,413	9,884
Energy Efficiency		7,690	15,380	23,069	30,759
Wind Energy Production		1,000	2,500	5,000	10,000
Solar Hot Water Energy Generation		1,000	2,500	5,000	10,000
Biomass Energy Generation		1,000	2,500	5,000	10,000
Biogas Energy Generation		5,000	10,000	20,000	30,000
Total		55,657	112,815	177,972	250,630

The benchmark minimum size of a marketable carbon offset package in the Canadian market is 10,000-tonnes CO_2e delivered annually. Using this benchmark value to compare to the total carbon offset development opportunities outlined in Table 9, it is evident that the maritime livestock sector could, working in aggregate, develop a number of marketable carbon offset packages.

The beef feeding sector was identified as having the greatest carbon offset development opportunity, followed by the dairy sector. In both cases, advances in stored forage quality and the adoption of a more aggressive manure application to cropland schedule accounted for the most significant GHG reduction opportunities.

Following the dairy sector were energy efficiency projects, biogas energy generation, hog sector feeding and manure management advancements, and finally wind, solar hot water and biomass energy generation in terms of the total carbon offset package that could be developed through an aggregated carbon offset project.

It was assumed that all dairy, pork, poultry and vegetable storage facilities currently operating in the Maritime region could generate carbon offset packages through the adoption of energy efficiency measures according to the results of on-farm audits conducted across the Maritime region. Potato storage facilities were included in the energy efficiency opportunity assessment as on-farm data was available for numerous potato warehouses through various pilot energy audit projects conducted in the Maritime region.

Wind, solar hot water and biogas energy generation projects were analysed not by the number of farms available for participation, but rather by the number of participant farms required to develop a reasonable sized carbon offsets package, irrespective of other industry sector participation. This analysis method was necessary given the complexities of determining the total number of farms that may be able to participate in a renewable energy generation project due to available wind resources, true south orientation of farm buildings for solar hot water heating system installation, and/or the availability of organic feedstocks for biogas energy generation.

More in depth analysis of the individual livestock sectors, energy efficiency and renewable energy generation project options are included below.

3.10. Carbon Offset Value to Industry

The total value of the carbon offset package development opportunity identified is outlined in Tables 11 & 12 below. Total farm participation in the '*Minimum Participation Level*' scenario (Table 11) was assumed to be 25% of the total farm population for each sector. This represents an aggressive but achievable goal for early participation in a carbon offsets development project.

The carbon offset values outlined in Table 12 assume 100% industry participation by sector, and represents a 'best case scenario'. It is unrealistic to assume that this level of participation could be achieved in the short term, however, with the delivery of a successful carbon offset project, more producer interest and participation can be expected.

Based on early indications from the Government of Canada that a technology fund would be developed, and allow large final emitter investment in the fund to achieve GHG emission regulatory compliance. The baseline value for technology fund investment was set at $15 per Tonne CO_2e. Further, carbon offsets in the Alberta Offset System have traded between $13-15 per Tonne CO_2e, establishing an unofficial benchmark carbon value for Canada. The benchmark carbon value is therefore assumed to be $15-Tonne CO_2e^{-1}. Escalating carbon offset values have been included to show the net value to producers over time as carbon prices escalate with increasing demand.

Table 11. Carbon Offset Project Revenue Generation Potential: Minimum Participation Level

		$ Tonne CO_2e^{-1}			
	Farm Participation	**$15.00**	**$25.00**	**$50.00**	**$100.00**
Dairy Sector	173	$239,700	$399,500	$799,000	$1,598,000
Beef Feedlot Sector	615	$322,740	$537,900	$1,075,800	$2,151,600
Pork Sector	11	$37,065	$61,775	$123,550	$247,100
Energy Efficiency	358	$115,350	$192,250	$384,500	$769,000
Wind Energy Generation	103	$15,000	$25,000	$50,000	$100,000
Solar Hot Water Energy Generation	210	$15,000	$25,000	$50,000	$100,000
Biomass Energy Generation	21	$15,000	$25,000	$50,000	$100,000
Biogas Energy Generation	5	$75,000	$125,000	$250,000	$500,000
Total	1495	$834,855	$1,391,425	$2,782,850	$5,565,700
Transaction Costs (15%)		$125,228	$208,714	$417,428	$834,855
Net Value to Producer Community		$709,627	$1,182,711	$2,365,423	$4,730,845

After deducting 15% from the gross value of carbon offsets for transaction costs, the net annual value to the producer community, assuming 25% industry participation, is $696,877. Based on a total of 1,474-particpant farms, this equates to an average annual payment of $472.64 per farm. Some farms will have a significantly greater revenue generation opportunity, based on the farms baseline condition, and the technology and/or management practices adopted through a GHG reduction initiative. Individual farm reports included in Sections 9-13 provide more detail on farm specific carbon revenue opportunities.

Table 12. Carbon Offset Project Revenue Generation Potential: Maximum Participation Level

		$ Tonne CO_2e^{-1}			
	Farm Participation	**$15.00**	**$25.00**	**$50.00**	**$100.00**
Dairy Sector	692	$958,815	$1,598,025	$3,196,050	$6,392,100
Beef Feedlot Sector	2458	$1,290,990	$2,151,650	$4,303,300	$8,606,600
Pork Sector	43	$148,260	$247,100	$494,200	$988,400
Energy Efficiency	1431	$461,385	$768,975	$1,537,950	$3,075,900
Wind Energy Generation	1032	$150,000	$250,000	$500,000	$1,000,000
Solar Hot Water Energy Generation	2,097	$150,000	$250,000	$500,000	$1,000,000
Biomass Energy Generation	207	$150,000	$250,000	$500,000	$1,000,000
Biogas Energy Generation	30	$450,000	$750,000	$1,500,000	$3,000,000
Total	7990	$3,759,450	$6,265,750	$12,531,500	$25,063,000
Transaction Costs (15%)		$563,918	$939,863	$1,879,725	$3,759,450
Net Value to Producer Community		$3,195,533	$5,325,888	$10,651,775	$21,303,550

4. Agricultural Sector Analysis

The following sections detail the results of the various on-farm case studies completed. Individual case study reports for audited farms are provided in Sections 9-13.

4.1. Dairy Sector

A summary of the dairy sector case study farm results is outlined in Table 13. The average net baseline emissions for the 6-farms studied were 1,014-tonnes CO_2e and the net project case was 988-tonnes CO_2e, an average reduction of 26.02-tonnes CO_2e per farm. The net emissions reduction per farm ranged from a minimum of -395-tonnes CO_2e for Perryhill Farms to a maximum of 339-tonnes CO_2e for the Elliotville Farms project case.

Table 13. Dairy Sector Case Study GHG Reduction Summary

	Baseline	Project	Reduction
Farm Case Study		Tonnes CO_2e	
Double Oord Farms	539.06	542.16	-3.10
Perryhill Farm	938.48	1,333.51	-395.03
Folly River Dairy	1,041.30	904.89	136.41
Fortlands Farm	689.73	674.65	15.08
Port Hill Milking*	2,017.13	1,953.88	63.25
Elliotville Farms	861.12	521.63	339.49
Average	**1,014.47**	**988.45**	**26.02**

*Average of 4-baseline and project cases

Perryill Farms has recently completed the construction of a new free-stall lactation barn and a significant herd expansion. The move from a tie-stall operation to a free stall slightly reduced the herds productivity and the animal population increased dramatically, owing to the net increase in GHG emissions. The Perryhill farms case study is likely representative of numerous farms across the Maritimes that have completed major construction and/or herd expansion projects over the past number of years. However, functional equivalence rules applied to carbon market transactions will dictate that the project and baseline cases for Perryhill Farm be analysed using identical herd sizes, the case study was included only as an illustrative example.

Elliotville Farms was the only full summer pasture based farm studied and showed the greatest opportunity for creating offsets by increasing the quality of dry matter intake through increased pasture management intensity. This was a theoretical case study completed by manipulating the calculator software to represent high and low quality pasture dry matter intake scenarios.

Table 14 outlines the potential carbon offset package that could be create assuming 25, 50, 75 and 100% industry participant in an aggregated maritime carbon offset project. This analysis is based on a net GHG emission reduction per farm of 26-tonnes CO_2e. Using a minimum required carbon offset package size of 10,000-tonnes CO_2e, 384-farms, or 55% industry participation would be necessary to consider initiating a carbon offset aggregation project.

Table 14. Dairy Sector Carbon Offsets Available for Market at Varying Industry Participation Levels

		Participation Level			
	Eligible Farms	**25%**	**50%**	**75%**	**100%**
New Brunswick	230	58	115	173	230
Nova Scotia	250	63	125	188	250
Prince Edward Island	212	53	106	159	212
Maritime Total	692	173	346	519	692
		Potential Offset Package (Tonnes CO_2e)			
New Brunswick		1,496	2,992	4,488	5,984
Nova Scotia		1,626	3,252	4,878	6,504
Prince Edward Island		1,379	2,758	4,137	5,515
Maritime Total		4,501	9,002	13,502	18,003

Tables 15 & 16 outline the potential carbon offsets package that could be available if negative GHG reductions at Double Oord and Perryhill Farms are excluded from the analysis. Removal of negative emissions values increases the net GHG reduction per farm from 26.02 to 92.37-tonnes CO_2e year^{-1}. Again assuming 10,000-tonnes CO_2e as the minimum required carbon offset package size, roughly 50% participation in any of the three Maritime provinces would create a large enough package of carbon offsets to engage the carbon marketplace. Maritime wide participation of 50% would result in the development of a 31,960-tonne CO_2e carbon offset package.

Table 15. Dairy Sector Case Study GHG Reduction Summary Excluding Negative Reduction Cases

	Baseline	Project	Reduction
Farm Case Study		tonne CO_2e	
*Double Oord Farms**	*539.06*	*542.16*	*0.00*
*Perryhill Farm**	*938.48*	*1,333.51*	*0.00*
Folly River Dairy	1,041.30	904.89	136.41
Fortlands Farm	689.73	674.65	15.08
Port Hill Milking	2,017.13	1,953.88	63.25
Elliotville Farms	861.12	521.63	339.49
Average	1,014.47	988.45	92.37

* Negative GHG Emission Reductions Removed

Table 16. Dairy Sector Carbon Offsets Available for Market at Varying Industry Participation Levels Negative GHG Reduction Case Study Values Excluded

		Participation Level (# Farms)			
	Eligible Farms	25%	50%	75%	100%
New Brunswick	230	58	115	173	230
Nova Scotia	250	63	125	188	250
Prince Edward Island	212	53	106	159	212
Maritime Total	692	173	346	519	692
		Potential Offset Package (Tonne CO_2e)			
New Brunswick		5,311	10,623	15,934	21,245
Nova Scotia		5,773	11,546	17,320	23,093
Prince Edward Island		4,896	9,791	14,687	19,583
Maritime Total		15,980	31,960	47,941	63,921

4.1.1. Dairy Sector Recommendations

Significant opportunity exists for the Maritime dairy sector to reduce its GHG emissions output by adopting a more aggressive forage harvest and manure management schedule. In numerous cases, the forage quality offered the lactation herd, determined through feed testing, was found to be less than optimal to maximize herd output and minimize GHG emissions.

The following recommendations should be considered by the Maritime dairy industry to reduce GHG emissions from the sector:

1. Increase the frequency of forage (grass/legume) harvest to increase the quality of stored forage. Ideally, stored forages would have the following quality parameters:

Ration Component	Target Values
Crude Protein	18-20%
Acid Detergent Fiber	30-40%
Neutral Detergent Fiber	40-50%

2. Include edible oils in cattle feeding ration the range of 4% to 6% (by dry weight). Feeding edible oils has been shown to reduce enteric fermentation emissions by 20%.

3. Increase pasture management intensity to ensure that high quality dry matter is being offered the lactation, dry cow and heifer herds while on pasture.

4. Engage the support of a professional nutritionist to properly balance rations in response to changes in forage quality.

5. Adopt an aggressive manure management schedule that minimizes the long term storage of liquid manure and maximizes the agronomic effectiveness of manure nutrients. Manure application to cropland in early spring, following each forage harvest and early in the fall season, preferably to a live cover crop will ensure minimal manure storage duration and maximum nutrient utilization efficiency.

6. Wherever possible install on-farm energy efficiency and renewable energy generation technologies such as solar hot water, biomass water heating or wind electricity generation.

4.2. Beef Sector

Two beef feedlot case studies were completed. RA Farms is a backgrounding operation receiving animals at roughly 270-kg head^{-1} and animals exit the herd at 455-kg head^{-1}. RA Farms generally maintains a feeding herd size of 1,200-animals on feed for 200-days average. Whalen Cattle Farms is a cattle fattening operation receiving animals at roughly 180-kg head^{-1} and animals will exit the herd at 615-kg head^{-1}. Whalen Farms generally maintains a feeding herd size of 280-animals on feed for 680-days average.

Forage component and total mixed ration sample analysis revealed that in both cases, the farms were not offering a high quality forage based ration to the respective cattle herds. In one case it was found that the crude protein content of the ration was well below that known to be required to support effective weight gain. The project case for each of the case studies was assumed to be a major shift in forage harvest scheduling to ensure as high a quality haylage as possible is entering the feed bunk, maximizing weight gain, minimizing days on feed and reducing the farms GHG output.

A summary of the beef feeding sector case study farm results is outlined in Table 17. The average net baseline emissions for the 2-farms studied were 1,444.21-tonnes CO_2e and the net project case was 1,160.40-tonnes CO_2e, an average reduction of 283.81-tonnes CO_2e per farm. The net emissions reduction per farm was similar between the two case study farms, despite the large difference in feedlot capacity for the two units. This reflects the difference in the total number of days on feed for the two operations, with RA Farms turning the feedlot approximately every 200-days, while the Whalen Farms feedlot is turned roughly once every two years.

Table 17. Beef Feedlot Sector Case Study GHG Reduction Summary

	Capacity	Days on Feed	Baseline	Project	Reduction	
			Tonnes CO_2e			Tonne CO_2e $head^{-1}$ $Year^{-1}$
RA Farms	1200	160	3,291.72	2,624.86	666.86	0.278
Whalen Farms	280	340	906.99	453.49	453.50	1.620
Average	740		2,099.36	1,539.17	560.18	0.949

Table 18 outlines the total carbon offsets opportunity for the Maritime cattle feeding sector based on the total number of farms fattening cattle from the 2006 Census of Agriculture and the total GHG reduction opportunity per head, as outlined in Table 17.

The census of agriculture identified a large number of farms finishing cattle, but the total capacity of each operation is relatively small. Census data indicates a total feeder cattle placement of 90,777-head per year for the Maritime region. Although this may be an aggressive placement number, Table 18 outlines the potential offset generation potential across varying industry participation levels. Assuming a conservative 25% industry participation rate, the feeding sector has the opportunity to readily engage in carbon offset project development with the potential to develop an offset package of over 21,000 Tonnes CO_2e.

Table 18. Beef Feedlot Sector Carbon Offsets Available for Market at Varying Industry Participation

			Participation Level (# Farms)			
	Eligible Farms	Average Capacity	25%	50%	75%	100%
New Brunswick	679	27	170	340	509	679
Nova Scotia	1,011	20	253	506	758	1011
Prince Edward Island	768	68	192	384	576	768
Maritime Total	2,458		615	1229	1844	2458
			Potential Offset Package (Tonnes CO_2e)			
New Brunswick			4,394	8,788	13,182	17,576
Nova Scotia			4,812	9,624	14,436	19,249
Prince Edward Island			12,310	24,621	36,931	49,241
Maritime Total			21,516	43,033	64,549	86,066

4.2.1. Beef Sector Recommendations

Beef feedlot sector recommendations for reducing GHG emissions focus on increasing the rate of cattle weight gain by offering a higher quality ration. On both case study farms, forage quality was found to be medium for both haylage and corn silage. Low forage quality was assumed to be a major limiting factor for maximizing cattle growth rates.

Cattle GHG emissions reduction projects, based on the quantification approaches developed in Alberta, generally focus on decreasing the cattle days to market, therefore reducing the methane emissions per finished animal. Increased growth rates and reduced days to market can be achieved by increasing the concentrate (grain) portion of the ration and/or increasing the quality of the forage component of the ration. The addition of edible oils such as canola oil has also been shown to suppress methane production in the rumen of beef and dairy cattle as well.

The following recommendations should be considered by the maritime beef feedlot industry to reduce GHG emissions from the sector:

1. Increase the frequency of forage (grass/legume) harvest to increase the quality of stored forage. Ideally, stored forages would have the following quality parameters:

Ration Component	Target Values
Crude Protein	18-20%
Acid Detergent Fiber	30-40%
Neutral Detergent Fiber	40-50%

2. Include edible oils in cattle feeding ration the range of 4% to 6% (by dry weight). Feeding edible oils has been shown to reduce enteric fermentation emissions by 20%.

3. Maintain a high herd health status to minimize the effect of disease on animal weight gain

4. Engage the support of a professional nutritionist to properly balance rations in response to changes in forage quality.

4.3. Pork Sector

Three pork farm case studies were completed. In all cases the farms had achieved a high level of production and boasted strong feed conversion efficiency in the present day.

In the case of van de Brand farms, a 350-sow farrow-to-finish operation, a major farm retrofit was completed in 2006. The farms dry mash feeding system was replaced with a state of the art liquid feeding system based on high moisture corn as the major carbohydrate component. Food industry byproducts such as brewer's yeast and residual bread products from a local bakery make up a sizable proportion of the ration as well. This modification allowed the farm to better utilize its manure resources in the production of grain corn, and significantly increased the farms output productivity and profitability. The baseline case for van de Brand farms was assumed to be the 2005 production year. The project case was assumed to be the 2007 fiscal year, which allowed the advances in farm productivity to be included in the analysis. A more aggressive manure management schedule was also assumed to be a component of the farms GHG project case.

Whalen Farms operates a modern 1,000-head hog finishing barn with a liquid feeding system based on locally produced high moisture corn as the major carbohydrate component of the ration. No changes in feed conversion efficiency were assumed between the baseline and project cases, however, the farms manure resources are currently applied to cropland only once per year. The GHG project case was therefore assumed to be status quo for feeding systems and productivity, but manure was assumed to be applied to cropland 3-times annually. This project concept is a plausible approach given that the farm manages a large pasture and forage landbase to which hog manure could be applied frequently.

Terry Beck hog farms is a 700-sow farrow-to-wean facility producing roughly 15,000-isowean piglets per year. This project case offered an opportunity to explore the effect of productivity advances only on the GHG emissions profile for the operation, as an aggressive manure management schedule is already being practiced on the farm. The baseline case was assumed to be the 2008 production year which saw a farrowing rate of 113-sows per month and 23.3-pigs produced per sow per year. The 2009 production year was considered the project case with a farrowing rate of 139-sows per month and 24.7-pigs pigs produced per sow per year. The productivity gains made in terms of the monthly farrowing rate was 23%, while gains in the actual iso-wean production per sow per year was 6%, both representing sizable advancements in productivity.

The results of the case study analysis for the three pork farm case studies are outlined in Table 19. The variation in achievable GHG reductions on the three farms was large, reflecting the variation in farm size and makeup. The farrow-to-finish van de Brand operation had a much greater GHG emissions profile, given the number of animals managed and the total volume of feed consumed throughout the year. The finishing and iso-wean Whalen and Beck Farms, respectively, had much smaller GHG profiles due to fewer animals being housed on farm throughout the year.

The average GHG emission reduction identified for the three farms was 230-tonnes CO_2e annually.

Table 19. Pork Sector Case Study GHG Reduction Summary

	Baseline	Project	Reduction
		Tonnes CO_2e	
van de Brand Farms	1,615	1,019	596
Whalen Farms	222	135	87
Beck Farms	300	294	7
Average	**712**	**482**	**230**

Table 20 provides additional detail on the productivity of each case study farm relative to the GHG emission reduction opportunity identified. Given the variability that exists between farms, individual producers may wish to use the metric of *kg CO_2e kg Live Weight Produced^{-1}* to estimate the GHG reduction potential that may exist for their particular operation setup and function, as opposed to applying the average 230-tonnes CO_2e reduction identified for the three case study farms.

Table 20. Pork Sector Case Study GHG Emission and Productivity Index

	Annual Production			Annual GHG Reduction	
Case Study	# Head	Live Weight Head^{-1} (kg)	Total Live Weight (kg)	Tonnes CO_2e	kg CO_2e kg Live Weight Produced^{-1}
van de Brand Farms	7,700	127	977,900	596	0.61
Whalen Farms	2,650	127	336,550	87	0.26
Beck Farms	15,000	6.2	93,000	7	0.07
Average				230	0.31

The sector wide carbon offset opportunity for the Maritime pork industry is outlined in Table 21. Given the major pork industry contraction witnessed over the past number of years, the total number of viable hog farms available for participation in a carbon offsets project was assumed to be 25% of the livestock population reported in the 2006 Census of Agriculture.

Based on a 25% participation rate for the current Maritime hog industry, it is estimated that a saleable carbon offset package of 2,471-tonnes CO_2e could be developed.

The innovative nature of the hog producers remaining in the industry may result in greater participation in a carbon offsets project, given the importance of production efficiency and incremental revenue to the sector.   In order to remain conservative in the estimate of total offsets development potential, 25% industry participation will remain the benchmark, but special attention should be offered the industry should an offsets project be developed in the future.

Table 21. Pork Sector Carbon Offsets Available for Market at Varying Industry Participation

			Participation Level (# Farms)			
	Eligible Farms	Average Capacity	25%	50%	75%	100%
New Brunswick	18	503	4	9	13	18
Nova Scotia	13	361	3	6	10	13
Prince Edward Island	13	426	3	6	9	13
Maritime Total	43		11	22	32	43
			Potential Offset Package (Tonnes CO_2e)			
New Brunswick			1,020	2,040	3,060	4,080
Nova Scotia			733	1,465	2,198	2,931
Prince Edward Island			718	1,437	2,155	2,873
Maritime Total			2,471	4,942	7,413	9,884

4.3.1. Pork Sector Recommendations

The pork operations that remain in production in the Maritime region have done so through the adoption of advanced management practice intensity with a strong focus on production efficiency. The following recommendations should be considered for their ability to decrease GHG emissions output of the sector, and increase farm productivity.

1. Increase feed conversion efficiency through ration balancing, phase feeding, liquid feeding, etc

2. Increase herd productivity by decreasing the average duration of dry sow status in the breeding herd

3. Adopt an aggressive manure management schedule to reduce the duration of liquid manure storage and increase the effective agronomic use of manure nutrients

4. Implement renewable energy production technologies such as biomass heating or biogas conversion of manure organic matter to heat and electrical energy

4.4. Energy Efficiency

In order to develop a comprehensive scope of potential GHG reductions that could be achieved through energy efficiency measures, the 2006 Census of Agriculture database was used to determine the total number of facilities, by sector, operating currently in the Maritime region. Table 22 outlines the total number of farms reporting in 2006 by sector.

A farm number retraction rate of 12% from the 2006 Census year was used to estimate the number of farms operating in 2010 for all sectors except pork production. It was estimated that the total number of operating hog farms has retracted by at least 75% in the Maritime region.

Table 22. Estimated Maritime Farm Operators by Sector

	2006	2006-2010 Retraction Rate	2010
Dairy cattle and milk production	788	12%	693
Beef cattle ranching and farming, including feedlots	1,645	12%	1,448
Hog and pig farming	172	75%	43
Chicken egg production	93	12%	82
Broiler and other meat-type chicken production	87	12%	77
Turkey production	13	12%	11
Poultry hatcheries	3	12%	3
Combination poultry and egg production	8	12%	7
Potato farming	585	12%	515
Total	3,394		2,878

The results of 25-comprehensive energy audits conducted throughout the Maritimes was used to estimate total energy savings available to maritime livestock and vegetable storage operators. These results were harvested from individual energy audit pilot projects completed for the New Brunswick Agriculture Alliance and Nova Scotia and Prince Edward Island Federations of Agriculture.

Each of the provincial energy audit pilot projects included a number of vegetable warehouse assessments. Although not part of the livestock community, the inclusion of these data increased the sample size of the dataset, increasing the accuracy of the analysis. Further, the relative simplicity of energy efficiency upgrades available to most potato warehouses (variable frequency drives on ventilation system controls) could provide a relatively simple bridge for the livestock industry to engage regional crop production sectors in a carbon offset project.

The results of the energy audits, by industry, are outlined in Table 23. Average energy cost savings per farm was $5,611.56 and the average GHG reduction identified was 32.72 tonnes CO_2e per farm per year. Significant variability between farm type was identified for the total GHG reduction opportunity from energy efficiency measures, therefore, each sector is reported individually, allowing for more accurate assessment of the opportunities between and across sectors.

Table 23. Average Energy Savings and Greenhouse Gas Emission Reductions by Farm Type

		Annual Energy Savings			GHG Reduction
Industry	Annual Savings	Electricity (kWh)	Heating Oil (L)	Propane (L)	Tonnes CO2e
Swine	$7,753.00	86,144	0	6,737	60.07
Poultry	$8,303.76	23,885	4,800	1,390	34.69
Dairy	$2,966.05	27,481	448	0	18.82
Potato	$3,423.44	27,399	0	0	17.28

The total energy efficiency carbon offset development opportunity for the Maritime livestock sector is outlined in Table 24. Sector specific GHG reductions and farm eligibility numbers were used in this analysis to increase the accuracy of the estimated carbon offset package that could be delivered to market.

Assuming 25% industry wide participation in an energy efficiency program, including the potato production sector, a carbon offset package of 7,690-tonnes CO_2e could be offered for sale to the carbon market.

Table 24. Average Energy Savings and Greenhouse Gas Emission Reductions by Farm Type

		Participation Level (# Farms)			
Sector	Eligible Farms	25%	50%	75%	100%
Swine	43	11	22	32	43
Poultry	180	45	90	135	180
Dairy	693	173	347	520	693
Potato	515	129	257	386	515
		Potential Offset Package (Tonnes CO_2e)			
Swine		646	1,292	1,937	2,583
Poultry		1,557	3,114	4,671	6,228
Dairy		3,263	6,525	9,788	13,050
Potato		2,224	4,449	6,673	8,898
Total		**7,690**	**15,380**	**23,069**	**30,759**

4.5. Renewable Energy Systems

Four renewable energy generation systems were analysed for their potential contribution to a carbon offset development project. Small scale wind, solar hot water, biomass heating and biogas (anaerobic digestion) energy systems were all analysed using on-farm data, collected directly from operators or harvested from the energy audit results database described in Section 6.2.

Renewable energy generation systems are applicable for all livestock and crop farms in the Maritime region. Cost of generation is the determining factor that farmers will use to gauge whether or not to invest in generation equipment. In order to determine the carbon offset potential for each individual technology, GHG reductions for a single project was estimated, and the total number of participating farms required to deliver a reasonably sized carbon offset package was calculated. This approach was necessary to avoid the interaction of critical energy output controlling factors such as regional wind energy production potential due to local wind regime, solar hot water collection panel orientation towards true south, BTU value of biomass feedstocks and maximum methane yield potential for biogas plant feedstocks.

This data is offered as an industry wide estimate for potential for GHG reductions and should not be considered accurate for any one potential installation. Producers considering the installation of a renewable energy generation technology should complete site-specific analysis in order to determine their system specific GHG reduction potential and carbon offset value.

In many cases, federal or provincial incentive programs are available to support the adoption of small scale renewable energy generation systems. While it is important for the producer community to understand the GHG reductions achieved with investments in on-farm energy generation, the carbon value of a project is often largely outweighed by the public incentive available. Producers should carefully consider the options for both revenue opportunities, and should be aware that public investment often forfeits the ability for carbon offsets to be generated by the project.

4.5.1. Small Scale Wind

Small scale wind production is a viable GHG reduction opportunity, not due to the reduction of on-farm GHG emissions, but through the offset of fossil energy based electricity on the provincial power grid. It is important to note that identical wind turbine installations at sister farms in New Brunswick, Nova Scotia and Prince Edward Island will all generate varying carbon offset packages, due to the various power grid GHG intensities in each province. The analysis outlined in Table 25 assumes an average grid intensity for all Maritime provinces of 0.72-kg CO_2e kWh^{-1}.

Data used to develop the GHG reduction potential for small scale wind electricity generation was collected from Jennings Poultry Farm located in Masstown, Nova Scotia. Three 1.5-kW wind turbines have been installed at the site, which has excellent wind production potential, being directly adjacent to the Cobequid Basin. The wind energy production producer profile located Section 13, presents farm specific GHG reduction information for Jennings Poultry Farm.

The data found in Table 25 used the wind energy production data from Jennings Poultry Farm, specifically for the 1.5-kW turbine class, to extrapolate the GHG reduction potential for each additional turbine class, based on a 10% escalation in turbine output with each incremental turbine size class.

Table 25. GHG Reduction Potential from Various Wind Turbine Capacities

		Carbon Offset Package (Tonnes CO_2e $Year^{-1}$)			
Turbine Output	Average Carbon Offset	1,000	2,500	5,000	10,000
kW	(Tonnes CO_2e $Year^{-1}$)	**Participation Required (# Farms)**			
1.5	2.1	484	1,209	2,418	4,836
3	4.5	220	549	1,099	2,198
5	7.6	132	330	659	1,319
10	15.2	66	165	330	659
15	22.7	44	110	220	440
20	30.3	33	82	165	330
25	37.9	26	66	132	264
50	75.8	13	33	66	132
100	151.7	7	16	33	66

The potential exists to generate a substantial carbon offset package from on-farm wind energy production. The importance of economies of scale is evident when the GHG reduction data in Table 25 is analysed. A 10,000-tonne CO_2e offset package could be created with the installation of 659-10-kW turbines, while roughly 2,200-3-kW units would be required to achieve the same carbon offsets package.

Agricultural producers should be encouraged to work in aggregate towards the development of region wind resources. This approach will maximize the return on investment in wind generation equipment and allow for the installation of turbines in the most appropriate geographical location, maximizing wind energy production and net GHG emissions reductions.

4.5.2. Solar Hot Water

Solar hot water energy generation is a simple and effective means of reducing electricity of heating fuel consumption for domestic or space hot water heating. Often, solar hot water systems are designed to preheat a mass of water that will ultimately be brought to final temperature by a subsequent heating appliance. Integrating large preheated water storage systems into the overall solar system design, allows for reliable solar hot water availability and reduces the variability in system output due to unfavourable weather conditions.

The results of a 3-technical feasibility studies for solar hot water heating systems (20-panels each) was used to estimate the GHG reduction opportunity for the technology. Table 26 outlines the energy generation potential for a range of panel array sizes and the corresponding GHG reduction that could be achieved in each province, based on provincial electricity grid GHG intensities.

Table 26. Energy Output and GHG Emissions Reductions for Various Solar Hot Water System Sizes

	System Production		Carbon Offset (Tonnes Year^{-1})			
Panels	kWh System Year^{-1}	kWh System Day^{-1}	New Brunswick	Nova Scotia	Prince Edward Island	Average
1	1,655.5	4.5	0.96	1.52	1.09	1.19
2	3,311.1	9.1	1.92	3.05	2.19	2.38
3	4,966.6	13.6	2.88	4.57	3.28	3.58
4	6,622.2	18.1	3.84	6.09	4.37	4.77
5	8,277.7	22.7	4.80	7.62	5.46	5.96
10	16,555.4	45.4	9.60	15.23	10.93	11.92
15	24,833.1	68.0	14.40	22.85	16.39	17.88
20	33,110.8	90.7	19.20	30.46	21.85	23.84

Based on the average GHG reduction per panel for the Maritime region, the total farm participation required to develop various carbon offset package sizes is outlined in Table 27.

Table 27. Farm Participation Required to Develop Marketable Carbon Offset Package

		Carbon Offset Package (Tonnes CO_2e Year^{-1})			
	Average Carbon Offset	**1,000**	**2,500**	**5,000**	**10,000**
Panels	(Tonnes CO_2e Year^{-1})	Participation Required (# Farms)			
1	1.2	839	2,097	4,195	8,389
2	2.4	419	1,049	2,097	4,195
3	3.6	280	699	1,398	2,796
4	4.8	210	524	1,049	2,097
5	6.0	168	419	839	1,678
10	11.9	84	210	419	839
15	17.9	56	140	280	559
20	23.8	42	105	210	419

Similar to small scale wind energy systems, the potential exists to generate a sizable carbon offset package with the installation of a series of solar hot water heating systems. A 10,000-tonne CO_2e offset package could be created with the installation of 419 20-panel systems, 839 10-panel systems, or 2,097 4-panel arrays across the region.

The opportunity for producer collaboration to reduce system capital and installation cost may exist through group purchasing, which could be facilitated by regional or provincial federations of agriculture, sector producer groups or regional development authorities.

4.5.3. Biomass Energy Systems

The maritime region has an abundance of available biomass that can be used to generate both heat and electricity. Numerous jurisdictions around the world provide specific incentives towards the production of biomass energy, however, the maritime region, despite the availability of abundant biomass resources, has lagged behind other regions such as Germany, Austria, Ireland and Great Britain in the deployment of biomass energy generation systems.

The GHG reduction potential for 5-farms, assuming a 100% offset of electricity and heating fuel use for domestic hot water and space heating, is outlined in Table 28. Each of the 5-case studies was completed using data collected during the completion of on-farm energy audits. In each case the provincial power grid GHG intensity and default GHG intensities for heating oil (2.8-kg CO_2e L^{-1}) and propane (1.5-kg CO_2e L^{-1}) were used to determine the total GHG reduction potential for the project. Biomass heating systems were assumed to be carbon neutral, resulting in no carbon dioxide emissions from the project.

No differentiation was made between specific sources of biomass (round wood, bark chips, pellets, hay or straw). Some high protein feedstocks such as legume hay may result in small emissions of nitrous oxide which would need to be accounted for in an offsets development project.

Table 28. Biomass Heating System Case Study Energy Consumption

	Water and Space Heating System Energy Consumption			
Case Study	**Electricity (kWh)**	**Heating Oil (L)**	**Propane (L)**	**Tonnes CO_2e**
Dairy 1	158,700	0	0	92.0
Dairy 2	19,700	19,045	0	66.9
Vegetable Processing	0	1,232	4,535	10.3
Poultry: Layer	0	5,910	0	16.7
Poultry: Broiler	0	0	37,161	55.7
Average				**48.3**

Based on the average GHG reduction opportunity of the 5-case studies explored, assuming 100% offset of fossil based energies, each on-farm biomass energy project could deliver 48-tonnes CO_2e to a carbon offset development project.

Table 29 outlines the potential to develop various carbon offset packages through the implementation of biomass energy generation projects across the region. Roughly 200-installations would be necessary to develop a 10,000-tonne CO_2e offset package.

Biomass energy systems have the potential to support rural economic development while providing a cost effective source of thermal energy and in some cases, electricity. Agricultural producers should be encouraged to explore how regional sources of biomass can be used to generate on-farm heat and power systems. A biomass carbon offset project could deliver a marketable carbon package with limited sector engagement.

Table 29. Farm Participation Required to Develop Various Carbon Offset Packages

	Carbon Offset Package (Tonnes CO_2e Year^{-1})			
Average Carbon Offset	**1,000**	**2,500**	**5,000**	**10,000**
(Tonnes CO_2e Year^{-1})	Participation Required (# Farms)			
48	21	52	103	207

4.5.4. Biogas Energy Systems

Biogas energy generation systems use anaerobic digestion technology to convert organic matter into biogas, a dilute fuel similar to, but containing roughly 50% of the energy value of natural gas. Biogas systems can generate carbon offsets by capturing and destroying baseline methane emissions from liquid manure storages and by offsetting the generation of fossil fuel-based electricity. Two case studies were explored based on technical feasibility studies previously completed by MacLeod Agronomics Ltd.

RA Farms explored biogas energy generation using the manure resources produced by a 2500-head capacity beef feedlot. It was determined that a 170-kW generator could be operated for 8,322-hours per year, generating 1,237-MWh of renewable electricity annually.

Archibald Dairy Farms explored of biogas energy generation potential for the manure resources generated by a 300-head lactating dairy herd, including dry cow and heifer herds and roughly 3,000-tonnes of Class-A municipal biosolids annually. It was determined that the biogas generated would be capable of operating a 120-kW generator for 8,322-hours per year, generating 914-MWh of renewable electricity annually.

The results of the GHG emissions assessments and the total value of carbon offset sales for these two projects are outlined in Table 30. The average GHG reduction opportunity for the two biogas energy case studies was found to be greater than the emissions reductions achievable with any other single on-farm management practice change or technology option explored.

Although technically challenging and difficult to finance given the lack of renewable energy policy sufficient to support the development of biogas energy systems in any of the maritime provinces, biogas energy systems remain as one of the largest and easily verifiable sources of carbon offsets available to the agriculture industry.

Table 30. Summary of Biogas System GHG Emissions and Carbon Offset Revenues

	Tonnes CO_2e			$ Tonne CO_2e^{-1}			
Case Study	Baseline	Project	Reduction	$15.00	$25.00	$50.00	$100.00
RA Farms	2,004.45	1,448.93	555.52	$8,332.74	$13,887.89	$27,775.79	$55,551.57
Archibald Dairy	2,256.67	786.62	1,470.05	$22,050.76	$36,751.26	$73,502.52	$147,005.05
Average	2,130.56	1,117.78	1,012.78	$15,191.75	$25,319.58	$50,639.15	$101,278.31

In order to develop a 10,000-tonne CO_2e offsets package, aggregation will still be necessary for biogas energy projects. It is estimated that the construction of 30-biogas plants could be realized across the Maritime region with supporting policy, based on regional sources of organic feedstocks. The development of 10-plants would provide the necessary 10,000-tonne CO_2e offsets package size, 30-installations would create a carbon offset package of 30,000-tonnes CO_2e annually.

Table 31. Farm Participation Required to Develop Marketable Carbon Offset Package

	Carbon Offset Package (Tonnes CO_2e Year^{-1})			
	5,000	10,000	20,000	30,000
Average Carbon Offset (Tonnes CO_2e Year^{-1})	**Participation Required (# Farms)**			
1,012.78	5	10	20	30

The development of a viable biogas energy sector in the Maritimes, is dependent on the development of a comprehensive renewable energy strategy. The strategy would ideally implement a cost-of-production plus reasonable rate of return feed-in-tariff (FIT) policy. FITs specify the price to be paid for renewable electricity that is exported off farm through the distribution power grid.

While Maritime power utilities have resisted the development of such programs, jurisdictions such as Germany, Ontario, Wisconsin, Spain, Philippines, Australia, Louisiana and Florida, among others, have implemented feed-in-tariff programs with varying success. In the majority of cases, regional power rates have been only marginally affected and in some cases, have declined due to reduce energy market volatility. Therefore, it is inappropriate to conclude that developing a FIT program will result in rapid escalation of electricity rates for retail consumers.

Maritime Federations of Agriculture are strongly encouraged to engage in discussions with provincial departments of agriculture and energy regarding the development of a comprehensive provincial and/or regional renewable energy strategy. This strategy should be comprehensive enough to consider all the available options for energy production; wind, solar, biomass, biogas, etc., the potential for both thermal and electrical energy generation, and the impacts that such a policy will have on the rural communities that manage the regions food and potential energy resources.

5. Conclusions

The results of the on-farm GHG audits and extrapolation of the results over various levels of industry participation have identified a viable opportunity for the Maritime agricultural sector to develop a saleable carbon offsets package.

Assuming a minimum participation scenario where 25% of the beef, dairy and pork sector herds (800-farms) engaged in a development project, nearly 40,000-tonnes CO_2e of carbon offsets could be generated annually. These offsets would be the result of increased forage quality production in the beef and dairy sectors, and increased feed conversion efficiency and manure management intensity for all sectors.

When the potential for on-farm energy efficiency projects and the installation of small scale renewable energy generation systems are considered, an additional 15,690-tonnes CO_2e GHG reduction could be achieved.

While a regulated federal carbon reduction strategy has not been developed to date in Canada, numerous regional carbon markets are currently operating or are in development. Maritime provincial departments of Agriculture and Environment have signalled their intention to develop voluntary provincial carbon market mechanisms, which may provide an opportunity for the primary agricultural sector to engage in a carbon offset development project.

Apart from participation in a provincial carbon marketing initiative, the option may exist to engage the Maritime large final emitter community to develop a project. The latter option is likely to be more difficult and require a significant investment in administration and negotiation labour to complete. The reduction in the CEPA reporting threshold for Canadian large final GHG emitters from 100,000-tonnes CO_2e to 50,000-tonnes CO_2e in 2009, will increase the visibility of small regional emitters who may be more willing to work with the agriculture sector to develop an offsets project than the current large emitter community.

Each of the large final emitters identified in section 5.7 were contacted to discuss their position on GHG management and carbon offset project development, either in-house or in partnership with the agricultural sector. Feedback was limited despite numerous attempts to contact each company. Those companies with an excess of banked carbon offsets tended to be the most willing to share information on their GHG management strategies. JD Irving, Lafarge Canada, Cavendish Farms and Nova Scotia Power all indicated that a proactive approach to amassing carbon offsets to cover any future carbon liabilities had been initiated and that the sale of carbon offsets may be a possibility for them in a regulated carbon reduction environment.

New Brunswick Power and Lafarge Canada indicated a willingness to explore a carbon offset development partnership with the maritime agriculture sector. Continued discussions with federal and provincial departments of environment, agriculture and energy should focus on regional or provincial carbon market mechanism development. A regional market will allow for broad industry participation and moderate capital redeployment throughout the region for the purchase of offset credits. A regional market is likely to stimulate innovation in primary production, energy efficiency and renewable energy generation systems on Maritime livestock farms.

The GHG reduction opportunities identified for the primary livestock sector were largely due to increased production efficiencies. In some cases, a significant increase in farm output with a decrease in farm inputs was identified as a plausible scenario. Livestock producers, especially beef and dairy, should be strongly encouraged to offer the highest quality feed possible, as part of a fully balanced and complete ration, to their herds. The beef sector in particular has a tremendous opportunity to increase the quality of stored forage and pastures. Productivity advances and increased profitability will be the most important results of an increased feed quality project, while GHG emissions will be reduced as well, possibly providing an additional revenue generation opportunity. All Maritime livestock operators should be encouraged, and supported in efforts, to increase production efficiency as a first step. Subsequent quantification of the resulting GHG reductions can then be completed for the purposes of developing a carbon offsets package. Producers should also be encouraged to keep meticulous farm production, manure management, and feed quantity and quality offering records to allow for quick and relatively easy validation and verification of potential on-farm GHG reduction projects.

Energy efficiency and on-farm renewable energy generation projects should also be encouraged and supported through innovating programming wherever possible. Investments in efficiency and renewable energy projects will increase industry experience in advanced energy management, benefit the rural economy through capital redeployment and create easily validated and verified GHG offset credits.

A net reduction in farm greenhouse gas emissions is likely to be tied directly to farm productivity and profitability. Operators should be strongly encouraged to consider all livestock herd, manure and land management practices known to increase production efficiency and adopt any practice applicable to their particular operation. Farm records should be kept in order to validate that a change was made, and allow for GHG quantification procedures to be completed. Widespread adoption of advanced management practices will be necessary in order to develop a marketable carbon offset package, once carbon markets become more fully mature.

6. Recommendations

The following recommendations are offered as guidance for the Maritime livestock sector in developing a carbon offset project.

1. Increase awareness of the scientific understanding of how agricultural greenhouse gas emissions are produced and controlled

2. Support livestock producers in the development of accurate and detailed farm productivity, feeding and manure management practices. Advanced record keeping will allow producers to more accurately assess advances in farm productivity due to the implementation of specific farm management innovations. Further, detailed management datasets will allow for more complete and cost effective validation and verification of on-farm carbon offsets projects. Offset project quantification protocols provide a detailed monitoring plan, according to project type. This could be used to develop a regional data management system for each sector, providing the data necessary to complete carbon offset project validation and verification. These data could also be used to estimate overall productivity indexes for the maritime livestock sectors, which could be used to encourage and support innovation and productivity advances.

3. Encourage livestock producers to adopt advanced feeding management strategies to reduce GHG emissions output while maximizing farm outputs

4. Encourage livestock producers to adopt advanced manure management strategies that minimize the duration of manure storage and maximize the agronomic value of manure nutrients and organic matter contents

5. Develop and deliver a professional development program for ruminant livestock producers focussing on the importance of pasture and stored forage quality to herd productivity and profitability. The GHG implications of improved forage quality projects can be highlighted through case study development and analysis.

6. Explore the options available for supporting on-farm investments in energy through power purchase policy and/or capital support programs. Energy consumption and renewable energy generation data could be used to develop an energy use and management benchmarking database for the agricultural sector. These data could be used for the development of a carbon offset package, and provide important

insight into the energy use profile of the maritime agriculture sector, allowing for effective energy policy development.

7. Engage in discussions with provincial departments of Agriculture, Environment and Energy regarding ongoing activities to support the development of provincial and/or regional voluntary carbon market mechanisms. The results presented here and the industry experience gained through the completion of ISO-14064 protocol based on-farm GHG audits will be valuable for informing policy makers of the opportunity presented by engaging the agricultural sector in regional carbon offset markets.

8. Develop a data management pilot project with select members of the livestock industry, and/or engage in initiatives currently underway that are focusing on increasing the quality and quantity of farm production records. Building on the experience gained in applying GHG quantification procedures to Maritime livestock farms, a data management project will form the basis of a carbon offsets development project

9. Engage provincial governments or crown corporations as possible local carbon offset project demand partners. Provincial governments are under increasing pressure to show leadership in GHG management. A pilot learning project where the agricultural sector would deliver a realistic carbon offset package to a specific department, power plant, etc., would provide valuable insight into validation, verification and monitoring requirements for locally traded carbon offset projects.

10. Continue to monitor and assess the Canadian Environmental Protection Act, 1999 Greenhouse Gas Emissions Reporting Program database. With the changes to the reporting protocol requiring any company emitting more than 50,000-tonnes CO_2e annually to report their emissions, it is likely that regional alliances with energy management, food processing or other agricultural related industries can be developed to support the development of a carbon offsets package.

7. Dairy Farm Case Studies

Double Oord Farms

Double Oord Farms is a freestall dairy operation milking roughly 50-cows in Springfield, York County, New Brunswick. The lactation herd is fed a TMR ration of corn silage, haylage and dairy concentrate. Dry cows and heifers are maintained on a corn silage, hay, and heifer concentrate ration. Manure is managed in a liquid form and is applied to corn silage and perennial forage land 3-times per year. No ionophores or edible oils are included in the lactation ration, however, an energy booster is currently being fed that could possibly be substituted with edible oils in the future as a GHG reduction measure.

GHG Baseline Case

The baseline case used to analyse the GHG emissions profile at Double Oord Farms was the 2006 calendar production year. The farm underwent a major shift in ration composition in 2007 with the addition of corn silage and a move from a 2-cut forage system to a 3-cut system. In the 2006 baseline year the entire herd was offered a ration of medium quality native grass and legume haylage, plus dairy and heifer concentrate as recommended by a professional nutritionist.

GHG Project Case

The project case for Double Oord Farms is the 2008 calendar year. The major differences between the baseline and project case are an overall increase in milk production per lactation animal, due to the inclusion of corn silage in the lactation ration as well as an overall increase in haylage quality due to the more aggressive 3-cut harvest system adopted in 2007.

GHG Analysis Summary

The large GHG profile changes at Double Oord Farms between the 2006 and 2008 calendar years is due to a large increase in milk production efficiency, table #1 outlines the base milk production data for 2006 and 2008.

Table 1. Double Oord Farms 2006 and 2008 Milk Production Data

	Baseline	Project	Change from Baseline	% of Baseline
Total Cows	55	58	3	4%
Lactation Cows	49	52	3	5%
Dry Cows	6	6	0	0%
Milk Production (kg/cow/day)	23.58	28.04	4	19%
Annual Milk Production (kg)	451,384	546,308	94,924	21%
Annual Fat Production (kg)	17,613	21,368	3,755	21%
Annual Protein Production (kg)	14,736	18,534	3,798	26%

Baseline and Project Case Comparison

The actual GHG emissions profile for Double Oord Farms between the 2006 baseline and 2008 project case production years differed by only 3.1-tonnes CO_2e, with the project year profile being the larger of the two years studied. The baseline and project case profiles are presented in Table 2.

While the Double Oord Farms case study did not identify a large quantity of carbon offsets available for sale off the farm due to substantial increases in production efficiency, the GHG intensity between the baseline and project case years was reduced substantially. Table #3 outlines the kg CO_2e per kg Fat Corrected Milk (FCM) for the baseline and project years. In the 2006 and 2008 production years the farm produced 1.33 and 1.08 kg CO_2e per kg FCM, respectively. This represents a GHG intensity reduction of 20% for the farm between 2006 and 2008.

Table 2. Baseline and Project Case GHG Emissions Profile and Reduction Summary (Tonnes CO_2e)

	Tonnes CO_2e			
	Baseline	**Project Case 1**	**GHG Reduction**	**% Reduction**
CH_4 from Enteric Fermentation				
Milking Cows	170.4	176.86	-6.46	-4%
Dry Cows	22.34	21.86	0.48	-4%
Heifers	54.41	55.2	-0.79	-4%
Total	247.16	253.92	-6.76	-4%
CH_4 from Manure Management				
Milking Cows	62.16	60.41	1.75	3%
Dry Cows	9.8	9.48	0.32	3%
Heifers	1.33	1.36	-0.03	3%
Total	73.29	71.25	2.04	3%
N_2O from Manure Storage				
Milking Cows	28.55	21.89	6.66	23%
Dry Cows	3.46	3.34	0.12	23%
Heifers	6.5	6.6	-0.1	23%
Total	38.5	31.84	6.66	23%
CO_2e from Feed Production				
Milking Cows	146.62	150.44	-3.82	-3%
Dry Cows	5.31	6.12	-0.81	-3%
Heifers	28.19	28.6	-0.41	-3%
Total	180.12	185.16	-5.04	-3%
Totals				
Milking Cows	407.73	409.59	-1.86	0%
Dry Cows	40.91	40.8	0.11	0%
Heifers	90.42	91.76	-1.34	0%
Total	539.06	542.16	-3.1	0%

Table 3. Baseline and Project Case GHG Emissions Profile and Reduction Summary (Kg CO_2e / Kg FCM)

	Kg CO_2e per Kg Fat Corrected Milk			
	Baseline	**Project Case 1**	**GHG Reduction**	**% Reduction**
CH_4 from Enteric Fermentation				
Milking Cows	0.42	0.35	0.07	17%
Dry Cows	0.06	0.04	0.02	17%
Heifers	0.13	0.11	0.02	17%
Total	0.61	0.51	0.1	17%
CH_4 from Manure Management				
Milking Cows	0.15	0.12	0.03	20%
Dry Cows	0.02	0.02	0	20%
Heifers	0	0	0	20%
Total	0.18	0.14	0.04	20%
N_2O from Manure Storage				
Milking Cows	0.07	0.04	0.03	43%
Dry Cows	0.01	0.01	0	43%
Heifers	0.02	0.01	0.01	43%
Total	0.1	0.06	0.04	43%
CO_2e from Feed Production				
Milking Cows	0.36	0.3	0.06	17%
Dry Cows	0.01	0.01	0	17%
Heifers	0.07	0.06	0.01	17%
Total	0.45	0.37	0.08	17%
Totals				
Milking Cows	1.01	0.81	0.2	20%
Dry Cows	0.1	0.08	0.02	20%
Heifers	0.22	0.18	0.04	20%
Total	1.33	1.08	0.25	20%

GHG Reduction Value Summary

The Double Oord case study did not identify a carbon package available for sale into the carbon market. The emissions profiles for the baseline and project cases were almost identical, despite a substantial increase in milk output in 2008 compared to 2006. The GHG intensity between the baseline and project cases, however, was found to be reduced by 20% for the project year.

While no income can be generated through carbon offset sales, the farms overall financial position is likely to be improved through increased production efficiency.

Recommendations

1. Further decreases in GHG production intensity may be possible with additional increases in the quality of the forages produced on-farm.

2. The quality of dry hay should be specifically targeted to decrease GHG emissions from the dry cow and replacement heifer herds.

Perryhill Farm

Perryhill Farms offered a unique opportunity to assess the GHG emissions profile for a farm that transitioned from a tie stall to a free stall based operation while increasing the size of the milking herd significantly. Currently, Perryhill Farms, Located in Perry Settlement, New Brunswick is milking 88-holsteins in a free stall barn built in 2006-2007. The feeding system is based on round bale silage that is offered free choice in a purpose built feed bunk and concentrate is offered through a number of feeding stations located strategically throughout the barn. The manure management system was altered significantly from a solid based system in the tie stall barn to a full liquid system in the free stall. Replacement heifers are now housed in the former tie stall barn and heifer manure is managed in a solid form.

GHG Baseline Case

The baseline case for Perryhill Farms was the 2006 production year, which was the last year the lactation herd was managed in the tie stall barn. The average number of milking and dry cows managed throughout the year was 56 and 12, respectively. Average milk production for the year was 32.69 kg/cow/day. Lactation, dry cow and heifer rations were all based on free choice hay and silage, with a complete feed concentrate offered as appropriate. The free choice forage offered was generally of medium quality as forages were harvested in a 2-cut system.

Manure was evacuated from the barn using an barn gutter cleaner and manure was applied directly to forage and annual cropland weekly from April-October as weather permitted, and stockpiled throughout the winter months until the spring thaw when the manure stack could be completely spread.

GHG Project Case 1

The Perryhill Farms project case was the second full production year after the lactation herd had been transferred from the tie stall to the newly constructed free stall barn. The herd size was increased to 87-lactating animals with 11-dry cows on average maintained each month throughout the year. Average milk production was slightly lower than the baseline case at 30 kg/cow/year.

The move to the new barn also brought on a complete change in the farms manure management system, which was moved from a solid based system to a full liquid system, excluding heifers which remained housed in the solid manure based tie stall barn. Manure was applied to cropland less frequently, in May, July and October.

GHG Project Case 2

The second project case analysed for Perryhill Farms was the adoption of a more intensive manure management schedule. The project goal was to reduce manure storage methane emissions by avoiding the presence of a large quantity of manure in storage over the hot summer months.

The manure application frequencies analysed in Project Cases 1 and 2 are outlined in Table 1. Project Case 2 assumes that the manure storage is completely emptied 3-times per year. Given that Perryhill farm does produce roughly 35-hectares of small grains annually, a more aggressive manure application schedule could be reasonably adopted with manure being applied to both perennial forage and annual cropland throughout the growing season.

Application schedules are based on the total amount of manure evacuated from storage at the time of application. In Project Case 2, 95% of all the manure contained in storage in May, July and September is removed and applied to cropland. This theoretical case study was developed to assume a complete emptying of the manure storage three-times annually, although the actual volumes removed for each event will vary significantly. It was assumed that 5% of the manure contained in a round concrete storage with a flat concrete bottom cannot be removed with traditional pumping equipment, a complete emptying was therefore assumed to be 95% of the available manure volume.

Table 1. Project Case 1 & 2 Manure Application to Cropland Schedules

	% of Total Applied	
Month	Project Case 1	Project Case 2
January	0%	0%
February	0%	0%
March	0%	0%
April	50%	0%
May	50%	95%
June	0%	0%
July	80%	95%
August	0%	0%
September	0%	95%
October	95%	0%
November	0%	0%
December	0%	0%

GHG Analysis Summary

GHG Project Case 1

The total GHG emissions profile for the farm is presented in Table 2. Emissions increased by 42% overall with the addition of 31-lactating animals to the herd in the project case and the move from a solid based manure management system to a full liquid manure collection system.

The increase in the lactation herd size and a corresponding increase in the replacement heifer herd resulted in a 61% and 35% increase in GHG emissions from enteric fermentation, respectively. This is an expected response from the addition of a relatively large number of animals to the herd. Manure management emissions also increased substantially due to an increase in both methane and nitrous oxide production. This is also an expected response when manure management is moved from a solid to a liquid based system.

The Dairy GHG Calculator, assumes that CO_2e emissions from feed production include cattle enteric fermentation emissions from dry matter intake on pasture. The Calculator does not assume that dry matter intake from pasture is of high quality, resulting in what might be an overestimation of methane emissions from enteric fermentation on pasture, if pastures are managed through intensive rotational grazing.

Total GHG emissions from feed production were decreased by 11% when the lactation herd was moved from a stored feed and pasture based feeding system to full confinement based production. As rotational grazing management was not practiced in the Perryhill Farms baseline case, the reduction in enteric fermentation methane emissions predicted by the calculator when lactation cattle were no longer granted access to pasture is therefore, likely to be quite accurate. The 35% increase in replacement heifer herd feed production emissions are due to the addition of roughly 20-heifer animals to the herd and the fact that the total dry matter intake for the heifer herd is serviced through grazing on a non-rotationally grazed pasture system throughout the summer.

From a GHG emissions intensity standpoint the farm increased from 1.36 in the baseline to 1.46 kg CO_2e per kg fat corrected milk in the project case.

Table 2. Baseline and Project Case GHG Emissions Profile and Reduction Summary (Tonnes CO_2e)

	Tonnes CO_2e			
	Baseline	**Project Case 1**	**GHG Reduction**	**% Reduction**
CH_4 from Enteric Fermentation				
Milking Cows	246.08	396.93	-150.85	-61%
Dry Cows	56.5	51.42	5.08	9%
Heifers	189.3	255.27	-65.97	-35%
Total	491.89	703.62	-211.73	-43%
CH_4 from Manure Management				
Milking Cows	7.24	146.52	-139.28	-1924%
Dry Cows	2.24	31.94	-29.7	-1326%
Heifers	6.53	8.66	-2.13	-33%
Total	16	187.12	-171.12	-1070%
N_2O from Manure Storage				
Milking Cows	28.29	74.72	-46.43	-164%
Dry Cows	7.48	7.89	-0.41	-5%
Heifers	15.05	20.47	-5.42	-36%
Total	50.81	103.08	-52.27	-103%
CO_2e from Feed Production				
Milking Cows	252.04	196.23	55.81	22%
Dry Cows	69.25	64.63	4.62	7%
Heifers	58.48	78.84	-20.36	-35%
Total	379.78	339.7	40.08	11%
Totals				
Milking Cows	533.66	814.4	-280.74	-53%
Dry Cows	135.47	155.88	-20.41	-15%
Heifers	269.36	363.24	-93.88	-35%
Total	938.48	1333.51	-395.03	-42%

GHG Project Case 2

Project Case 2 offers an entirely different perspective on the GHG emissions profile for Perryhill Farms. The adoption of the more aggressive manure management schedule outlined in Table 1 was assumed to be Project Case 2, and was compared to Project Case 1, which is based on the farms current size and manure management system.

Implementing the more aggressive manure application schedule would result in a net GHG reduction of 31.93 tonnes CO_2e annually. The farms GHG emissions intensity was reduced from 1.46 to 1.43 kg CO_2e per kg fat corrected milk produced, which represents a net reduction in GHG emissions intensity of 2% from Project Case 1 levels. The total emission profiles for Project Cases 1 and 2 are outlined in Table 3.

Table 3. Project Cases 1 & 2 GHG Emissions Profile and Reduction Summary (Tonnes CO_2e)

	Tonnes CO_2e			
	Project Case 1	**Project Case 2**	**GHG Reduction**	**% Reduction**
CH_4 from Enteric Fermentation				
Milking Cows	396.93	396.93	0	0%
Dry Cows	51.42	51.42	0	0%
Heifers	255.27	255.27	0	0%
Total	703.62	703.62	0	0%
CH_4 from Manure Management				
Milking Cows	146.52	118.78	27.74	19%
Dry Cows	31.94	27.75	4.19	13%
Heifers	8.66	8.66	0	0%
Total	187.12	155.18	31.94	17%
N_2O from Manure Storage				
Milking Cows	74.72	74.72	0	0%
Dry Cows	7.89	7.89	0	0%
Heifers	20.47	20.47	0	0%
Total	103.08	103.08	0	0%
CO_2e from Feed Production				
Milking Cows	196.23	196.23	0	0%
Dry Cows	64.63	64.63	0	0%
Heifers	78.84	78.84	0	0%
Total	339.7	339.7	0	0%
Totals				
Milking Cows	814.4	786.66	27.74	3%
Dry Cows	155.88	151.69	4.19	3%
Heifers	363.24	363.24	0	0%
Total	1333.51	1301.58	31.93	2%

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of \$15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

GHG Project Case 1

No GHG emissions were identified for potential sale between the baseline case and project case 1.

GHG Project Case 2

If Project Case 1 was considered as the farms secondary Baseline and the more aggressive manure management schedule outlined in Table 1 were adopted as Project Case 2, the annual value of the carbon offsets created are outlined in Table 4.

Table 4. Project Case 2: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			\$ Tonne CO_2e			
Project Case 1	Project Case 2	Reduction	\$15	\$25	\$50	\$100
1,333.51	1,301.58	31.93	\$478.95	\$798.25	\$1,596.50	\$3,193.00

Recommendations

1. Increase forage harvest intensity from a 2-cut to a 3-cut system to improve forage quality. A three cut system may not always be feasible given climate constrains such as a cold wet spring or very dry summer conditions. A three cut system is however, advisable whenever possible. Forage should be harvested (silage)between 35% - 50% dry matter, this will support higher feed intake. These changes will result in fewer enteric fermentation emissions and reduce the farms GHG output. Further study of forage quality after implementation of the recommendation will be necessary to determine the net GHG emissions achieved. Offering higher quality forage is likely to result in greater milk production as well, which will lower the farms net GHG emissions intensity per unit of milk output.

2. A 3-cut forage system will allow for the manure storage to be completely emptied following each forage harvest. As outlined in Table 4, this will reduce the farms net GHG emissions by 31.93-tonnes CO_2e annually.

3. Implement an intensive rotational grazing system for your dry cow and heifer herds. This will result in higher feed quality being available on pasture, which will reduce enteric fermentation GHG emissions. Rotational grazing will also allow you to increase the productivity of your grazing lands and increase the legume content of the pasture sward, reducing nitrous oxide emissions from the application of manure and/or fertilizer nitrogen to pastureland.

Folly River Holsteins

Folly River Holsteins is a modern dairy operating a freestall barn with liquid manure collection and milking between 60-65 Holstein cattle in Folly River, Nova Scotia. All haylage and corn silage are produced on site, as well as barley grain and contract carrots. Cattle are milked in a double-4 herringbone milking parlour.

GHG Baseline Case

The baseline case used to analyse the GHG emissions profile at Folly River Holsteins was the 2008 calendar production year. Lactation cattle were fed a ration of generally high quality haylage and corn silage, barley grain and commercial lactation cow concentrate. Dry cows and replacement heifers are fed a ration of haylage, corn silage, hay and commercial concentrates, depending on the animal size class. Liquid manure was surface applied and incorporated into annual corn and carrot cropland and surface applied to forage land a total of 5-times throughout the season. No ionophores or edible canola oil are included in the lactation ration as a GHG reduction measure.

GHG Project Case 1

Folly River Holsteins routinely tests individual forage ration components and adjusts their ration according to feed quality and protein content. The amount of forage quality data available allowed for a direct comparison of 2008 and 2009 calendar years of milk production. The farms 2009 milk output was greater than 2008, and was achieved with fewer lactation and dry cows. This constituted a general herd productivity increase for 2009 over the 2008 baseline and was considered Project Case 1.

GHG Project Case 2

The addition of ionophores to the lactation ration was contemplated for Folly River Holsteins as Project Case 2. This project case was evaluated as a potential herd management practice that could be adopted with the specific aim of achieving a net reduction in farm GHG emissions.

GHG Analysis Summary

Project Case 1

The increase in milk production efficiency between 2008 and 2009 resulted in a GHG reduction of 137-tonnes CO_2e. The increase was largely attributed to a slight increase in forage quality between 2008 and 2009 and increased attention to production detail in the barn such as breeding intervals, animal health and comfort, etc. The net GHG reduction between 2008 and 2009 represents a 13% reduction in emissions from Folly River Holsteins.

Table 1. Baseline and Project Case 1 GHG Emissions Profile and Reduction Summary

	Tonnes CO_2e			
	Baseline	**Project Case 1**	**GHG Reduction**	**% Reduction**
CH_4 from Enteric Fermentation				
Milking Cows	291.97	231.49	60.48	21%
Dry Cows	31.52	33.85	-2.33	-7%
Heifers	76.4	76.19	0.21	0%
Total	399.88	341.53	58.35	15%
CH_4 from Manure Management				
Milking Cows	75.74	59.84	15.9	21%
Dry Cows	9.63	10.6	-0.97	-10%
Heifers	54.79	54.64	0.15	0%
Total	140.16	125.08	15.08	11%
N_2O from Manure Storage				
Milking Cows	57.18	45.7	11.48	20%
Dry Cows	5.36	5.71	-0.35	-7%
Heifers	16.42	16.38	0.04	0%
Total	78.96	67.79	11.17	14%
CO_2e from Feed Production				
Milking Cows	321.46	267.29	54.17	17%
Dry Cows	17.75	20.34	-2.59	-15%
Heifers	83.09	82.87	0.22	0%
Total	422.3	370.5	51.8	12%
Totals				
Milking Cows	746.34	604.33	142.01	19%
Dry Cows	64.25	70.49	-6.24	-10%
Heifers	230.7	230.07	0.63	0%
Total	1041.3	904.89	136.41	13%

Project Case 2

The theoretical inclusion of ionophores in the lactation ration resulted in a net GHG reduction of 23.15-tonnes CO_2e. This reduction represents a 10% reduction in lactation herd enteric fermentation emissions and an overall net reduction of 3% annually for the farm.

Table 2. Project Cases 1 & 2 GHG Emissions Profile and Reduction Summary

	Tonnes CO_2e			
	Project Case 1	**Project Case 2**	**GHG Reduction**	**% Reduction**
	CH_4 from Enteric Fermentation			
Milking Cows	231.49	208.34	23.15	10%
Dry Cows	33.85	33.85	0	0%
Heifers	76.19	76.19	0	0%
Total	341.53	318.38	23.15	7%
	CH_4 from Manure Management			
Milking Cows	59.84	59.84	0	0%
Dry Cows	10.6	10.6	0	0%
Heifers	54.64	54.64	0	0%
Total	125.08	125.08	0	0%
	N_2O from Manure Storage			
Milking Cows	45.7	45.7	0	0%
Dry Cows	5.71	5.71	0	0%
Heifers	16.38	16.38	0	0%
Total	67.79	67.79	0	0%
	CO_2e from Feed Production			
Milking Cows	267.29	267.29	0	0%
Dry Cows	20.34	20.34	0	0%
Heifers	82.87	82.87	0	0%
Total	370.5	370.5	0	0%
	Totals			
Milking Cows	604.33	581.18	23.15	4%
Dry Cows	70.49	70.49	0	0%
Heifers	230.07	230.07	0	0%
Total	904.89	881.74	23.15	3%

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of $15 Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

Project Case 1

If the calendar years 2008 and 2009 were accepted as the Baseline and Project cases for Folly River Farms, respectively, the annual value of the carbon offsets created are outlined in table 3.

Table 3. Project Case 1: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			$ Tonne CO_2e^{-1}			
Baseline	Project Case 1	Reduction	$15	$25	$50	$100
1041.3	904.89	136.41	$2,046.15	$3,410.25	$6,820.50	$13,641.00

Project Case 2

If Project Case 1 was considered as the farms secondary Baseline and Ionophores were included in the lactation ration as Project Case 2, the annual value of the carbon offsets created are outlined in table 4.

Table 4. Project Case 2: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			$ Tonne CO_2e^{-1}			
Project Case 1	Project Case 2	Reduction	$15	$25	$50	$100
904.89	881.74	23.15	$347.25	$578.75	$1,157.50	$2,315.00

Recommendations

1. Decrease moisture content of haylage and corn silage to achieve 50% and 33% dry matter content, respectively. This will ensure proper ensiling of both products and may increase lactation herd intake.
2. Consider the financial ramifications of including edible oils in the lactation ration as an energy booster and GHG reduction measure.

Fortlands Farm

Fortlands Dairy Farm is a 50-cow free stall dairy located in Stewiacke, Nova Scotia. Lactation cattle are offered a diet of high quality haylage, corn silage, and complete feed concentrate through a computerized feeding station. Manure is managed in a liquid form and removed from the deep pit manure storage for application on annual cropland and perennial forage land three times annually.

GHG Baseline Case

The Fortlands Farm baseline case was the 2009 calendar production year. Feed tests determined that the farms lactation and dry cow ration components were all of high quality. Manure was applied to cropland three times throughout the year in the spring, mid-summer following first cut forage harvest, and again in October.

GHG Project Case 1

Given that the production system at Fortlands Farm is well managed from a feed quality and manure application scheduling standpoint, the project case options were limited to the adoption of advanced feeding strategies. The farm project case was therefore assumed to be the theoretical addition of ionophores to the lactation ration as an enteric fermentation emissions reduction strategy.

GHG Analysis Summary

GHG Project Case

The inclusion of ionophores in the Fortlands Farm lactation ration would result in a GHG emission reduction of roughly 15-tonnes CO_2e annually. The baseline and project case GHG emission profiles for the farm are outlined in Table 1.

Table 1. Baseline and Project Case GHG Emissions Profile and Reduction Summary (Tonnes CO_2e)

	Tonnes CO_2e			
	Baseline	**Project Case**	**GHG Reduction**	**% Reduction**
CH_4 from Enteric Fermentation				
Milking Cows	150.78	135.7	15.08	10%
Dry Cows	17.65	17.65	0	0%
Heifers	88.16	88.16	0	0%
Total	256.59	241.51	15.08	6%
CH_4 from Manure Management				
Milking Cows	52.61	52.61	0	0%
Dry Cows	0.68	0.68	0	0%
Heifers	2.31	2.31	0	0%
Total	55.59	55.59	0	0%
N_2O from Manure Storage				
Milking Cows	18.48	18.48	0	0%
Dry Cows	2.31	2.31	0	0%
Heifers	15.79	15.79	0	0%
Total	36.58	36.58	0	0%
CO_2e from Feed Production				
Milking Cows	207.73	207.73	0	0%
Dry Cows	44.78	44.78	0	0%
Heifers	88.47	88.47	0	0%
Total	340.97	340.97	0	0%
Totals				
Milking Cows	429.59	414.51	15.08	4%
Dry Cows	65.42	65.42	0	0%
Heifers	194.72	194.72	0	0%
Total	689.73	674.65	15.08	2%

Table 3 outlines the baseline and project case GHG production intensity for the 2009 production year at Fortlands Farm. The addition of ionophores to the lactation ration would theoretically reduce enteric fermentation emissions from 1.60 to 1.57 kg CO_2e per kg fat corrected milk.

Table 3. Baseline and Project Case 1 GHG Emissions Profile and Reduction Summary

	Kg CO_2e per Kg Fat Collected Milk			
	Baseline	**Project Case 1**	**GHG Reduction**	**% Reduction**
CH_4 from Enteric Fermentation				
Milking Cows	0.35	0.32	0.03	9%
Dry Cows	0.04	0.04	0	0%
Heifers	0.2	0.2	0	0%
Total	0.6	0.56	0.04	7%
CH_4 from Manure Management				
Milking Cows	0.12	0.12	0	0%
Dry Cows	0	0	0	0%
Heifers	0.01	0.01	0	0%
Total	0.13	0.13	0	0%
N_2O from Manure Storage				
Milking Cows	0.04	0.04	0	0%
Dry Cows	0.01	0.01	0	0%
Heifers	0.04	0.04	0	0%
Total	0.09	0.09	0	0%
CO_2e from Feed Production				
Milking Cows	0.48	0.48	0	0%
Dry Cows	0.1	0.1	0	0%
Heifers	0.21	0.21	0	0%
Total	0.79	0.79	0	0%
Totals				
Milking Cows	1	0.96	0.04	4%
Dry Cows	0.15	0.15	0	0%
Heifers	0.45	0.45	0	0%
Total	1.6	1.57	0.03	2%

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of \$15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

GHG Project Case

The theoretical ionophores feeding project would provide the following financial return to the farm annually. The revenue assessment does not take into account the cost of including ionophores in the ration, nor the additional labour and management required to alter and manage the more complex feeding system.

Table 3. Project Case 1: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			\$ Tonne CO_2e			
Baseline	Project Case 1	Reduction	\$15	\$25	\$50	\$100
689.73	674.65	15.08	\$226.20	\$377.00	\$754.00	\$1,508.00

Recommendations

1. Upgrade barn lighting and ventilation systems to provide an optimal housing environment for the lactation herd. This may increase milk production without any changes to the feeding program, further decreasing the farms GHG output per unit of milk produced.

2. Consider including ionophores or edible oils in the lactation ration as a GHG reduction measure.

Port Hill Milking

Port Hill Milking, Located in Port Hill, Prince Edward Island is a modern free stall dairy operation milking roughly 150-cows. Cattle are offered a well balanced ration of haylage, corn silage, small grains, soybean meal and vitamins and mineral supplement. Dry cows and replacements are housed on site. The farms manure is produced and managed in a liquid form.

GHG Baseline Case

The Port Hill Milking baseline case is the 2008 production year. The forage components of the total mixed ration offered the lactating and dry cow herds had an excellent ADF score at roughly 30%, although feed tests showed higher than expected NDF values of 50-60%. Forage quality would be considered medium to high quality. The total quantity of each ration component offered was taken directly from total mixed ration recipes developed by the farm nutritionist, and is therefore considered to be an extremely accurate depiction of the farms actual, as fed ration makeup.

The baseline manure management system assumed that 90% of the available manure in storage was applied to annual and perennial forage cropland three times annually in May, July and November before fall freeze up.

GHG Project Case 1

Project case 1 assumed that feed quality and ration makeup were identical to the baseline case. The major variance factor between the baseline and project case 1 was the assumption of a fall only manure application schedule. Although Port Hill Milking currently manages manure using a three-times per year application schedule, project case 1 was included as a potential scenario to determine the relative importance of manure application schedule on the farms GHG emissions profile.

GHG Project Case 2

Project case 2 assumed that feed quality and ration makeup were identical to the baseline case. The manure was assumed to be emptied twice annually, compared to the more aggressive three-times per year application practiced in the baseline. Port Hill Milking moved to the baseline case manure management schedule in 2006, therefore, project case 2 would be considered the farm baseline case prior to 2006. The project was analysed to further explore the importance of manure application scheduling on the farms GHG emissions profile.

GHG Project Case 3

Project Case 3 assumed that edible oils were included as a lactation ration component. Edible oils have been proven to suppress rumen methanogenic bacteria activity, resulting in an overall decrease in enteric fermentation emissions.

GHG Project Case 4

Project case 4 assumed that ionophores were include in the lactation ration as a GHG reduction measure instead of edible oils. Ionophores have been proven to increase feed conversion efficiency in cattle and therefore produce a net reduction in enteric fermentation GHG emissions.

GHG Analysis Summary

Project cases 1 and 2 represent retroactive assessments for Port Hill Milking which currently practices a 3-times per year manure application schedule. Project cases 3 and 4 were assessed as actual project opportunities for the farm.

GHG Project Case 1

The GHG emissions reductions achieved by moving from a 1-time per year manure storage emptying versus the baseline 3-times annual case is 154.09-tonnes CO_2e. The GHG intensity for project case 1 was 1.89 kg CO_2e per kg fat corrected milk (FCM) versus 1.75 CO_2e per kg FCM in the baseline case.

Table 1. Fall Manure Application Case and Baseline Case GHG Emissions Profile and Reduction Summary (Tonnes CO_2e)

	Tonnes CO_2e			
	Fall Manure Case	**Baseline Case**	**GHG Reduction**	**% Reduction**
CH_4 from Enteric Fermentation				
Milking Cows	558	558	0	0%
Dry Cows	60.52	60.52	0	0%
Heifers	221.19	221.19	0	0%
Total	839.72	839.72	0	0%
CH_4 from Manure Management				
Milking Cows	314.11	178.39	135.72	43%
Dry Cows	39.8	21.42	18.38	46%
Heifers	6.63	6.63	0	0%
Total	360.53	206.44	154.09	43%
N_2O from Manure Storage				
Milking Cows	103.01	103.01	0	0%
Dry Cows	11.33	11.33	0	0%
Heifers	39.96	39.96	0	0%
Total	154.3	154.3	0	0%
CO_2e from Feed Production				
Milking Cows	514	514	0	0%
Dry Cows	49.18	49.18	0	0%
Heifers	203.88	203.88	0	0%
Total	767.06	767.06	0	0%
Totals				
Milking Cows	1489.11	1353.4	135.71	9%
Dry Cows	160.83	142.46	18.37	11%
Heifers	471.67	471.67	0	0%
Total	2121.61	1967.52	154.09	7%

GHG Project Case 2

The GHG emissions reductions achieved by moving from a 2-time per year manure storage emptying versus the baseline 3-times annual case is 44.35 tonnes CO_2e. The GHG intensity for project case 1 was 1.79 kg CO_2e per kg fat corrected milk (FCM) versus 1.75 CO_2e per kg FCM in the baseline case.

Table 2. 2x Manure Application Case and Baseline Case GHG Emissions Profile and Reduction Summary

	Tonnes CO_2e			
	2x Manure Case	**Baseline Case**	**GHG Reduction**	**% Reduction**
	CH_4 from Enteric Fermentation			
Milking Cows	558	558	0	0%
Dry Cows	60.52	60.52	0	0%
Heifers	221.19	221.19	0	0%
Total	839.72	839.72	0	0%
	CH_4 from Manure Management			
Milking Cows	219.35	178.39	40.96	19%
Dry Cows	24.81	21.42	3.39	14%
Heifers	6.63	6.63	0	0%
Total	250.79	206.44	44.35	18%
	N_2O from Manure Storage			
Milking Cows	103.01	103.01	0	0%
Dry Cows	11.33	11.33	0	0%
Heifers	39.96	39.96	0	0%
Total	154.3	154.3	0	0%
	CO_2e from Feed Production			
Milking Cows	514	514	0	0%
Dry Cows	49.18	49.18	0	0%
Heifers	203.88	203.88	0	0%
Total	767.06	767.06	0	0%
	Totals			
Milking Cows	1394.36	1353.4	40.96	3%
Dry Cows	145.84	142.46	3.38	2%
Heifers	471.67	471.67	0	0%
Total	2011.87	1967.52	44.35	2%

GHG Project Case 3

The addition of edible canola oil to the lactation ration reduced the enteric fermentation emissions from the lactation herd and methane emissions from the manure storage, but increased the CO_2 emissions from feed production enough to cancel out the reductions achieved and create a net increase in GHG emissions for the project. The energy intensity of canola production is greater than soybean meal production due to the nitrogen fertilizer requirements for canola. This case study identified that although edible oils addition to ruminant lactation rations represents an opportunity to reduce enteric and manure storage

GHG emissions, these emissions reductions must be carefully considered against the energy intensity of crop production.

Table 3. Baseline Case and Edible Oils Project Case GHG Emissions Profile and Reduction Summary

	Tonnes CO_2e			
	Baseline Case	**Edible Oils Project**	**GHG Reduction**	**% Reduction**
CH_4 from Enteric Fermentation				
Milking Cows	558	552.95	5.05	1%
Dry Cows	60.52	60.52	0	0%
Heifers	221.19	221.19	0	0%
Total	839.72	834.67	5.05	1%
CH_4 from Manure Management				
Milking Cows	178.39	167.94	10.45	6%
Dry Cows	21.42	21.42	0	0%
Heifers	6.63	6.63	0	0%
Total	206.44	195.99	10.45	5%
N_2O from Manure Storage				
Milking Cows	103.01	106.14	-3.13	-3%
Dry Cows	11.33	11.33	0	0%
Heifers	39.96	39.96	0	0%
Total	154.3	157.43	-3.13	-2%
CO_2e from Feed Production				
Milking Cows	514	529.38	-15.38	-3%
Dry Cows	49.18	49.18	0	0%
Heifers	203.88	203.88	0	0%
Total	767.06	782.44	-15.38	-2%
Totals				
Milking Cows	1353.4	1356.41	-3.01	0%
Dry Cows	142.46	142.46	0	0%
Heifers	471.67	471.67	0	0%
Total	1967.52	1970.53	-3.01	0%

GHG Project Case 4

The addition of ionophores to the lactation ration reduced the farms total GHG emissions profile by 57.56-tonnes CO_2e. The GHG intensity for the ionophores feeding project is 1.70 kg CO_2e per kg FCM versus 1.75 CO_2e per kg FCM in the baseline case.

Table 4. Baseline Case and Ionophores Plus Edible Oils Project Case GHG Emissions Profile and Reduction Summary

	Tonnes CO_2e			
	Baseline Case	**Ionophores Project**	**GHG Reduction**	**% Reduction**
		CH_4 from Enteric Fermentation		
Milking Cows	558	502.19	55.81	10%
Dry Cows	60.52	60.52	0	0%
Heifers	221.19	221.19	0	0%
Total	839.72	783.91	55.81	7%
		CH_4 from Manure Management		
Milking Cows	178.39	176.24	2.15	1%
Dry Cows	21.42	21.42	0	0%
Heifers	6.63	6.63	0	0%
Total	206.44	204.29	2.15	1%
		N_2O from Manure Storage		
Milking Cows	103.01	103.41	-0.4	0%
Dry Cows	11.33	11.33	0	0%
Heifers	39.96	39.96	0	0%
Total	154.3	154.7	-0.4	0%
		CO_2e from Feed Production		
Milking Cows	514	514	0	0%
Dry Cows	49.18	49.18	0	0%
Heifers	203.88	203.88	0	0%
Total	767.06	767.06	0	0%
		Totals		
Milking Cows	1353.4	1295.84	57.56	4%
Dry Cows	142.46	142.46	0	0%
Heifers	471.67	471.67	0	0%
Total	1967.52	1909.96	57.56	3%

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of \$15 Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

GHG Project Case 1

The retroactive comparison of a once per year versus 3-times per year manure storage emptying schedule identified the opportunity to create a carbon offset package of 154 tonnes CO_2e. This is the result of reduced microbial decomposition of manure organic matter during the hot summer months. The carbon value that would be available to the farm is outlined in Table 5.

Table 5. Project Case 1: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			**\$ Tonne CO_2e**			
Fall Manure Case	Baseline Case	Reduction	\$15	\$25	\$50	\$100
2,121.61	1,967.52	154.09	\$2,311.35	\$3,852.25	\$7,704.50	\$15,409.00

GHG Project Case 2

The retroactive comparison of a twice per year versus 3-times per year manure storage emptying schedule identified the opportunity to create a carbon offset package of 44-tonnes CO_2e. This is the result of reduced microbial decomposition of manure organic matter during the hot summer months. The carbon value that would be available to the farm is outlined in Table 6.

Table 6. Project Case 2: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			**\$ Tonne CO_2e**			
2x Manure Case	Baseline Case	Reduction	\$15	\$25	\$50	\$100
2,011.87	1,967.52	44.35	\$665.25	\$1,108.75	\$2,217.50	\$4,435.00

GHG Project Case 3

Due to a significant increase in CO_2e emissions from the addition of canola oil to the lactation ration, Project Case 3 increased the farms net GHG emissions profile. This was largely due to the increased energy intensity associated with the ration, and the production of canola oil in particular, which requires significant nitrogen fertilizer inputs. The carbon value for this project concept is presented in Table 7, note the negative value of the proposed GHG reduction project.

Table 7. Project Case 3: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			**\$ Tonne CO_2e**			
Baseline Case	Edible Oils Project	Reduction	$15	$25	$50	$100
1967.52	1970.53	-3.01	-$45.15	-$75.25	-$150.50	-$301.00

GHG Project Case 4

The addition of ionophores to the lactation ration was found to reduce the net farm GHG emissions by roughly 45-tonnes CO_2e annually. The potential value creation for the farm is outlined in table 8.

Table 8. Project Case 4: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			**\$ Tonne CO_2e**			
Baseline Case	Edible Oils & Ionophores Project	Reduction	$15	$25	$50	$100
1967.52	1922.77	44.75	$671.25	$1,118.75	$2,237.50	$4,475.00

Recommendations

1. Continue to intensify the manure management schedule to reduce manure storage volumes throughout the summer months.

2. Continue to produce high quality forages and make additional quality improvements where possible

3. Consider the addition of ionophores to the lactation ration.

4. Consider installing a solar hot water or biomass water heating system to reduce propane use.

Elliotville Farms

Elliotville Farms is a 50-cow lactation herd, summer pasture based, tie stall dairy operation located in Pleasant Valley, Prince Edward Island. Elliotville Farms is currently undergoing a major barn retrofit which has disrupted the farms breeding program significantly. Stray voltage has also disrupted the farms normal operations, resulting in significant reductions in milk production. The farm offered an interesting opportunity to study the effects of a major disruption in milk productivity on the net farm GHG emissions profile. The effect of maintaining high and low quality rotationally grazed pastures was also studied.

GHG Baseline Case

The baseline case for Ellitoville Farms is the 2009 production year with solid manure resources applied to annual cropland and perennial forage land once in May and again in October. The farm milked an average of 47-cows throughout the year, and due to breeding challenges maintained 24-dry cows as well which increased the net farm GHG emissions significantly relative to the size of the milking herd.

GHG Project Case

The Dairy GHG Calculator was manipulated in order to assess what effect improved rotational pasture management would have on the GHG emissions profile for Elliotville Farms. Animal performance was assumed to be identical to the baseline case, which was based on actual animal performance records. The project case assumed that cattle were allowed access to pasture for 4-hours per day, as opposed to the 12-16 hours the lactation herd is currently maintained on pasture, mimicking a confinement based dairy operation with an exercise yard. The Dairy GHG Calculator does not take into account the potential to produce exceptional quality pasture forage, and assigns a high emissions value to pasture based milk production. The comparison of the baseline case to the project case attempts to quantify the net GHG reductions achieved by providing exceptional quality forage to the lactation herd through intensive rotational pasture management.

GHG Analysis Summary

GHG Project Case

Practicing intensive rotational grazing to provide exceptional quality pasture dry matter to the lactation herd had little effect on enteric fermentation and manure storage emissions, but decreased CO_2e emissions from feed production significantly. The farms baseline and project case emissions profiles are outlined in Table 1.

Table 1. Baseline and Project Case GHG Emissions Profile and Reduction Summary (Tonnes CO_2e)

	Tonnes CO_2e			
	Baseline	**Project Case**	**GHG Reduction**	**% Reduction**
	CH_4 from Enteric Fermentation			
Milking Cows	134.21	141.19	-6.98	-5%
Dry Cows	66.3	60.8	5.5	8%
Heifers	75.3	77.43	-2.13	-3%
Total	275.81	279.42	-3.61	-1%
	CH_4 from Manure Management			
Milking Cows	6.19	6.35	-0.16	-3%
Dry Cows	3.05	2.56	0.49	16%
Heifers	2.44	2.53	-0.09	-4%
Total	11.69	11.44	0.25	2%
	N_2O from Manure Storage			
Milking Cows	10.43	7.87	2.56	25%
Dry Cows	4.79	4.43	0.36	8%
Heifers	7.38	7.6	-0.22	-3%
Total	22.6	19.9	2.7	12%
	CO_2e from Feed Production			
Milking Cows	473.79	131.5	342.29	72%
Dry Cows	0	0	0	0%
Heifers	77.24	79.37	-2.13	-3%
Total	551.03	210.86	340.17	62%
	Totals			
Milking Cows	624.62	286.9	337.72	54%
Dry Cows	74.15	67.8	6.35	9%
Heifers	162.36	166.93	-4.57	-3%
Total	861.12	521.63	339.49	39%

Milk production at Elliotville Farms due to the production challenges experienced during 2009, were exceptionally low, averaging 14 kg/cow/day throughout the calendar year. This is reflected in the relatively high CO_2e emissions per kg fat corrected milk for the farm compared to the other farms evaluated. The emissions profile on a kg CO_2e per kg fat corrected milk are outlined in Table 2.

Table 2. Baseline and Project Case GHG Emissions Profile and Reduction Summary (Kg CO_2e / Kg FCM)

Kg CO_2e per Kg Fat Collected Milk				
	Baseline	**Project Case 1**	**GHG Reduction**	**% Reduction**
CH_4 from Enteric Fermentation				
Milking Cows	0.57	0.6	-0.03	-5%
Dry Cows	0.28	0.26	0.02	7%
Heifers	0.32	0.33	-0.01	-3%
Total	1.18	1.2	-0.02	-2%
CH_4 from Manure Management				
Milking Cows	0.03	0.03	0	0%
Dry Cows	0.01	0.01	0	0%
Heifers	0.01	0.01	0	0%
Total	0.05	0.05	0	0%
N_2O from Manure Storage				
Milking Cows	0.04	0.03	0.01	25%
Dry Cows	0.02	0.02	0	0%
Heifers	0.03	0.03	0	0%
Total	0.1	0.09	0.01	10%
CO_2e from Feed Production				
Milking Cows	2.03	0.56	1.47	72%
Dry Cows	0	0	0	0%
Heifers	0.33	0.34	-0.01	-3%
Total	2.36	0.9	1.46	62%
Totals				
Milking Cows	2.68	1.23	1.45	54%
Dry Cows	0.32	0.29	0.03	9%
Heifers	0.7	0.72	-0.02	-3%
Total	3.69	2.23	1.46	40%

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of $15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

GHG Project Case

Maintaining exceptionally high quality summer pastures as the primary dry matter production system at Elliotville farms has the potential to produce over 300-tonnes of carbon offsets annually. The potential revenue generation for the project case is outlined in Table 3. Note that this analysis and project concept cannot be supported by the Dairy GHG Quantification Protocol, which does not account for pasture quality, but rather assigns a high emissions value to all pasture based management systems. Additional study of the dynamics of enteric fermentation and energy inputs for intensively managed rotational grazing systems will be necessary in order to capitalize on the potential for maintaining high rates of milk and meat production on Maritime pastures, while reducing the net system GHG emissions.

Table 3. Project Case: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			$ Tonne CO_2e			
Baseline	Project Case	Reduction	$15	$25	$50	$100
861.12	521.63	339.49	$5,092.35	$8,487.25	$16,974.50	$33,949.00

Recommendations

1. Increase the quality of haylage and hay produced on the farm by adopting an aggressive 3-cut forage management system.

2. Continue to intensify the farms manure management system by applying manure to cropland following each forage harvest.

3. Increase milk production by reduced the breeding interval for the lactation herd.

4. Intensify rotational grazing system management to allow for daily pasture allocation to the lactation herd.

5. Conduct an energy audit to determine how electrical energy use on the farm can be reduced with upgraded equipment and energy management systems

6. Conduct a lighting audit and replace the existing lactation barn lighting system to provide optimal lighting intensity, which is likely to increase milk production and improve breeding success.

7. Consider installing a solar hot water heating system to reduce electricity consumption in the milk parlour.

8. Beef Sector Case Studies

RA Farms

RA Farms is a 1,200-head capacity background and finishing beef feedlot located in Cookville, New Brunswick. Cattle are raised on a ration of haylage, corn silage, brewers grain and ground barley or corn, depending on availability and market conditions. Annual and perennial forage crops are established in a zero-till cropping system. Manure is collected weekly and stored in a solid. Manure is applied to cropland periodically throughout the year, depending on weather conditions and forage harvest scheduling.

Dry matter intake assumptions for individual animals are averaged over the feedlot term and are summarized in Table 1.

Table 1. RA Farms Backgrounding Cattle Dry Matter Intake Detail

Average Animal Weight (kg)	364
Dry Matter Intake (% of Body Weight)	2.7%
Dry Matter Intake (kg/animal/day)	9.8

GHG Baseline Case

The baseline case for RA Farms was assumed to be the 2009 calendar production year. Through feed testing it was determined that the forage component of the total mixed ration was only of medium quality which limited the cattle rate of gain. Tables 2 and 3 provide detail on 2009 individual ration component quality and total mixed ration quality, respectively.

Table 2. RA Farms Ration Component Feed Test Results

Sample	**ADF**	**NDF**	**Crude Protein**	**TDN**
Haylage	44%	68%	10%	48%
Corn Silage	36%	61%	8%	63%
Brewers Grain	29%	63%	21%	

Table 3. RA Farms Total Mixed Ration Feed Test Results

	ADF	NDF	Crude Protein
August 2009	42%	63%	14%
December 2009	30%	52%	11%
Average	36%	57%	12%

Research data on forage quality and backgrounding cattle gains completed at the University of Manitoba, Department of Animal Science, is presented in Table 4. This research shows the importance of forage quality on the maintenance of acceptable rates of average daily gain (ADG).

Table 4. Feeder Cattle Average Daily Gain at Various Forage Ration Qualities

	Background Ration Forage Quality			
ADF	42.5%	34.3%	34.6%	34.0%
NDF	51.9%	46.2%	45.5%	40.7%
	Average Daily Gain (kg/animal/day)			
Period 1	0.73	0.91	1.47	1.05
Period 2	0.33	1.00	1.50	1.27
Period 3	0.15	0.75	0.67	0.84
Period 4	0.40	1.36	1.40	0.62
Average	0.40	1.01	1.26	0.95
Source: http://www.gov.mb.ca/agriculture/research/ardi/projects/pdf/99-277.pdf				

Total weight gain for background animals before they enter the finishing phase was 273-kg. With an average daily gain for the herd of 0.91 kg/animal/day, animals were assumed to remain in the backgrounding system for a total of 200-days to reach the target weight of 455-kg.

GHG Project Case

The Project Case assumed that RA Farms, by adopting a more aggressive forage harvesting schedule to make higher quality stored feed, would increase the rate of animal ADG by 25%. The animal performance assumptions for the baseline and project cases are outlined in Table 5.

Table 5. Animal Performance Assumptions for Baseline and Project Case 1

Baseline Case		Project Case	
Weight In (kg)	273	Weight In (kg)	273
Weight Out (kg)	455	Weight Out (kg)	455
Total Gain (kg)	182	Total Gain (kg)	182
Gain/Day (kg)	0.91	Gain/Day (kg)	1.14
Days on Feed	**200**	Days on Feed	**160**

By increasing the ADG from 0.91 kg/head/day in the baseline case to 1.14 kg/head/day in the project case, animals would exit the feedlot at target weight within 160-days, as opposed to the 200-days estimated for the 2009 baseline case. Reducing the number of days on feed results in fewer herd GHG emissions from enteric fermentation methane as well as manure management methane and nitrous oxide.

GHG Analysis Summary

GHG Project Case

GHG profiles for the RA Farms baseline and project cases are outlined in Table 6.

By increasing the quality of the forage component in total mixed ration mixes offered at RA Farms, the increase in cattle average daily gain and reduction in cattle days on feed will decrease the farms GHG emissions output by 333.43-tonnes CO_2e for one lot fill of 1,200-cattle. This reduction is equal to a 20% reduction in the farms net GHG emissions output.

Based on a 160-day backgrounding period, the farm would theoretically be able to turn the lot over two times per year, therefore the total project emissions reductions would be 666.86-tonnes CO_2e annually if forage quality were maintained.

Table 6. Baseline and Project Case GHG Emissions Profiles and Reduction Estimates per Lot Fill

	Tonnes CO_2e			
	Baseline	Project	Reduction	% of Baseline
Herd Enteric CH_4 Emissions	1064.39	851.51	212.88	20%
Manure CH_4 Emissions	40.42	28.08	12.34	20%
Direct N_2O Emissions	375.08	300.06	75.02	20%
Manure Storage N_2O Emissions	105.02	84.02	21.00	20%
Indirect Volatilization N_2O Emissions	37.51	30.01	7.50	20%
Indirect Leaching N_2O Emissions	23.44	18.75	4.69	20%
Total	1645.86	1312.43	333.43	20%

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of $15 Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

Project Case

The value of implementing a reduced days on feed project at RA Farms is outlined in Tables 7 and 8. Table 7 outlines the carbon offset value that could be developed for each lot fill and Table 8 outlines the annual value based on the assumption that the feedlot would be turned twice annually.

Table 7. Carbon Offset Value per Feedlot Fill Assuming Escalating Offset Value

Tonnes CO_2e			**$ Tonne CO_2e**			
Baseline	Project	Reduction	$15	$25	$50	$100
1,645.86	1,312.43	333.43	$5,001.47	$8,335.78	$16,671.55	$33,343.10

Table 8. Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			**$ Tonne CO_2e**			
Baseline	Project	Reduction	$15	$25	$50	$100
3,291.72	2,624.86	666.86	$10,002.93	$16,671.55	$33,343.10	$66,686.21

Recommendations

1. Enlist the support of a ruminant livestock nutritionist in balancing rations on a regular basis (monthly) to maximize cattle weight gain throughout the herd lifecycle.

2. Sample and test individual ration components and total mixed ration on a regular basis to track changes in individual component and overall TMR quality.

3. Target late-May/early June for the first forage harvest event of the year and increase the frequency of forage harvest to include 3-cuts per year. Early cutting has been shown to maximize forage quality and dry matter digestibility, as well as the crude protein content of the forage.

4. Apply manure to perennial cropland following each harvest to minimize the loss of valuable manure nutrients during storage and maximize the agronomic use of manure nutrients and forage nutrient density.

Whalen Cattle Farms

The Whalen Cattle Farm is a 280-head feedlot operation located in Avondale, Prince Edward Island. Feedlot cattle are brought onto the farm at roughly 227-kg and exit at a finish weight of 614-kg. The ration is composed of mixed grass/legume haylage, corn silage, high moisture corn, rolled barley and potato culls based on market conditions and the availability of small grains and potato culls.

Cattle are offered 3-TMR (Total Mixed Ration) mixes every three days. Dry matter intake assumptions for Whalen Cattle Farm are outlined in Table 1 and were estimated based on feed test results and TMR ration formulation detail acquired from the farm.

Table 1. Whalen Cattle Farm Cattle Dry Matter Intake Detail

Average Animal Weight (kg)	420
Dry Matter Intake (% of Body Weight)	1.9%
Dry Matter Intake (kg/animal/day)	8.0

GHG Baseline Case

The baseline case for Whalen Cattle Farm was assumed to be the 2009 calendar production year. Through feed testing it was determined that the haylage component of the total mixed ration was only of medium quality and had a relatively low crude protein content of 10.38% Corn silage was determined to be of high quality and had a crude protein content of 7.82%.

The protein content of the total mixed ration was determined to be 6.24% through feed bunk sampling and analysis.   It was assumed that due to the TMR protein content being below a level needed to maintain efficient weight gain for young cattle, the cattle rate of gain was not being maintained at a desired level.   Table 2 provides detail on 2009 individual ration component quality and total mixed ration quality.

Table 2. Whalen Cattle Farm Ration Component and Total Mixed Ration Feed Test Results

Component	ADF	NDF	Crude Protein	TDN
Haylage	40%	58%	10%	54.7%
Corn Silage	23%	39%	8%	71.6%
Total Mixed Ration	21%	27%	6%	72.4%

Research data on forage quality and backgrounding cattle gains completed at the University of Manitoba, Department of Animal Science, is presented in Table 3. This research shows the importance of forage quality on the maintenance of acceptable rates of average daily gain (ADG).

Table 3. Feeder Cattle Average Daily Gain at Various Forage Ration Qualities

Background Ration Forage Quality				
ADF	42.5%	34.3%	34.6%	34.0%
NDF	51.9%	46.2%	45.5%	40.7%
Average Daily Gain (kg/animal/day)				
Period 1	0.73	0.91	1.47	1.05
Period 2	0.33	1.00	1.50	1.27
Period 3	0.15	0.75	0.67	0.84
Period 4	0.40	1.36	1.40	0.62
Average	0.40	1.01	1.26	0.95

Source: http://www.gov.mb.ca/agriculture/research/ardi/projects/pdf/99-277.pdf

GHG Project Case

The theoretical Project Case assumed that Whalen Cattle Farm, by adopting a more aggressive forage harvesting schedule in order to make higher quality haylage with a more desirable crude protein content, would increase the rate of animal ADG (Average Daily Gain) from 0.57 to 1.14 kg/head/day (1.25 to 2.5 lb/head/day). While this represents a very substantial increase in ADG, consultation with industry experts validated the GHG Project Case, given the exceptionally low crude protein content of the fall 2009 TMR sample.

Animal performance assumptions for the baseline and project cases are outlined in Table 4. By increasing the ADG from 0.57 kg/head/day in the baseline case to 1.14 kg/head/day in the project case, animals would exit the feedlot at target weight within 340-days, as opposed to the 680-days estimated for the 2009 baseline case. Reducing the number of days on feed results in fewer herd GHG emissions from enteric fermentation (methane) and manure management (methane and nitrous oxide).

Table 4. Animal Performance Assumptions for Baseline and Project Case

Baseline Case		***Project Case***	
Weight In (kg)	227	Weight In (kg)	227
Weight Out (kg)	614	Weight Out (kg)	614
Total Gain (kg)	386	Total Gain (kg)	386
Gain/Day (kg)	0.57	Gain/Day (kg)	1.14
Days on Feed	**680**	Days on Feed	**340**

GHG Analysis Summary

GHG Project Case

GHG profiles for Whalen Cattle Farm baseline and project cases are outlined in Tables 5 and 6. Table 5 presents GHG emission reductions on a total emissions output basis, Table 6 presents data based on the expected GHG reductions per head of cattle produced.

By increasing forage ration component feed quality at Whalen Cattle Farms, the subsequent increase in cattle average daily gain and reduction in cattle days on feed will decrease the farms GHG emissions output by 453.49-tonnes CO_2e per cattle cycle. This theoretical reduction is equal to a 50% reduction in the farms net GHG emissions output.

Based on a 340-day backgrounding and finishing period in the project case, the farm would theoretically be able to turn the lot over once per year, therefore the total project emissions reductions would be 453.49-tonnes CO_2e annually if improved forage quality and ration balancing to correct protein deficiencies were maintained throughout the year.

Table 5. Baseline and Project Case GHG Emission Profiles

	Tonnes CO_2e			
	Baseline	Project	Reduction	% Baseline
Herd Enteric CH_4 Emissions	689.32	344.66	344.66	50%
Manure CH_4 Emissions	20.18	10.09	10.09	50%
Direct N_2O Emissions	136.91	68.46	68.46	50%
Manure Storage N_2O Emissions	38.34	19.17	19.17	50%
Indirect Volatilization N_2O Emissions	13.69	6.85	6.85	50%
Indirect Leaching N_2O Emissions	8.56	4.28	4.28	50%
Total	906.99	453.49	453.49	50%

Table 6. Baseline and Project Case GHG Emission Profiles

	Tonnes CO_2e Head^{-1}			
	Baseline	Project	Reduction	% Baseline
Herd Enteric CH_4 Emissions	2.46	1.23	1.23	50%
Manure CH_4 Emissions	0.07	0.04	0.04	50%
Direct N_2O Emissions	0.49	0.24	0.24	50%
Manure Storage N_2O Emissions	0.14	0.07	0.07	50%
Indirect Volatilization N_2O Emissions	0.05	0.02	0.02	50%
Indirect Leaching N_2O Emissions	0.03	0.02	0.02	50%
Total	3.24	1.62	1.62	50%

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of \$15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

GHG Project Case

The total carbon offset revenue that could potentially be created through a reduced days on feed project at Whalen Cattle Farm is outlined in Table 6.

Table 6. Carbon Offset Value per Feedlot Fill Assuming Escalating Offset Value

Tonnes CO_2e			$ Tonne CO_2e			
Baseline	Project	Reduction	$15	$25	$50	$100
906.99	453.49	453.49	$6,802.42	$11,337.37	$22,674.75	$45,349.49

When calculated on a revenue per head of finished cattle basis, Table 7 outlines the carbon revenue that could be expected to be generated. This analysis does not include the reduction in production costs associated with an increased rate of gain through improved forage quality and fewer feeding days required for animals to reach market weight.

Table 7. Carbon Offset Value per Head per Cycle Assuming Escalating Offset Value

	$ Tonne CO_2e			
	$15	$25	$50	$100
Animals Cycle^{-1}	**Revenue Head^{-1}**			
280	$24.29	$40.49	$80.98	$161.96

Recommendations

1. Enlist the support of a ruminant livestock nutritionist in balancing rations on a regular basis (monthly) to maximize cattle weight gain throughout the herd lifecycle.

2. Sample and test individual ration components and total mixed ration on a regular basis to track changes in individual component and overall TMR quality.

3. Target late-May/early June for the first forage harvest event of the year and increase the frequency of forage harvest to include 3-cuts per year. Early cutting has been shown to maximize forage quality and dry matter digestibility, as well as the crude protein content of the forage.

4. Apply manure to perennial cropland following each harvest to minimize the loss of valuable manure nutrients during storage and maximize the agronomic use of manure nutrients and forage nutrient density.

9. Pork Sector Case Studies

van de Brand Hog Farm

The van de Brand hog farm is a 350-sow farrow-to-finish operation located in Salisbury, New Brunswick. The farm has recently undergone significant alterations to the feeding system with the addition of liquid feeding and high moisture corn storage infrastructure. The result being a significant increase in production efficiency and feed conversion rate in the starter, grower and finishing hog classes. Manure is frequently applied, 3-4 times per year to annual corn production land and neighbouring perennial forage production land. The farm is often engaged in environmental and public outreach projects.

GHG Baseline Case

The van de Brand hog farms case study offered a unique opportunity to assess how advanced feeding systems and increased herd productivity can affect the farms GHG emissions profile. The baseline case was the 2005 production year, where hogs were fed on dry mash feed prior to the installation of liquid feeding infrastructure. Manure was applied to local cropland in May, July and October.

GHG Project Case 1

Project Case 1 was assumed to be the 2007 production year, which was the 2nd year of operations for the farm following the installation of the liquid feeding system. The base energy ingredients in the dry mash feeding baseline scenario were barley and corn grain, but in the project case high moisture corn represented a much greater proportion of the ration. In addition to increased herd productivity on the liquid feeding system, the reduced inclusion rate of barley grain reduced the volatile solids loading to manure storage. The manure application rate schedule in Project Case 1 was identical to the baseline case manure application schedule.

GHG Project Case 2

Project Case 2 was a theoretical increase in the amount and frequency of manure removal from storage and application to cropland. Project Case 2 assumed that the manure storage would be 75% emptied in June in addition to the baseline case removals in May, July and October. This was considered a viable option as manure is currently applied to local dairy forage production land which could receive an additional manure application in June following first cut forage harvest.

GHG Analysis Summary

GHG Project Case 1

Table 1 outlines the baseline case, project case 1 and comparative GHG emissions decrease between the two cases.

Table 1. Baseline and Project Case 1 GHG Emissions Profiles.

	Baseline	Project	Reduction	% of Baseline
Methane Emissions From Manure Storage (g/kg pig raised)				
Dry Sows and Boars	292.71	386.72	-94.01	-32%
Finishers	28.12	24.15	3.97	14%
Growers	25.31	22.55	2.76	11%
Nursing Sows	25.27	27.21	-1.94	-8%
Starters	19.02	16.64	2.38	13%
Methane Carbon Dioxide Equivalent Emissions From Manure Storage (g/kg pig raised)				
Dry Sows and Boars	6146.81	8121.13	-1974.32	-32%
Finishers	590.48	507.07	83.41	14%
Growers	531.43	473.53	57.9	11%
Nursing Sows	530.72	571.42	-40.7	-8%
Starters	399.36	349.51	49.85	12%
Nitrous Oxide Emissions From Manure Spreading (g/kg pig raised)				
Dry Sows and Boars	43.299	31.62	11.679	27%
Finishers	2.517	2.107	0.41	16%
Growers	2.762	2.07	0.692	25%
Nursing Sows	3.647	2.983	0.664	18%
Starters	1.944	1.343	0.601	31%
Nitrous Oxide Carbon Dioxide Equivalent Emissions From Manure Spreading (g/kg pig raised)				
Dry Sows and Boars	13422.6	9802.222	3620.328	27%
Finishers	780.273	653.201	127.072	16%
Growers	856.357	641.842	214.515	25%
Nursing Sows	1130.64	924.863	205.775	18%
Starters	602.693	416.28	186.413	31%
Total Project Carbon Dioxide Equivalent Emissions (g/kg pig raised)				
Dry Sows and Boars	19569.4	17923.35	1646.01	8%
Finishers	1370.76	1160.275	210.48	15%
Growers	1387.79	1115.371	272.419	20%
Nursing Sows	1661.36	1496.285	165.078	10%
Starters	1002.05	765.793	236.26	24%

Table 2 outlines the monthly methane emissions profile for the baseline and project 1 scenarios.

Table 2. Baseline and Project Case 1 Monthly Methane Emissions Profile

Monthly Methane Emissions From Manure Storage (kg)				
	Baseline	Project	Reduction	% of Baseline
January	1,035.8	883.3	152.5	15%
February	1221	1,039.4	181.6	15%
March	1,393.4	1,184.7	208.7	15%
April	1,939.5	1,647.6	291.9	15%
May	3,343.2	3,416.4	-73.2	-2%
June	4630	4,554.2	75.8	2%
July	6015	5,725.9	289.1	5%
August	4,482.2	4,128.9	353.3	8%
September	2,684.8	2,410.7	274.1	10%
October	1,660.1	1,465.9	194.2	12%
November	679.2	589.8	89.4	13%
December	862.3	742.8	119.5	14%

The total GHG emissions for the baseline and project case 1 scenarios are outlined in Table 3. The move to a liquid feeding system, and the resulting increase in herd productivity and reduction in volatile solids loading to manure storage resulted in net farm GHG emissions of roughly 270-tonnes CO_2e, representing a 17% decrease in net farm GHG reductions.

Table 3. Net Project Case 1 and Baseline Case GHG Emissions Profile

Total Project Carbon Dioxide Equivalent Emissions (Mg/year)			
Baseline	Project	Reduction	% of Baseline
1,614.6	1,345.0	269.6	17%

GHG Project Case 2

Table 4 outlines the baseline case, project case 2 and comparative GHG emissions decrease between the two cases.

Table 4. Baseline and Project Case 2 GHG Emissions Profiles.

	Baseline	Project	Reduction	% of Baseline
Methane Emissions From Manure Storage (g/kg pig raised)				
Dry Sows and Boars	292.71	291	1.71	1%
Finishers	28.12	18.17	9.95	35%
Growers	25.31	16.97	8.34	33%
Nursing Sows	25.27	20.48	4.79	19%
Starters	19.02	12.52	6.5	34%
Methane Carbon Dioxide Equivalent Emissions From Manure Storage (g/kg pig raised)				
Dry Sows and Boars	6146.81	6111.08	35.73	1%
Finishers	590.48	381.57	208.91	35%
Growers	531.43	356.33	175.1	33%
Nursing Sows	530.72	429.99	100.73	19%
Starters	399.36	263.01	136.35	34%
Nitrous Oxide Emissions From Manure Spreading (g/kg pig raised)				
Dry Sows and Boars	43.299	24.07	19.229	44%
Finishers	2.517	1.604	0.913	36%
Growers	2.762	1.576	1.186	43%
Nursing Sows	3.647	2.271	1.376	38%
Starters	1.944	1.022	0.922	47%
Nitrous Oxide Carbon Dioxide Equivalent Emissions From Manure Spreading (g/kg pig raised)				
Dry Sows and Boars	13422.55	7462.97	5959.58	44%
Finishers	780.273	497.32	282.953	36%
Growers	856.357	488.672	367.685	43%
Nursing Sows	1130.638	704.152	426.486	38%
Starters	602.693	316.938	285.755	47%
Total Project Carbon Dioxide Equivalent Emissions (g/kg pig raised)				
Dry Sows and Boars	19569.36	13574.05	5995.31	31%
Finishers	1370.755	878.889	491.866	36%
Growers	1387.79	844.999	542.791	39%
Nursing Sows	1661.363	1134.14	527.223	32%
Starters	1002.053	579.944	422.109	42%

Table 5 outlines the monthly methane emissions profile for the baseline and project 2 scenarios.

Table 5. Baseline and Project Case 2 Monthly Methane Emissions Profile

Monthly Methane Emissions From Manure Storage (kg)				
	Baseline	Project	Reduction	% of Baseline
January	1,035.8	834.2	201.6	19%
February	1,221.0	993.8	227.2	19%
March	1,393.4	1,142.2	251.2	18%
April	1,939.5	1,598.2	341.3	18%
May	3,343.2	3,329.7	13.5	0%
June	4,630.0	4,460.2	169.8	4%
July	6,015.0	2,283.9	3,731.1	62%
August	4,482.2	2,306.2	2,176.0	49%
September	2,684.8	1,655.4	1,029.4	38%
October	1,660.1	1,131.6	528.5	32%
November	679.2	506.9	172.3	25%
December	862.3	669.1	193.2	22%

The total GHG emissions for the baseline and project case 2 scenarios are outlined in Table 6. In addition to the herd productivity increases detailed in project case 1, project case 2 assumed that the farm adopt a more aggressive manure application schedule by including a 75% manure storage emptying event in June of each year. Project 2 scenario analysis resulted in net farm GHG emissions of roughly 596-tonnes CO_2e, representing a 37% increase in net farm GHG reductions.

Table 6. Net Project Case 2 and Baseline Case GHG Emissions Profile

Total Project Carbon Dioxide Equivalent Emissions (Tonnes CO_2e $Year^{-1}$)			
Baseline	Project	Reduction	% of Baseline
1,614.6	1,018.9	595.7	37%

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of \$15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

GHG Project Case 1

The annual carbon offset value for the increased herd productivity project case 1 at van de Brand Hog Farms is outlined in Table 7.

Table 7. Project Case 1: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			**\$ Tonne CO_2e**			
Baseline	Project	Reduction	\$15	\$25	\$50	\$100
1,614.6	1,345.0	269.6	\$4,044.00	\$6,740.00	\$13,480.00	\$26,960.00

GHG Project Case 2

The annual carbon offset value for the increased herd productivity and advanced manure management scheduling project case 2 at van de Brand Hog Farms is outlined in Table 8.

Table 8. Project Case 2: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			**\$ Tonne CO_2e**			
Baseline	Project	Reduction	\$15	\$25	\$50	\$100
1,614.6	1,018.9	595.7	\$8,935.50	\$14,892.50	\$29,785.00	\$59,570.00

Recommendations

1. Continue to advance the herd productivity through feeding system refinements and attention to herd management detail

2. Continue to intensify the manure management schedule to minimize the duration of manure storage during the hot summer months, and to maximize the agronomic value of manure nutrients.

Whalen Hog Farm

Whalen Hog Farms is a 1000-head hog finishing operation located in Avondale, Prince Edward Island. Starter, grower and finisher hog groups are offered a liquid feed ration primarily composed of high moisture corn, soybean meal, minerals and supplements. Rations are professionally balanced with synthetic amino acids to minimize feed costs and reduce nitrogen output to manure storage. Manure is applied to cropland in September of each year, when the manure storage is emptied 100%.

GHG Baseline Case

The Whalen Hog Farm baseline case was the 2009 production year. Actual ration composition and animal inventories were used to populate the GHG assessment calculator, so simulation results are considered to be very accurate. Liquid manure was 100% applied in September to cropland that had been seeded to barley in May 2009, and was recently harvested.

GHG Project Case

The project case for Whalen Hog Farms was a theoretical alteration of the current single manure application event in September to a 3-times per year manure application schedule where the manure storage would be 100% emptied in May, July and September of each year. This is a realistic project concept as manure can be applied to annual cropland prior to seeding in spring and following harvest in fall, and the July application event can be targeted towards the farms perennial forage production land.

GHG Analysis Summary

GHG Project Case

The baseline and project case GHG emission profiles for Whalen Hog Farms are outlined in Table 1. For all indexes, the move to a more aggressive manure application schedule reduced the farms output of methane and nitrous oxide GHG emissions.

Methane emissions were reduced by limiting the exposure of manure carbon constituents to an active population of methanogenic bacteria in manure storage during the hot summer months. This phenomenon has been widely proved and represents a realistic GHG reduction project option. Similarly, nitrous oxide emissions are reduced by applying manure nitrogen to cropland throughout the growing season, avoiding nitrogen loading during the fall as in the baseline case, and subsequent late fall and early spring nitrous oxide emissions form saturated soils. A more aggressive manure application schedule is also an effective agronomic measure to better utilize manure nitrogen.

Table 1. Baseline and Project Case GHG Emissions Profiles.

	Baseline	Project	Reduction	% of Baseline
Methane Emissions From Manure Storage (g/kg pig raised)				
Finishers	31.78	15.72	16.06	51%
Growers	21.01	10.4	10.61	50%
Starters	27.44	13.58	13.86	51%
Methane Carbon Dioxide Equivalent Emissions From Manure Storage (g/kg pig raised)				
Finishers	667.32	330.18	337.14	51%
Growers	441.28	218.34	222.94	51%
Starters	576.31	285.15	291.16	51%
Nitrous Oxide Emissions From Manure Spreading (g/kg pig raised)				
Finishers	0.816	0.747	0.069	8%
Growers	0.385	0.353	0.032	8%
Starters	0.793	0.726	0.067	8%
Nitrous Oxide Carbon Dioxide Equivalent Emissions From Manure Spreading (g/kg pig raised)				
Finishers	252.975	231.602	21.373	8%
Growers	119.408	109.319	10.089	8%
Starters	245.84	225.069	20.771	8%
Total Project Carbon Dioxide Equivalent Emissions (g/kg pig raised)				
Finishers	920.295	561.779	358.516	39%
Growers	560.692	327.658	233.034	42%
Starters	822.146	510.214	311.932	38%

The baseline and project case methane emissions profiles for Whalen Hog Farms are outlined in Table 2. Note that the more aggressive project case manure application schedule resulted in significant reductions in methane output in June through September.

Table 2. Baseline and Project Case Monthly Methane Emissions Profile

Monthly Methane Emissions From Manure Storage (kg)				
	Baseline	Project	Reduction	% of Baseline
January	205.8	205.8	0	0%
February	250.1	250.1	0	0%
March	291.3	291.3	0	0%
April	399.4	399.4	0	0%
May	825.4	825.4	0	0%
June	1,439.6	233.3	1,206.3	84%
July	1,798.3	567.3	1,231.0	68%
August	1,362.9	314.8	1,048.1	77%
September	775.6	339.8	435.8	56%
October	121.9	121.9	0	0%
November	133.1	133.1	0	0%
December	158.2	158.2	0	0%

The net GHG emissions reductions that could be achieved by Whalen Hog Farms with a move to an aggressive 3-time per year manure application schedule are outlined in Table 3. The farms net emissions would be reduced by 39%, or 87.4-tonnes CO_2e annually.

Table 3. Net Project and Baseline Case GHG Emissions Profile

Total Project Carbon Dioxide Equivalent Emissions (Tonnes CO_2e $Year^{-1}$)			
Baseline	Project	Reduction	% of Baseline
222.3	134.9	87.4	39%

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of $15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

GHG Project Case

The annual carbon offset value for the theoretical Whalen Hog Farms manure application GHG reduction project is outlined in Table 4.

Table 4. Project Case: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			$ Tonne CO_2e			
Baseline	Project	Reduction	$15	$25	$50	$100
222.3	134.9	87.4	$1,311.00	$2,185.00	$4,370.00	$8,740.00

Recommendations

1. Increase the frequency of manure application throughout the growing season to minimize the duration of manure storage during the hot summer months.

2. Whenever possible, apply manure early in the growing season to maximize the effective use of manure nitrogen throughout the active growing season. This measure will minimize nitrogen losses due to leaching and reduce nitrous oxide emissions compared to a 100% fall manure application schedule.

Beck Hog Farm

Terry and Justin Beck operate a 700-sow farrow-to-wean hog operation in Kingston, Nova Scotia. Early weaned piglets are marketed when they reach a body weight of roughly 6.2-kg. Farm output and productivity have increased over the past number of years showing a steady increase in the number of farrowings per month and pigs weaned per sow per year. Manure is applied to local annual cropland and perennial hay land 3-times per year.

GHG Baseline Case

The 2008 production year was considered the Beck Hog Farm baseline case. A total of 693-sows were reported in the herd in 2008, with a farrowing rate of 113-sows per month and 23.3-pigs produced per sow per year. An aggressive manure application schedule was maintained throughout 2008 with manure applied to a local landbase in May, July and September.

GHG Project Case

The 2009 production year was considered the project case for Beck Hog Farm. The major variance between the baseline and project years was the overall productivity of the sow herd. The 2009 project case year was a slightly more productive than the 2008 baseline year, with a farrowing rate of 139-sows per month and 24.7-pigs produced per sow per year. The manure application schedule was identical to the 2008 baseline year.

The analysis was based on actual on-farm production and feed use data however, and is therefore an accurate depiction of the farms actual baseline and project case emissions profiles.

GHG Analysis Summary

GHG Project Case

The significant increase in the number of farrowings per month in the project year increased the amount of lactation sow ration consumed over the production year, which contained roughly 17% crude protein, versus 15% in the dry sow ration. The lactation ration alternatively, had a slightly lower volatile solids content than the dry sow ration. Crude protein and volatile solids contents affect the output of nitrous oxide from cropland soils and liquid manure storages, respectively.

The farms baseline and project case GHG profiles are outlined in detail in Table 1. The project case shows an increase in GHG emissions for both manure storage methane and nitrous oxide measures. This is due to the changing dynamics at the farm from 2008 to 2009 with a major increase in the number of farrowings per month in the project year and the increased consumption of higher crude protein lactation ration.

Despite the increased emissions in the project case over the baseline year, based on GHG output on an individual animal basis, the net emissions for the project year were actually 6.5-tonnes CO_2e less than the baseline year. This analysis represents well the complexities of GHG auditing in the hog sector, especially given the rapid evolution that many maritime hog farms have undergone recently due to significant cash flow challenges over the last decade.

Table 1. Baseline and Project Case GHG Emissions Profiles.

	Baseline	Project	Reduction	% of Baseline
Methane Emissions From Manure Storage (g/kg pig raised)				
Dry Sows and Boars	591.92	625.06	-33.14	-6%
Nursing Sows	5.69	8.61	-2.92	-51%
Methane Carbon Dioxide Equivalent Emissions From Manure Storage (g/kg pig raised)				
Dry Sows and Boars	12430.25	13126.27	-696.02	-6%
Nursing Sows	119.59	180.85	-61.26	-51%
Nitrous Oxide Emissions From Manure Spreading (g/kg pig raised)				
Dry Sows and Boars	66.867	70.668	-3.801	-6%
Nursing Sows	-0.185	0.238	-0.423	-229%
Nitrous Oxide Carbon Dioxide Equivalent Emissions From Manure Spreading (g/kg pig raised)				
Dry Sows and Boars	20728.88	21907.18	-1178.3	-6%
Nursing Sows	-57.389	73.783	-131.172	-229%
Total Project Carbon Dioxide Equivalent Emissions (g/kg pig raised)				
Dry Sows and Boars	33159.14	25033.45	8125.69	25%
Nursing Sows	62.197	254.636	-192.439	-309%

The monthly methane emissions from manure storage for the Beck Hog Farm project and baseline cases are outlined in Table 2. Note that methane emissions increased slightly in the project year, but represented a less than 1% increase.

Table 2. Baseline and Project Case Monthly Methane Emissions Profile

Monthly Methane Emissions From Manure Storage (kg)				
	Baseline	Project	Reduction	% of Baseline
January	226.4	226.8	-0.4	0%
February	274.5	274.9	-0.4	0%
March	319.2	319.7	-0.5	0%
April	533.4	534.1	-0.7	0%
May	1,023.3	1,024.8	-1.5	0%
June	950.6	951.9	-1.3	0%
July	1,267.1	1,268.9	-1.8	0%
August	714.8	715.8	-1	0%
September	521.6	522.3	-0.7	0%
October	152.4	152.37	0.03	0%
November	162.2	162.5	-0.3	0%
December	174.9	175.2	-0.3	0%

The farms net GHG emissions in the baseline and project cases are outlined in Table 3. Despite a slight increase in emissions on a pig produced basis, improved farm productivity in the 2009 project year over the 2008 baseline year resulted in a slight net reduction in emissions of 6.5-tonnes CO_2e in the project year.

Table 3. Net Project and Baseline Case GHG Emissions Profile

Total Project Carbon Dioxide Equivalent Emissions (Tonnes CO_2e $Year^{-1}$)			
Baseline	Project	Reduction	% of Baseline
300.1	293.6	6.5	2%

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of \$15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

GHG Project Case

The annual value of carbon offset created through increased production efficiencies at Beck Hog Farms is outlined in Table 4.

Table 4. Project Case: Annual Carbon Offset Value Assuming Escalating Offset Value

Tonnes CO_2e			**\$ Tonne CO_2e**			
Baseline	Project	Reduction	\$15	\$25	\$50	\$100
300.1	293.6	6.5	\$97.50	\$162.50	\$325.00	\$650.00

Further increases to farm productivity are currently being considered with a move to high moisture corn as the base energy component of the lactation and dry sow ration. Reassessing the farms GHG emissions profile following the installation of high moisture corn infrastructure will likely prove to increase the annual carbon offset revenue generation potential as has been identified in other hog sector GHG assessments. The Beck Hog Farm case demonstrated the importance of net farm GHG emissions reductions that can be achieved with small and continuous improvements in production efficiency.

Recommendations

1. Continue improvements in breeding efficiency to maximize the effective use of lactation ration, and minimizing the total offering of dry sow ration throughout the year.

2. Increase the proportion of high moisture grain corn in the dry sow and lactation rations. The lower volatile solids loading rate to manure storage for corn versus barley will reduce the manure storage system methane emissions

10. Energy Efficiency Case Studies

Energy Efficiency

The results of 25-energy audits performed on livestock and potato farms through energy efficiency pilot projects in New Brunswick (12), Nova Scotia (7) and Prince Edward Island (6) were analysed to determine the total estimated greenhouse gas emission reductions that could be achieved through energy efficiency measures.

GHG Baseline Case

For each case study farm, the baseline case was a preceding years worth of energy use data including electricity, heating oil and propane.

GHG Project Case

The project case for each farm assumed that all energy efficiency measures recommended through the audit were implemented. The project case does not include the adoption of small scale renewable electricity and heating systems such as solar hot water or biomass heating.

GHG Analysis Summary

In order to develop a comprehensive scope of potential GHG reductions that could be achieved through energy efficiency measures, the 2006 Census of Agriculture database was used to determine the total number of facilities, by sector, are operating currently in the Maritime region. Table 1 outlines the total number of farms reporting in 2006 by sector. A retraction rate of 12% since the 2006 Census year was used to estimate the number of farms currently operating in all sectors but pork production. It was estimated that the pork industry has retracted by at least 75% in the Maritime region.

Table 1. Estimated Maritime Farm Operators by Sector in 2006 & 2010

	2006	2006-2010 Retraction Rate	2010
Dairy cattle and milk production	788	12%	693
Beef cattle ranching and farming, including feedlots	1,645	12%	1,448
Hog and pig farming	172	75%	43
Chicken egg production	93	12%	82
Broiler and other meat-type chicken production	87	12%	77
Turkey production	13	12%	11
Poultry hatcheries	3	12%	3
Combination poultry and egg production	8	12%	7
Potato farming	585	12%	515
Total	**3,394**		**2,878**

The results of 25-comprehensive energy audits conducted throughout the Maritimes was used to estimate total energy savings available to maritime livestock and vegetable storage operators. These results were harvested from individual energy audit pilot projects completed for the New Brunswick Agriculture Alliance and Nova Scotia and Prince Edward Island Federations of Agriculture. Each of the provincial energy audit pilot projects included a number of potato warehouse assessments.

Although not part of the livestock community, the inclusion of these data increased the sample size of the dataset, increasing the accuracy of the analysis. Further, the relative simplicity of energy efficiency upgrades available to most vegetable warehouses (variable frequency drives on ventilation system controls) could provide a relatively simple bridge for the livestock industry to engage regional crop production sectors in a carbon offset project.

The results of the energy audits, by industry are outlined in Table 2. Average energy cost savings per farm was $5,611.56 and the average GHG reduction identified was 32.72-tonnes CO_2e per farm per year. Significant variability between farm types was identified for the total GHG reduction opportunity from energy efficiency measures, therefore, each sector is reported individually, allowing for more accurate assessment of the opportunities between and across sectors.

Table 2. Average Energy Savings and Greenhouse Gas Emission Reductions by Farm Type

		Annual Energy Savings			GHG Reduction
Industry	Annual Savings	Electricity (kWh)	Heating Oil (L)	Propane (L)	Tonnes CO_2e
Swine	$7,753.00	86,144	0	6,737	60.07
Poultry	$8,303.76	23,885	4,800	1,390	34.69
Dairy	$2,966.05	27,481	448	0	18.82
Potato	$3,423.44	27,399	0	0	17.28

The total energy efficiency carbon offset development opportunity for the Maritime livestock sector is outlined in Table 3. Sector specific GHG reductions and farm eligibility numbers were used in this analysis to increase the accuracy of the estimated carbon offset package that could be delivered to market.

Assuming 25% industry participation in an energy efficiency program, including the potato production sector, a carbon offset package of 7,690-tonnes CO_2e could be developed.

Table 3. Average Energy Savings and Greenhouse Gas Emission Reductions by Farm Type

		Participation Level (# Farms)			
Sector	Eligible Farms	25%	50%	75%	100%
Swine	43	11	22	32	43
Poultry	180	45	90	135	180
Dairy	693	173	347	520	693
Potato	515	129	257	386	515
		Potential Offset Package (Tonnes CO_2e)			
Swine		646	1,292	1,937	2,583
Poultry		1,557	3,114	4,671	6,228
Dairy		3,263	6,525	9,788	13,050
Potato		2,224	4,449	6,673	8,898
Total		**7,690**	**15,380**	**23,069**	**30,759**

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of \$15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

Table 4 outlines the total GHG reductions that could be achieved with varied industry participation levels, as well as the total value that can be extracted from the carbon marketplace.

Table 4. Project Case: Annual Carbon Offset Value Assuming Escalating Offset Value

		\$ Tonne CO_2e^{-1}			
Participation Level	Reduction (Tonnes CO_2e)	**\$15**	**\$25**	**\$50**	**\$100**
25%	7,690	\$115,347	\$192,245	\$384,490	\$768,980
50%	15,380	\$230,694	\$384,490	\$768,980	\$1,537,961
75%	23,069	\$346,041	\$576,735	\$1,153,471	\$2,306,941
100%	30,759	\$461,388	\$768,980	\$1,537,961	\$3,075,922

Recommendations

A host of energy efficiency incentives are available in New Brunswick, Nova Scotia and Prince Edward Island through respective Departments of Agriculture and Provincial Energy Efficiency Offices.

Wherever possible, farms should take part in energy audit programs to identify any farm specific opportunities to reduce electricity or fuel consumption. Programs vary by province, however, implementation incentives are available for upgrading electrical equipment, lighting systems, installing smart control systems, etc. Farms should be encouraged to make use of available incentives to reduce energy expenditures in the short term. As carbon marketing opportunities become available, any carbon offsets created through reduced energy use may be eligible for carbon offset payments in the future.

11. Renewable Energy System Case Studies

Wind Energy Generation

Bayview Poultry Farms is a 12,000-laying hen egg production farm and processing facility located in Masstown, Nova Scotia. As part of a commitment to more ecologically sensitive egg production, Bayview Poultry has installed three 1.5-kW Skystream wind turbines on site in a grid tied, net metering agreement with Nova Scotia Power Inc. The net metering program allows Bayview Poultry to offset a portion of its use of grid based electricity by injecting the wind produced electricity directly into the rid as it is produced. Accounting for power use and production is achieved by a specialized energy meter that turns forward when power is being drawn from the grid and in reverse when the wind turbines are operating. Bayview Poultry is not reimbursed for any power produced above and beyond what the farms consumes on an annual basis, thus, the net metering program allows for potential energy self-sufficiency, but not revenue generation from the sale of renewable electricity.

Bayview Poultry made a number of alterations to the farms energy systems in the 2006-2007 fiscal year. Significant lighting system changes were made to replace incandescent lighting with fluorescent lighting fixtures, in addition to the installation of three wind turbines. Having energy efficiency and renewable energy systems installed simultaneously makes the analysis of actual energy use reduction due to renewable wind energy production slightly more difficult. Fortunately, Bayview Poultry has recently installed a wireless wind turbine monitoring system that allows for direct measurement of electricity production from the wind turbines.

GHG Baseline and Project Cases

For the purposes of GHG emissions reductions analysis, the 2006-2007 production year, before the wind turbines were installed, was considered the baseline case. The project case was assumed to be the 2007-2008 fiscal year which included wind turbine operation.

GHG Analysis Summary

Table 1 outlines the farms baseline and project case annual electricity consumption. It is important to consider the total energy use profile of the farm for the purpose of analysing GHG reductions achieved due to wind energy generation, as energy efficiency and wind energy generation projects were implemented simultaneously.

Table 1. Baseline and Project Case Farm Electricity Consumption

	Meter 1 (kWh)	
Baseline	Project	**Reduction**
13,766	9,399	**4,367**
	Meter 2 (kWh)	
Baseline	Project	**Reduction**
41,668	28,119	**13,549**
	Farm Total (kWh)	
Baseline	Project	***Reduction***
55,434	37,518	***17,916***

Wind turbine electricity generation data was collected from Bayview Poultry's turbine monitoring system for an entire calendar year (May 25, 2009 – May 24, 2010). Table 2 contains the wind turbine performance data for one turbine only and for the complete wind turbine installation (3-units) at Bayview Poultry.

Table 2. Bayview Poultry Wind Turbine Performance

kWh $Year^{-1}$ $Turbine^{-1}$	Turbines Installed	Total Generation (kWh $Year^{-1}$)
2,872.22	3	8,616.66

Wind energy production can vary seasonally, depending on the wind regime in the installation area. As Bayview Poultry is located in an ideal wind production location adjacent to the Cobequid basin, turbine performance is fairly stable throughout the year, with December yielding the greatest wind output for the year. Table 3 outlines the total wind electricity generation per turbine in each calendar month.

Table 3. Monthly Wind Production Data (1-Turbine)

	kWh Month	% of Year Total
January	269.94	9%
February	248.49	9%
March	276.92	10%
April	225.27	8%
May	317.63	11%
June	199.42	7%
July	175.04	6%
August	180.52	6%
September	170.85	6%
October	212.11	7%
November	239.2	8%
December	356.83	12%
	2,872.22	100%

Table 4 outlines to total electricity consumption reduction achieved due to the installation of 3- 1.5-kW wind turbines at the Bayview Poultry site.

Table 4. Annual Wind Turbine Electricity Generation Offset Analysis

	Wind Energy Production	
Baseline Annual Electricity Consumption (kWh $Year^{-1}$)	kWh $Year^{-1}$	% of Annual Consumption
55,434	8,616.66	16%

GHG Analysis Summary

Based on the wind energy generation data collected in the 2009-2010 production year and the electricity grid GHG intensity factor for the Nova Scotia Power Inc generation fleet, the total carbon offsets generated through wind electricity generation at Bayview Poultry Farms is 7.93-tonnes CO_2e annually. Details are outlined in Table 5.

Table 5. Annual Wind Energy Production GHG Reduction Summary

		Annual GHG Reduction	
Wind Energy Production (kWh)	Grid Intensity (kg CO_2e kWh^{-1})	kg	Tonnes CO_2e
8,616.66	0.92	7,927.33	7.93

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of \$15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

GHG Project Case

The total carbon offset revenue generation potential for the small scale wind farm installed at Bayview Poultry farm is outlined in Table 6.

Table 6. Annual Carbon Offset Value from Wind Electricity Generation

	\$ Tonne CO_2e			
Tonnes CO_2e	\$15	\$25	\$50	\$100
7.93	\$118.91	\$198.18	\$396.37	\$792.73

Recommendations

1. Any future investment in renewable energy generation capacity at Jennings Poultry Farm should take into account the relative energy output from a single, large generator compared to a number of smaller generators. The total electricity offset for the wind generation project would likely be greater if the total investment in 3-turbines was combined and allocated to a single, large turbine.

Solar Hot Water Energy Generation

Source: http://www.eeca.govt.nz/node/301

Solar hot water heating systems offer an opportunity for Maritime livestock operations to offset the use of electricity, heating oil and/or propane for space and domestic hot water heating. Recent advancements in solar thermal system component and project design have increased the potential contribution of solar thermal energy to a farms overall energy use profile.

Numerous collector designs are available including flat plate collectors and evacuated tube systems. Freezing temperatures during the winter months in Maritime Canada dictate that freeze protection is a must for solar thermal hot water systems in the region. While warmer climates are able to pass water directly through the panel array, Maritime farms are required to use food grade glycol solution to transfer thermal energy from the panel array to a heat exchanger where energy is extracted and stored in a traditional hot water tank until it is required for use.

GHG Baseline Case

The electricity and heating oil use for hot water and space heating duties on three Maritime dairy farms was used to assess the potential GHG reductions that could be achieved with solar hot water heating. The baseline case was considered to be status quo operation of hot water heating systems using non-renewable electricity or heating oil.

GHG Project Case

In each case a 20-panel solar thermal hot water system was designed to provide roughly 50% of the farms total hot water requirement. In order to assess the potential for the whole of the Maritime livestock industry to reduce GHG emissions by adopting solar hot water systems, the results of the three case studies was extrapolated over a range of system sizes, from a simple 1-panel system to a large 20-panel array.

GHG Analysis Summary

Based on the modelled solar system energy output for the three Maritime dairy farm case studies, Table 1 outlines the total thermal energy output that would be expected from various panel array sizes. The annual carbon offset package that would be created by each array size have been calculated using provincial power grid GHG intensity values, owing to the differences in GHG reductions in each province.

Table 1. Energy Output and GHG Emissions Reductions for Various Solar Hot Water System Sizes

	System Production		Carbon Offset (Tonnes Year-1)			
Panels	kWh System Year^{-1}	kWh System Day^{-1}	New Brunswick	Nova Scotia	Prince Edward Island	**Average**
1	1,655.5	4.5	0.96	1.52	1.09	**1.19**
2	3,311.1	9.1	1.92	3.05	2.19	**2.38**
3	4,966.6	13.6	2.88	4.57	3.28	**3.58**
4	6,622.2	18.1	3.84	6.09	4.37	**4.77**
5	8,277.7	22.7	4.80	7.62	5.46	**5.96**
10	16,555.4	45.4	9.60	15.23	10.93	**11.92**
15	24,833.1	68.0	14.40	22.85	16.39	**17.88**
20	33,110.8	90.7	19.20	30.46	21.85	**23.84**

Based on the average GHG reduction per solar hot water heating panel over the three Maritime provinces, the total farm participation required to develop various marketable carbon package sizes is outlined in Table 2. As a point of reference, there are 692-dairy farms currently operating throughout the Maritime region.

Table 2. Farm Participation Required to Develop Marketable Carbon Offset Package

		Carbon Offset Package (Tonnes CO_2e Year^{-1})			
	Average Carbon Offset	**1,000**	**2,500**	**5,000**	**10,000**
Panels	(Tonnes CO_2e Year^{-1})	Participation Required (# Farms)			
1	1.2	839	2,097	4,195	8,389
2	2.4	419	1,049	2,097	4,195
3	3.6	280	699	1,398	2,796
4	4.8	210	524	1,049	2,097
5	6.0	168	419	839	1,678
10	11.9	84	210	419	839
15	17.9	56	140	280	559
20	23.8	42	105	210	419

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of \$15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

Tables 3-5 outline the total carbon offset value for each Maritime province that would be generated with various solar hot water panel array sizes. Results vary by province based on the GHG intensity of the provincial electricity grid.

Table 3. New Brunswick Annual Carbon Offset Value: 50% Solar Hot Water Heating Offset

	Carbon Offset	**$ Tonne CO_2e^{-1}**			
Panels	Tonnes CO_2e Year^{-1}	$15	$25	$50	$100
1	0.96	$14.40	$24.01	$48.01	$96.02
2	1.92	$28.81	$48.01	$96.02	$192.04
3	2.88	$43.21	$72.02	$144.03	$288.06
4	3.84	$57.61	$96.02	$192.04	$384.09
5	4.80	$72.02	$120.03	$240.05	$480.11
10	9.60	$144.03	$240.05	$480.11	$960.21
15	14.40	$216.05	$360.08	$720.16	$1,440.32
20	19.20	$288.06	$480.11	$960.21	$1,920.43

Table 4. Nova Scotia Annual Carbon Offset Value: 50% Solar Hot Water Heating Offset

	Carbon Offset	**$ Tonne CO_2e^{-1}**			
Panels	Tonnes CO_2e Year^{-1}	$15	$25	$50	$100
1	1.52	$22.85	$38.08	$76.15	$152.31
2	3.05	$45.69	$76.15	$152.31	$304.62
3	4.57	$68.54	$114.23	$228.46	$456.93
4	6.09	$91.39	$152.31	$304.62	$609.24
5	7.62	$114.23	$190.39	$380.77	$761.55
10	15.23	$228.46	$380.77	$761.55	$1,523.10
15	22.85	$342.70	$571.16	$1,142.32	$2,284.65
20	30.46	$456.93	$761.55	$1,523.10	$3,046.19

Table 5. Prince Edward Island Annual Carbon Offset Value: 50% Solar Hot Water Heating Offset

	Carbon Offset	**$ Tonne CO_2e^{-1}**			
Panels	Tonnes CO_2e Year^{-1}	$15	$25	$50	$100
1	1.09	$16.39	$27.32	$54.63	$109.27
2	2.19	$32.78	$54.63	$109.27	$218.53
3	3.28	$49.17	$81.95	$163.90	$327.80
4	4.37	$65.56	$109.27	$218.53	$437.06
5	5.46	$81.95	$136.58	$273.16	$546.33
10	10.93	$163.90	$273.16	$546.33	$1,092.66
15	16.39	$245.85	$409.75	$819.49	$1,638.98
20	21.85	$327.80	$546.33	$1,092.66	$2,185.31

Recommendations

The results of this analysis does not take into account any site specific variations in solar thermal system output that may occur due to geographic location, panel orientation towards true south, panel shading or loss of efficiency due to poor system design, operation or maintenance. A full solar thermal system assessment should be completed at each potential farm site to identify the expected return on investment.

A host of energy efficiency incentives are available in New Brunswick, Nova Scotia and Prince Edward Island through respective Departments of Agriculture and Provincial Energy Efficiency Offices. The installation of renewable energy production systems, including solar thermal, may qualify for financial support.

Wherever possible, farms should take part in energy audit programs to identify any farm specific opportunities to reduce electricity or fuel consumption used in space or domestic hot water heating applications. Farms should be encouraged to make use of available incentives to reduce energy expenditures and install renewable heating system infrastructure in the short term. As carbon marketing opportunities become available, carbon offsets created by offsetting fossil energy use may be eligible for carbon offset payments in the future.

Biomass Energy Generation

Biomass heating systems are a carbon neutral option for space heating and domestic hot water supply applications. Wood biomass, harvested from the region where it is to be utilized, is part of the active carbon cycle. Carbon dioxide, bound up in the wood fibres, is released to the atmosphere when wood is burned, and is recaptured in new plant growth. In contrast to the active carbon cycle, fossil fuels release non-active carbon into the atmosphere when they are burned. Fossil fuel carbon is considered non-active as it is stored underground in large reservoirs developed over millennia. Replacing fossil fuel based space and water heating systems with biomass combustion appliances represents and opportunity to reduce a farms greenhouse emissions.

Source: www.pellagri.com

GHG Baseline Case

Based on the results of energy audits conducted throughout the Maritime region, 5-farm case studies were developed to determine the opportunity to reduce GHG emissions through the adoption of biomass heating systems. Two large dairies, one layer operation, one multi unit broiler facility and a vegetable processing facility were analysed. The existing fossil fuel based space and domestic hot water heating system was considered as the baseline in each case.

GHG Project Case

The project case for each case study farm was a 100 per cent offset of fossil based energy consumption with carbon neutral biomass combustion.

GHG Analysis Summary

The total energy consumption for each case study farm is outlined in Table 1. There and two distinct farm size groupings included in this analysis. The two dairy farms and the broiler poultry case studies would be considered large operations for the maritime region. The layer poultry and vegetable processing operations are representative of the energy use profiles of a wider range of Maritime agricultural operations.

Based on province specific electricity grid GHG intensities and standard emissions factors for heating oil and propane combustion, the total GHG emissions reductions that could be achieved by replacing fossil energy based heating systems with biomass heating systems range from 10.3 to 92.0-tonnes CO_2e annually. The average offset is 48.3-tonnes CO_2e annually.

Table 1. Biomass Heating System Case Study Energy Consumption

	Water and Space Heating System Energy Consumption			
Case Study	Electricity (kWh)	Heating Oil (L)	Propane (L)	Tonnes CO_2e
Dairy	158,700	0	0	92.0
Dairy	19,700	19,045	0	66.9
Vegetable Processing	0	1,232	4,535	10.3
Poultry: Layer	0	5,910	0	16.7
Poultry: Broiler	0	0	37,161	55.7
Average				**48.3**

It is difficult to determine the total opportunity that exists for Maritime livestock operations to adopt biomass heating systems based on the results of the relatively small data sample size available from completed energy audits. However, Table 2 outlines the total number of participants required to develop various carbon offset packages, depending on the market being engaged. This analysis based on average GHG reductions per farm of 48.3-tonnes CO_2e, as per the average reduction presented in Table 1.

Table 2. Farm Participation Required to Develop Various Carbon Offset Packages

	Carbon Offset Package (Tonnes CO_2e Year^{-1})			
Average Carbon Offset	**1,000**	**2,500**	**5,000**	**10,000**
(Tonnes CO_2e Year^{-1})	Participation Required (# Farms)			
48	21	52	103	207

The values in Table 2 are based on annual reductions, therefore a 5-year project with 21-participants would result in a total project offset of 5,000-tonnes CO_2e over the life of the project.

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of \$15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

Table 3 outlines the total annual carbon offset value for each individual case study and the average of the 5-case study farms.

Table 3. Annual Farm Gate Carbon Offset Value for Biomass Heating Systems

	GHG Reduction	**\$ Tonne CO_2e^{-1}**			
Case Study	Tonnes CO_2e	\$15	\$25	\$50	\$100
Dairy	92.0	\$1,380.69	\$2,301.15	\$4,602.30	\$9,204.60
Dairy	66.9	\$1,003.49	\$1,672.48	\$3,344.97	\$6,689.94
Vegetable Processing	10.3	\$154.34	\$257.23	\$514.45	\$1,028.91
Poultry: Layer	16.7	\$250.88	\$418.13	\$836.27	\$1,672.53
Poultry: Broiler	55.7	\$836.12	\$1,393.54	\$2,787.08	\$5,574.15
Average	**48.3**	**\$725.10**	**\$1,208.51**	**\$2,417.01**	**\$4,834.02**

Recommendations

A host of energy efficiency incentives are available in New Brunswick, Nova Scotia and Prince Edward Island through respective Departments of Agriculture and Provincial Energy Efficiency Offices. The installation of renewable energy production systems, including biomass heating, may qualify for financial support

Wherever possible, farms should take part in energy audit programs to identify any farm specific opportunities to reduce electricity or fuel consumption used in space or domestic hot water heating applications. Farms should be encouraged to make use of available incentives to reduce energy expenditures and install renewable heating system infrastructure in the short term. As carbon marketing opportunities become available, carbon offsets created by offsetting fossil energy use may be eligible for carbon offset payments in the future.

Biogas Energy Generation

Biogas is produced when organic material is degraded by methanogenic bacteria under anaerobic conditions. Over 2500-biogas plants are currently operating in Germany using various feedstocks, based primarily on livestock manure and food wastes.

Biogas systems reduce farm GHG emissions in two ways. When a biogas plant is constructed to treat manure feedstocks, methane emissions from the baseline manure storage system are largely eliminated through the capture and combustion of methane within the biogas reactor. Second, if biogas is used to produce energy for on-farm use or if electrical or heat energy is exported off-farm, renewable energy is likely to substitute fossil based energy generation. The reduction of baseline methane emissions from manure storage or other organic matter management systems and renewable energy offset of fossil energies results in biogas energy systems generating a larger carbon offset package compared to other on-farm energy production systems.

Two case studies were analysed to determine the total carbon offsets package that would be created with the construction of a biogas plant at the farm site.

GHG Baseline Case 1

RA Farms is a 1,500-head cattle backgrounding and finishing operation located in southeastern New Brunswick. Manure is managed in a solid form and stockpiled weekly until field conditions allow for application to corn and forage cropland.

Acton Farms manages an additional 1,000-head of backgrounding cattle adjacent to, and manages manure and forage crops similar to RA Farms.

The baseline case is assumed to be the management of 2,500-head of 365-kg (800-lb) beef feeders and the manure resources produced using a scrape, stack and spread manure management system. While liquid manure is a preferred biogas plant feedstock, the sheer volume of manure produced at RA and Acton Farms makes the site one of the most viable biogas plant sites in the Maritime provinces.

GHG Baseline Case 2

Archibald Dairy Farm, located in South Central Nova Scotia has been exploring the use of anaerobic digestion technology for energy production for a number of years. The farm is currently milking 170-cows and is in a period of expansion with a milking herd size target of 300-lactation animals. The farm imports and manages 3,000-tonnes of Class-A bio-solids annually in a partnership with the county of Pictou.

The baseline case is assumed to be the management of a 300-head lactating dairy and replacement herds, manure is managed in a liquid form and is stored in two earthen manure storages until it can be field applied. Manure is applied to forage and corn cropland 3-4 times annually using tractor drawn tankers quipped with coulter injection systems.

GHG Project Case 1

Project case 1 includes the construction of a 170-kW biogas generator set to run on the biogas generated from the anaerobic digestion treatment of manure produced by 2,500-backgrounding feeder cattle. Electricity is exported off-farm through the distribution power grid and purchased by NB Power at the power utilities offset cost of generation.

Solids remaining in the digestate stream are removed using a screw press separator and used as animal bedding, replacing the need to import barley straw from Prince Edward Island. Thin liquids are stored in earthen manure storage for eventual application to forage land. Manure is applied to cropland 4-times per year. Once before first cut and subsequent applications are made following each of the 3-forage cuts taken throughout the growing season.

The total carbon offset package available for sale due to the operation of a biogas plant at RA Farms is comprised of manure system methane and nitrous oxide emissions reductions and the offset of grid based electricity generation. Methane emissions reductions are based on default Intergovernmental Panel on Climate Change (IPCC) emissions factors for the semi-solid handling system baseline and liquid management system project case. Nitrous oxide emissions for the project case are assumed to be reduced by 70% over the baseline case. The GHG intensity of grid based electricity used in the analysis was 0.58 kg CO_2e kWh^{-1}.

GHG Project Case 2

Project case 2 includes the construction of a 120-kW biogas plant and generator set to run on the biogas at Archibald Dairy Farms. Biogas feedstocks include the manure produced by a 300-head lactating dairy herd and replacements plus roughly 3000-tonnes of Class-A biosolids annually. It is assumed that electricity is exported off-farm through the distribution power grid and purchased by Nova Scotia Power Inc offsetting the generation of largely fossil fuel based electricity.

Solids remaining in the digestate stream are removed using a screw press separator and used as animal bedding, replacing the locally sourced wood shavings currently used. Thin liquids are stored in earthen manure storage for eventual application to forage and corn croplands.

The total carbon offset package available for sale due to the operation of a biogas plant at Archibald Dairy Farms is comprised of manure system methane emissions based on IPCC default emissions factors, nitrous oxide emissions reductions of 70% for the project case over the baseline case and the offset of grid based electricity generation. The GHG intensity of grid based electricity used in the analysis was 0.92 kg CO_2e kWh^{-1}.

GHG Analysis Summary

The biogas plant case studies offered an interesting opportunity to explore the impact of baseline manure management system, biogas plant design and provincial power grid GHG intensity on the total GHG emissions reductions achieved by the project.

Baseline Manure System Impacts

The baseline manure management system at RA Farms is classified as a solid to semi-solid system, managed using loaders and verti-spread box spreaders. According to IPCC guidance documents, semi-solid manure systems are an aerobic manure management system and therefore produce much smaller quantities of methane compared to anaerobic liquid manure systems commonly used by dairy operations. When solid manures are used as a biogas plant feedstock, it is possible for baseline case GHG emissions to be less than the project case emissions. While this represents an actual GHG increase from a manure management perspective, the overall project often still provides a net GHG reduction. This highlights the importance of quantification methods in GHG accounting.

Biogas System Design Impacts

Further to the impact of baseline manure management, biogas plant design can also have a great effect on the total carbon offsets created by a project. As warm digestate is forced out of the biogas reactor by the addition of fresh feedstock, it passes through a screw press separator to remove large solids and the liquids flow to long-term digestate storage. Bacteria in the digestate storage will continue to degrade organic matter that was not removed by the screw press separator, producing biogas and releasing methane directly to atmosphere if the digestate storage is not covered to allow for the harvest of this methane. German biogas industry practitioners estimate that 30% of the total biogas yield can be expected during long-term digestate storage.

Tables 1 & 2 outline the total GHG emissions profile for the biogas project at RA Farms, with an uncovered and a covered digestate storage system respectively. The uncovered digestate storage would release 916-tonnes CO_2e annually, while the covered storage would release only 10% of the uncovered storage emissions or 91.61-tonnes CO_2e. This illustrates the importance of biogas plant design on the total GHG reduction potential of a biogas plant installation.

Table 1. Biogas System GHG Sinks, Sources and Reservoirs: Uncovered Digestate Storage

SSR1	Manure Storage Emissions	942.89
SSR2	AD System Emissions	546.44
SSR3	Digestate Storage Emissions	916.09
SSR4	Imported Fuel Emissions	89.19
SSR5	Transport to Flare	--
SSR6	Flare Emissions	13.66
SSR7	Transport to Combustion Device	--
SSR8	Combustion Device Emissions	--
SSR9	Transport to Natural Gas Pipeline	--
SSR10	Genset Emissions	604.80
SSR11	Natural Gas Pipeline Emissions	--

Table 2. Biogas System GHG Sinks, Sources and Reservoirs: Covered Digestate Storage

SSR1	Manure Storage Emissions	942.89
SSR2	AD System Emissions	546.44
SSR3	Digestate Storage Emissions	91.61
SSR4	Imported Fuel Emissions	89.19
SSR5	Transport to Flare	--
SSR6	Flare Emissions	13.66
SSR7	Transport to Combustion Device	--
SSR8	Combustion Device Emissions	0.00
SSR9	Transport to Natural Gas Pipeline	--
SSR10	Genset Emissions	604.80
SSR11	Natural Gas Pipeline Emissions	0.00

Provincial Power Grid Greenhouse Gas Intensity Impacts

The GHG intensity of the provincial power grid in the province where a biogas plant is to be constructed can play an important role in the total carbon offset package that the project can be expected to generate. For the purposes of this analysis, Table 3 outlines the provincial power grid GHG intensities used in offset opportunity analysis and the total GHG emissions reductions that would be achieved in each province with the production of 1,000,000-kWh of renewable electricity.

Nova Scotia is the province most highly dependent on fossil energy based electricity generation in the Maritime region. Biogas generated electricity in Nova Scotia will, therefore, generate a larger carbon offset package than an identical sized plant in New Brunswick or Prince Edward Island.

Table 3. Maritime Province Electrical Power Grid GHG Intensities

Province	Power Grid GHG Intensity ($kg\ CO_2e\ kWh^{-1}$)	$kg\ CO_2e\ MWh^{-1}$	Tonnes $CO_2e\ MWh^{-1}$
New Brunswick	0.58	580,000	580
Nova Scotia	0.92	920,000	920
Prince Edward Island	0.66	660,000	660

GHG Project Case 1

Tables 4 & 5 outlines the net GHG emissions reductions that could be expected from the construction of a biogas plant at RA Farms. Table 4 outlines the emissions profile for a plant constructed with an uncovered digestate storage, and results in a net increase in GHG emissions for the project. The emissions profile for a plant constructed with a covered digestate storage is outlined in Table 5. The net GHG emissions for this scenario are 555.52 tonnes CO_2e annually.

Table 4. Biogas energy production system GHG emission reductions: Open Digestate Storage

Offset Type	Baseline	Project	Offset
Manure Management Methane	942.89	2,170.18	-1,227.29
Manure Management Nitrous Oxide	344.10	103.23	240.87
Electricity Offset Carbon Dioxide	717.46	0.00	717.46
Project Total	2,004.45	1,357.33	-268.96

Table 5. Biogas energy production system GHG emission reductions: Covered Digestate Storage

Offset Type	Baseline	Project	Offset
Manure Management Methane	942.89	1,345.70	-402.81
Manure Management Nitrous Oxide	344.10	103.23	240.87
Electricity Offset Carbon Dioxide	717.46	0.00	717.46
Project Total	2,004.45	1,357.33	555.52

GHG Project Case 2

The Archibald Dairy Farms biogas case study offered a much more straightforward assessment opportunity compared to the RA Farms case. Note that in all aspects of the GHG emissions profile the project case offers a net GHG reduction over the baseline case. Table 6 outlines the emissions profile for the Archibald Dairy biogas plant project.

The net GHG emissions reductions for a biogas plant project at Archibald Dairy Farms are estimated at 1,470.05 tonnes CO_2e annually.

Table 6. Archibald Dairy Farm Biogas Plant Project GHG Emissions Profile

Offset Type	Baseline	Project	Offset
Manure Management Methane	1,211.56	755.99	455.57
Manure Management Nitrous Oxide	204.23	30.63	173.60
Manure Management Total	1,415.79	786.62	629.17
Electricity Offset Carbon Dioxide	840.88	0.00	840.88
Project Total	2,256.67	786.62	1,470.05

GHG Reduction Value Summary

The theoretical carbon offset values presented are based on a baseline price of $15-Tonne CO_2e^{-1}, which is a reasonable value in the 2010 carbon marketplace, and future projected values that anticipate steady growth in carbon offset values that track the adoption of more stringent GHG emission reduction legislation worldwide. No carbon offset sales transaction costs have been deducted from the annual value estimates, but will likely represent 15-25% of the gross value of the offset package created.

GHG Project Case 1

The annual carbon offset value for the RA Farms biogas plant project, constructed with a covered digestate storage, is outlined in Table 7.

Table 7. Annual Carbon Offset Value for RA Farms Biogas Plant Project

Tonnes CO_2e			$ Tonne CO_2e^{-1}			
Baseline	Project	Reduction	$15	$25	$50	$100
2,004.45	1,448.93	555.52	$8,332.74	$13,887.89	$27,775.79	$55,551.57

GHG Project Case 2

The annual carbon offset value for the Archibald Dairy Farms biogas plant project is outlined in Table 8.

Table 8. Annual Carbon Offset Value for Archibald Dairy Farm Biogas Plant Project

Tonnes CO_2e			$ Tonne CO_2e^{-1}			
Baseline	Project	Reduction	$15	$25	$50	$100
2,256.67	786.62	1,470.05	$22,050.76	$36,751.26	$73,502.52	$147,005.05

GHG Reduction Value Summary

A compilation of the results of the two biogas system case studies are provided in Table 9. The average marketable carbon offsets package per project is assumed to be 1,012.78 tonnes CO_2e annually, the average of the two case studies completed.

Table 9. Summary of Biogas System GHG Emissions and Carbon Offset Revenues

	Tonnes CO_2e			$ Tonne CO_2e^{-1}			
Case Study	Baseline	Project	Reduction	$15.00	$25.00	$50.00	$100.00
RA Farms	2,004.45	1,448.93	555.52	$8,332.74	$13,887.89	$27,775.79	$55,551.57
Archibald Dairy	2,256.67	786.62	1,470.05	$22,050.76	$36,751.26	$73,502.52	$147,005.05
Average	2,130.56	1,117.78	1,012.78	$15,191.75	$25,319.58	$50,639.15	$101,278.31

Carbon offsets generated from the treatment of organic feedstocks using anaerobic digestion technology are highly valued in the voluntary and regulatory carbon marketplaces. Biogas plants equipped with sufficient monitoring equipment to create hourly data logs of biogas produced, biogas sent to flare, biogas sent to combustion device, etc., allow for rapid validation and verification of GHG reductions. Ease in validation and verification tends to reduce transaction costs, and readymade data sets increase the value of carbon offsets as little uncertainly exists in the verification data, ie. it is not necessary to use industry benchmarks, as site specific, real-time data is available to monitor GHG destruction performance.

Table 10 outlines the total number of biogas plants required to be built in the region to develop various marketable carbon offset package sizes. It is reasonable to expect that 10-viable biogas energy generation plants could be developed in each of the Maritime provinces, or a total of 30-plants in the region. Using the average offset package generated at each facility, as per Table 9, 30-biogas plants would generate an annual 30,000-tonne CO_2e offset package. An offset package of this size, based on anaerobic digestion of organic feedstocks, is likely to attract significant attention from the carbon market.

Table 10. Farm Participation Required to Develop Marketable Carbon Offset Package

	Carbon Offset Package (Tonnes CO_2e $Year^{-1}$)			
	5,000	10,000	20,000	30,000
Average Carbon Offset (Tonnes CO_2e $Year^{-1}$)	**Participation Required (# Farms)**			
1,012.78	5	10	20	30

Table 11 outlines the total value of various carbon offset packages that could be developed with the construction of a cluster of biogas plants throughout the Maritimes.

Table 11. Total Carbon Offset Value Based on Total Marketable Package Size

	$ Tonne CO_2e^{-1}			
Carbon Offset Package (Tonnes CO_2e Year^{-1})	**$15.00**	**$25.00**	**$50.00**	**$100.00**
5,000	$75,000	$125,000	$250,000	$500,000
10,000	$150,000	$250,000	$500,000	$1,000,000
20,000	$300,000	$500,000	$1,000,000	$2,000,000
30,000	$450,000	$750,000	$1,500,000	$3,000,000

Recommendations

While the development of a number of biogas plants in the Maritime region would result in the creation of a large marketable carbon offset package, GHG reduction value alone will not create sufficient revenue to allow for a biogas plant to be constructed where renewable energy policy does not exist to support project revenues.

Renewable energy policies will need to be more fully developed to allow independent power producers to sell renewable electricity to the provincial power utility at a rate that is sufficient to provide a reasonable return on investment. The Maritime region has long relied on imported fossil fuels for generating electricity, which has had negative consequences for the development of our own natural energy resources. The total societal value of adopting an advanced electricity feed-in-tariff, similar to what currently exists in Germany and more recently Ontario, should be considered when developing a feed-in-tariff rate structure. Green collar job creation and investments in rural infrastructure are two key benefits of deploying renewable energy generation systems in rural Maritime Canada.

Maritime federations of agriculture are encouraged to engage in formal discussions with provincial power utilities and Provincial Departments of Agriculture and Energy in order to have a comprehensive electricity feed-in-tariff implemented that will allow for investment in biogas and other small scale renewable electricity generation systems throughout New Brunswick, Nova Scotia and Prince Edward Island.

APPENDIX A
Canadian Large Final Emitter Profiles

Rank	Facility	Reporting Company	City	Province	Tonnes CO_2e
1	Nanticoke Generating Station	Ontario Power Generation	Nanticoke	Ontario	15,427,913.40
2	Sundance Thermal Electric Power Generation Plant	TransAlta Generation Partnership	Duffield	Alberta	14,898,726.88
3	Mildred Lake and Aurora North Plant Sites	Syncrude Canada Ltd.	Fort McMurray	Alberta	12,226,819.97
4	Suncor Energy Inc. Oil Sands	Suncor Energy Inc. Oil Sands	Fort McMurray	Alberta	8,821,642.57
5	Genesee Thermal Generating Station	EPCOR Power Generation Services Inc.	Warburg	Alberta	8,365,279.01
6	Boundary Dam Power Station	Saskatchewan Power Corporation	Estevan	Saskatchewan	6,899,820.50
7	Lambton Generating Station	Ontario Power Generation	Courtright	Ontario	6,405,361.30
8	Keephills Thermal Electric Power Generating Plant	TransAlta Generation Partnership	Duffield	Alberta	6,131,883.66
9	Sheerness Generating Station	Alberta Power (2000) Ltd.	Hanna	Alberta	6,024,761.31
10	Battle River Generating Station	Alberta Power (2000) Ltd.	Forestburg	Alberta	5,074,915.66
11	Cold Lake	Imperial Oil Resources	Bonnyville	Alberta	4,532,550.35
12	ArcelorMittal Dofasco Hamilton	ArcelorMittal Dofasco Inc	Hamilton	Ontario	4,227,882.11
13	Lingan Generating Station	Nova Scotia Power Incorporated	Lingan	Nova Scotia	4,138,005.75

14	Essar Steel Algoma Inc	Essar Steel Algoma Inc	Sault Ste. Marie	Ontario	3,861,646.27
15	Poplar River Power Station	Saskatchewan Power Corporation	Coronach	Saskatchewan	3,835,843.80
16	Lake Erie Works	US Steel Canada Inc.	Haldimand County	Ontario	3,648,937.00
17	Belledune Generating Station	NB Power Generation Corporation	Belledune	New Brunswick	3,150,000.00
18	Refinery	Irving Oil Refining G.P.	Saint John	New Brunswick	2,981,743.00
19	Wolf Lake/Primrose Thermal Operation	Canadian Natural Resources Limited	Bonnyville	Alberta	2,866,488.53
20	INVISTA (Canada) Company- Maitland Site	INVISTA (Canada) Company	Maitland	Ontario	2,753,739.62
21	U. S. Steel Canada Hamilton Works (formerly Stelco Hamilton)	U.S. Steel Canada	Hamilton	Ontario	2,732,201.45
22	NOVA Chemicals Corporation (Joffre)	NOVA Chemicals Corporation	Red Deer	Alberta	2,710,320.90
23	WABAMUN THERMAL ELECTRIC POWER GENERATING PLANT	TransAlta Generation Partnership	Wabamun	Alberta	2,433,286.57
24	Trenton Generating Station	Nova Scotia Power Incorporated	Trenton	Nova Scotia	2,171,380.50
25	Shand Power Station	Saskatchewan Power Corporation	Estevan	Saskatchewan	2,157,739.00
26	Dalhousie Generating Station	NB Power Generation Corporation	Dalhousie	New Brunswick	1,860,000.00
27	TransCanada Pipeline, Alberta System	Nova Gas Transmission Ltd.	Fairview	Alberta	1,810,481.79
28	Scotford Upgrader and Upgrader Cogeneration	Shell Canada Energy Limited	Fort Saskatchewan	Alberta	1,788,752.10
29	Canadian Fertilizers Limited	Canadian Fertilizers Limited	Medicine Hat	Alberta	1,640,775.70

30	TransCanada Pipeline, Ontario	TransCanada PipeLines Ltd.	Kenora	Ontario	1,595,161.80
31	NOVA Chemicals - Corunna Site	NOVA Chemicals (Canada) Ltd.	Corunna	Ontario	1,503,605.63
32	Raffinerie Jean-Gaulin	Ultramar limitée	Lévis	Quebec	1,500,168.55
33	Sarnia Refinery Plant	Imperial Oil	Sarnia	Ontario	1,445,400.46
34	Edmonton Refinery	Petro-Canada	Edmonton	Alberta	1,438,114.17
35	Aluminerie de Baie-Comeau	Alcoa Limitée	Baie-Comeau	Quebec	1,436,371.03
36	Point Aconi Generating Station	Nova Scotia Power Incorporated	Point Aconi	Nova Scotia	1,434,807.13
37	CCRL Refinery Complex	Consumers' Co-operative Refineries Limited	Regina	Saskatchewan	1,427,852.41
38	Strathcona Refinery	Imperial Oil Limited	Edmonton	Alberta	1,417,154.44
39	Western Canada Operations	Dow Chemical Canada ULC	Fort Saskatchewan	Alberta	1,394,698.02
40	Complexe métallurgique de Sorel-Tracy	QIT - Fer et Titane Inc.	Sorel-Tracy	Quebec	1,288,830.22
41	North Atlantic Refinery	North Atlantic Refining LP	Come by Chance	Newfoundland & Labrador	1,285,356.00
42	Montreal East Refinery	Shell Canada Products	Montreal	Quebec	1,275,400.40
43	Pine River Gas Plant	Spectra Energy Transmission	Chetwynd	British Columbia	1,267,969.82
44	Carol Project	Iron Ore Company of Canada	Labrador City	Newfoundland & Labrador	1,243,582.13
45	Aluminerie Alouette inc.	Aluminerie Alouette inc.	Sept-Îles	Quebec	1,233,080.00
46	Fort Nelson Gas Plant	Spectra Energy Transmission	Fort Nelson	British Columbia	1,224,601.84
47	Rio Tinto Alcan Primary	Rio Tinto Alcan 1188	Kitimat	British Columbia	1,205,270.34

	Metal - BC	Sherbrooke Ouest Montreal H3A3G2			
48	Agrium Redwater Fertilizer Operation	Agrium Inc.	Redwater	Alberta	1,174,417.57
49	St. Marys Cement Bowmanville	St. Marys Cement Inc.	Bowmanville	Ontario	1,161,332.78
50	Muskeg River Cogeneration Plant	ATCO Power Canada Ltd.	Fort McMurray	Alberta	1,141,426.79
51	Sarnia Regional Cogeneration Plant	TransAlta Generation Partnership	Sarnia	Ontario	1,113,136.55
52	Exshaw Cement Plant	Lafarge Canada Inc	Exshaw	Alberta	1,112,559.87
53	Raffinerie de Montreal	Petro-Canada	Montreal	Quebec	1,100,859.37
54	Mississauga Plant	Holcim (Canada) Inc.	Mississauga	Ontario	1,078,975.00
55	Nanticoke Refinery	Imperial Oil	Nanticoke	Ontario	1,052,064.88
56	Point Tupper Generating Station	Nova Scotia Power Incorporated	Port Hawkesbury	Nova Scotia	1,047,105.63
57	Husky Lloydminster Upgrader	Husky Oil Operations Ltd	Lloydminster	Saskatchewan	1,035,788.30
58	Shell Scotford Refinery	Shell Canada Products	Fort Saskatchewan	Alberta	1,006,910.74
59	Picton Plant	Essroc Canada Inc	Picton	Ontario	998,893.00
60	Tufts Cove Generating Station	Nova Scotia Power Incorporated	Dartmouth	Nova Scotia	990,949.58
61	Coleson Cove Generating Station	NB Power Coleson Cove Corporation	Saint John	New Brunswick	976,000.00
62	Delta Plant	Lehigh Cement	Delta	British Columbia	963,195.00
63	Usine de Bouletage	ArcelorMittal Mines Canada	Port-Cartier	Quebec	908,952.69
64	TransCanada Pipeline, Saskatchewan	TransCanada PipeLines Ltd.	Burstall	Saskatchewan	907,417.87
65	Lafarge Richmond Cement	Lafarge Canada Inc	Richmond	British Columbia	871,273.00
66	Holyrood Thermal	Newfoundland and	Holyrood	Newfoundland & Labrador	867,606.59

	Generating Station	Labrador Hydro			
67	Sarnia Manufacturing Centre	Shell Canada Products	Corunna	Ontario	861,832.95
68	Meridian Generating Facility	TransAlta Generation Partnership	Lloydminster	Saskatchewan	838,309.30
69	Lehigh Inland Cement	Lehigh Cement	Edmonton	Alberta	838,009.00
70	Thunder Bay Generating Station	Ontario Power Generation Inc.	Thunder Bay	Ontario	832,867.80
71	Cimenterie de Saint-Basile	Ciment Québec Inc.	Saint-Basile	Quebec	812,292.10
72	Mackay River Power Plant, Alberta	TransCanada Energy Ltd.	Fort McMurray	Alberta	786,858.95
73	Island Cogeneration No. 2 Inc.	Island Cogeneration No. 2 Inc.	Campbell River	British Columbia	786,213.60
74	Lafarge Bath Cement Plant	Lafarge Canada Inc	Bath	Ontario	781,264.00
75	Usine Alma	Rio Tinto Alcan inc	Alma	Quebec	773,471.99
76	H.R. Milner Generating Station	Milner Power Limited Partnership by its GP Milner Power Inc.	Grande Cache	Alberta	756,678.60
77	Long Lake Project	Nexen Inc.	Fort McMurray	Alberta	753,049.51
78	Pipeline-Transmission	Spectra Energy Transmission	Prince George	British Columbia	740,885.80
79	Aluminerie de Bécancour	Aluminerie de Bécancour inc.	Bécancour	Quebec	740,036.68
80	Dartmouth Refinery	Imperial Oil	Dartmouth	Nova Scotia	727,008.29
81	Koch Fertilizer Canada, ULC	Koch Fertilizer Canada, ULC	Brandon	Manitoba	684,088.72
82	Foster Creek SAGD Bitumen Battery	FCCL Oil Sands Partnership	Bonnyville	Alberta	683,702.33
83	Usine de Joliette	Holcim (Canada) inc.	Joliette	Quebec	682,306.00
84	Usine Arvida	Rio Tinto Alcan ; 1188	Saguenay	Quebec	662,766.55

		Sherbrooke Ouest Montréal H3A 3G2			
85	Ram River	Husky Oil Operations Ltd	Ram River	Alberta	662,620.77
86	Sarnia Refinery	Suncor Energy Products Inc.	Sarnia	Ontario	661,316.90
87	Cimenterie de St-Constant	LAFARGE CANADA INC.	St-Constant	Quebec	651,393.19
88	Edmonton-1 and 2 Hydrogen Facility	Air Products Canada Ltd	Edmonton	Alberta	649,437.24
89	Shell Caroline Complex	Shell Canada Limited	Caroline	Alberta	638,823.06
90	Usine Vaudreuil	Rio Tinto Alcan	Jonquière	Quebec	634,423.42
91	Mosaic Potash Belle Plaine	Mosaic Canada ULC	Belle Plaine	Saskatchewan	632,861.81
92	Terra Nova	Petro-Canada	St. John's	Newfoundland & Labrador	618,326.29
93	Mines Wabush - Pointe Noire	Mines Wabush	Sept-Iles	Quebec	596,806.46
94	Hibernia Platform	Hibernia Management and Development Company Limite	St. John's	Newfoundland & Labrador	595,749.00
95	Shell Albian Sands Muskeg River Mine	Shell Canada Energy	Fort McMurray	Alberta	566,911.31
96	Alberta Pipeline System	Alliance Pipeline Ltd.	Calgary	Alberta	563,835.25
97	Cory Cogeneration Station	ATCO Power Canada Ltd.	Corman Park	Saskatchewan	558,492.34
98	Carseland Works	Orica Canada Inc	Carseland	Alberta	556,425.51
99	White Rose FPSO	Husky Oil Operations Limited	Atlantic	Newfoundland & Labrador	555,534.00
100	Yara Belle Plaine Inc.	Yara Belle Plaine Inc.	Belle Plaine	Saskatchewan	554,504.90
101	Queen Elizabeth Power Station	Saskatchewan Power Corporation	Saskatoon	Saskatchewan	549,064.30
102	Carmeuse Lime	carmeuse lime	Ingersoll	Ontario	543,146.79

	(Canada) limited, Beachville Operation	(canada) limited			
103	Carseland Nitrogen Operations	Agrium Inc	Carseland	Alberta	529,263.51
104	Federal White Cement Ltd.	Federal White Cement Ltd.	Embro	Ontario	512,946.84
105	Cardinal Power	Cardinal Power of Canada, L.P.	Cardinal	Ontario	511,648.12
106	Terra International (Canada) Inc - Courtright Plant	Terra International (Canada) Inc.	Courtright	Ontario	509,752.62
107	Fort Saskatchewan Nitrogen Operation	Agrium Inc.	Fort Saskatchewan	Alberta	509,487.90
108	McMahon Cogen Plant	Spectra Energy Transmission	Taylor	British Columbia	500,364.90
109	Usine Grande-Baie	Rio Tinto Alcan-Métal Primaire - Québec	La Baie	Quebec	500,280.15
110	Natural Gas Transmission System	Union Gas Limited	Chatham	Ontario	497,759.45
111	Carmeuse Dundas(Flamborough) Facility	Carmeuse Lime (Canada) Limited	Hamilton	Ontario	494,106.34
112	Air Products, Corunna Hydrogen Facility	Air Products Canada, Ltd	Corunna	Ontario	484,442.31
113	Foster Creek Cogeneration Facility	FCCL Oil Sands Partnership	Bonnyville	Alberta	474,306.92
114	Bedford	Graymont (QC) Inc.	Bedford	Quebec	470,755.23
115	K3 1-15 GP	SemCams ULC	Fox Creek	Alberta	468,367.50
116	Brandon Generating Station	Manitoba Hydro	Brandon	Manitoba	467,712.71
117	Alcoa Aluminerie de Deschambault	Alcoa Aluminereie de Deschambault Ltée	Deschambault	Quebec	459,960.25

118	Horizon Oil Sands Processing Plant and Mine	Canadian Natural Resources Limited	Fort McMurray	Alberta	444,151.41
119	Bayside Power	Bayside Power L.P.	Saint John	New Brunswick	443,330.20
120	Fording River Operations	Teck Coal Limited	Elkford	British Columbia	439,350.98
121	Scotford Complex	Air Liquide Canada Inc.	Fort Saskatchewan	Alberta	424,910.84
122	Usine Laterrière	Rio Tinto Alcan	Laterrière	Quebec	424,273.07
123	St. Marys Cement Inc. plant in St. Marys	St. Marys Cement Inc.	St. Marys	Ontario	421,501.00
124	Atikokan Generating Station	Ontario Power Generation Inc.	Atikokan	Ontario	413,638.90
125	Saskatchewan Pipeline System	Alliance Pipeline Ltd.	Calgary	Saskatchewan	408,814.64
126	Hanlan Robb Gas Plant	Petro-Canada Oil & Gas	Edson	Alberta	408,296.17
127	Mississauga Lubricant Center	Petro-Canada	Mississauga	Ontario	403,113.92
128	Ridge Landfill	BFI Canada Inc.	Blenheim	Ontario	391,020.00
129	Peace River Complex	Shell Canada Limited	Peace River	Alberta	386,544.20
130	Trail Operations	Teck Metals Ltd.	Trail	British Columbia	384,960.74
131	Empress Straddle Plant System	Spectra Energy Empress LP	Cypress County	Alberta	379,835.70
132	West Windsor Power	Tractebel Canada Inc.	Windsor	Ontario	379,458.76
133	Fort Frances Mill	Abitibi-Consolidated Company of Canada	Fort Frances	Ontario	378,474.00
134	Usine de réduction - ArcelorMittal Contrecoeur	ArcelorMittal Montréal Inc.	Contrecoeur	Quebec	369,468.72
135	Mississauga Cogeneration Plant	TransAlta Generation Partnership	Mississauga	Ontario	368,157.63

136	Cochrane Extraction Plant	Inter Pipeline Extraction Ltd.	Cochrane	Alberta	360,115.57
137	Iroquois Falls Generating Station	Northland Power Inc.	Iroquois Falls	Ontario	357,186.90
138	Shell Jumping Pound Gas Plant	Shell Canada Limited	Calgary	Alberta	356,416.33
139	Greenhills Operations	Teck Coal Limited	Elkford	British Columbia	351,731.48
140	CITY OF MEDICINE HAT, ELECTRIC UTILITY - GENERATION	CITY OF MEDICINE HAT	MEDICINE HAT	Alberta	350,960.79
141	Brighton Beach Power	Brighton Beach Power L.P.	Windsor	Ontario	348,804.00
142	Fort Saskatchewan Thermal Electric(Cogeneration) Power Plant	TransAlta Generation Partnership	Fort Saskatchewan	Alberta	345,684.70
143	McMahon Gas Plant	Spectra Energy Transmission	Taylor	British Columbia	343,563.53
144	Burnaby Refinery	Chevron Canada Limited	Burnaby	British Columbia	340,523.00
145	Keele Valley Landfill	City of Toronto	Maple	Ontario	339,186.76
146	Brookfield Plant	Lafarge Canada Inc.	Brookfield	Nova Scotia	332,782.00
147	Surmont Central Processing Facility	ConocoPhillips Canada Resources Corp.	Anzac	Alberta	325,898.36
148	Elkview Operations	Teck Coal Limited	Sparwood	British Columbia	325,415.56
149	Weyburn Oil Battery	EnCana Corporation	Weyburn	Saskatchewan	320,070.33
150	Scotford Chemical Plant	Shell Chemicals Canada Ltd	Strathcona County	Alberta	319,230.37
151	Carseland Power Plant, Alberta	TransCanada Energy Ltd.	Carseland	Alberta	310,737.24
152	Brady Road Landfill	City of Winnipeg,	Winnipeg	Manitoba	299,565.00

		Water & Waste Department			
153	Bolney Thermal	Husky Energy	Lloydminster	Saskatchewan	293,309.40
154	Waterton Complex	Shell Canada Limited	Pincher Creek	Alberta	293,277.41
155	Fort Saskatchewan	Sherritt International Corporation	Fort Saskatchewan	Alberta	292,274.63
156	Usine Shawinigan	Rio Tinto Alcan Inc., 1188 Sherbrooke ouest, Montréal, H3A3G	Shawinigan	Quebec	290,695.97
157	TransCanada Pipeline, Manitoba	TransCanada PipeLines Ltd.	Rapid City	Manitoba	290,213.88
158	Enbridge Gas Distribution Inc.	Enbridge Gas Distribution Inc.	North York	Ontario	288,694.36
159	Lennox Generating Station	Ontario Power Generation	Greater Napanee	Ontario	288,674.40
160	TransGas Limited	TransGas Limited	Regina	Saskatchewan	288,049.06
161	usine de La Tuque	Emballages Smurfit-Stone canada inc.	La Tuque	Quebec	284,951.33
162	Alberta Envirofuels Inc.	Alberta Envirofuels Inc.	Edmonton	Alberta	281,064.35
163	Copper Cliff Smelter	Vale Inco Limited	Copper Cliff	Ontario	276,688.35
164	Strachan GP	Keyera Energy	Rocky Mountain House	Alberta	275,225.11
165	Calgary Energy Center	Calgary Energy Centre No. 2 Inc	Calgary	Alberta	275,014.61
166	Foothills Pipeline, Alberta	Foothills Pipe Lines Ltd.	Airdrie	Alberta	269,631.54
167	Jackfish SAGD Plant	Devon Canada Corporation	Conkin	Alberta	267,048.84
168	Harmattan Gas Processing Plant	Taylor Processing Inc.	Didsbury	Alberta	264,156.40
169	Sarnia Cogen Plant	Imperial Oil	Sarnia	Ontario	252,880.51

170	Sarnia Chemical Plant	Imperial Oil	Sarnia	Ontario	250,714.85
171	Tucker Thermal	Husky Oil Operations Limited	Cold Lake	Alberta	248,880.84
172	Foothills Pipeline, Saskatchewan	Foothills Pipe Lines Ltd.	Richmond	Saskatchewan	244,675.77
173	Rainbow Lake Cogeneration Power Plant (Units 4-5)	ATCO Power Canada Ltd	Rainbow Lake	Alberta	243,693.72
174	Natural Gas Distribution System	Union Gas Limited	Chatham	Ontario	243,105.84
175	Elmworth Gas Plant	ConocoPhillips Canada (BRC) Ltd.	Elmworth	Alberta	242,639.57
176	Edson Gas Plant	Talisman Energy Inc.	Edson	Alberta	242,051.69
177	Rimbey Gas Plant	Keyera Energy	Rimbey	Alberta	241,890.73
178	Neucel Specialty Cellulose	Neucel Specialty Cellulose	Port Alice	British Columbia	238,833.82
179	KA 1-12 GP	SemCams ULC	Fox Creek	Alberta	238,136.22
180	Diavik Diamond Mine	Diavik Diamond Mines Inc.	Lac de Gras	Northwest Territories	235,100.89
181	Hangingstone SAGD Demonstration Facility	Japan Canada Oil Sands Limited	RM of Wood Buffalo	Alberta	234,713.21
182	Balzac Gas Processing Plant	Nexen Inc.	Balzac	Alberta	227,946.95
183	TransCanada Pipeline, British Columbia System	TransCanada PipeLines Ltd.	Cranbrook	British Columbia	224,223.34
184	Chimie ParaChem s.e.c	Chimie ParaChem s.e.c	Montréal-Est	Quebec	223,109.69
185	Chatham Plant	Greenfield Ethanol Inc.	Chatham	Ontario	221,484.34
186	Cabot Canada Limited	Cabot Canada Limited	Sarnia	Ontario	220,993.71
187	Lafarge Canada Inc. - Woodstock Plant	Lafarge Canada Inc.	Woodstock	Ontario	220,315.00

188	Highvale Coal Mine	TransAlta Generation Partnership	Duffield	Alberta	220,285.21
189	Marbleton	Graymont (QC) Inc.	Marbleton	Quebec	218,669.99
190	Pikes Peak	Husky Oil Operations Limited	Lloydminster	Saskatchewan	216,147.50
191	EVRAZ Inc NA Canada - Regina Facilities	EVRAZ Inc NA Canada	Regina	Saskatchewan	215,078.94
192	Ste Sophie Landfill	Waste Management of Canada Corporation	Ste Sophie	Quebec	210,777.00
193	Shell Burnt Timber Gas Plant	Shell Canada Limited	Sundre	Alberta	209,840.02
194	Kirkland Lake Generating Station	Northland Power Inc.	Kirkland Lake	Ontario	207,966.00
195	NPIF Kingston CoGen Corp.	Kingston CoGen Limited Partnership	Bath	Ontario	205,724.79
196	ATCO Gas - Distribution Systems and Carbon Plant	ATCO Gas and Pipelines Ltd	Alberta	Alberta	203,828.45
197	Region of Peel - Britannia Sanitary Landfill Site	Region of Peel - Britannia Sanitary Landfill Site	Mississauga	Ontario	201,810.00
198	Brunswick Smelter	Xstrata Canada Corporation	Belledune	New Brunswick	200,467.82
199	Greenfield Energy Centre	Greenfield Energy Centre, LP	Courtright	Ontario	193,668.18
200	Ottawa Health Sciences Centre (OHSC) Cogeneration Facility	TransAlta Generation Partnership	Ottawa	Ontario	191,669.07
201	Hamilton	Columbian Chemicals Canada ULC	Hamilton	Ontario	188,601.00
202	EKATI Diamond Mine	BHP Billiton Diamonds Inc.	Yellowknife	Northwest Territories	187,914.42

203	Windsor Essex Cogeneration Plant	TransAlta Generation Partnership	Windsor	Ontario	185,970.07
204	HBM&S Co., Limited - Metallurgical Complex	Hudson Bay Mining and Smelting Co., Limited	Flin Flon	Manitoba	185,189.94
205	Balzac Power Station	Nexen Inc.	Balzac	Alberta	182,946.56
206	Trail Road Landfill Facility	Dillon Consulting Limited	Ottawa	Ontario	180,940.02
207	Lafarge Kamloops Plant	Lafarge Canada Inc.	Kamloops	British Columbia	180,895.00
208	Carmeuse Lime (Canada) Ltd Northern	Carmeuse Lime (Canada) Limited	Blind River	Ontario	178,635.37
209	Christina Lake SAGD Bitumen Battery	FCCL Oil Sands Partnership	Lac La Biche	Alberta	178,306.90
210	KRONOS Canada, Inc.	KRONOS Canada, Inc.	Varennes	Quebec	178,301.39
211	SaskEnergy Incorporated	SaskEnergy Incorporated	Regina	Saskatchewan	176,361.90
212	Redwater Cogeneration Facility, Alberta	TransCanada Energy Ltd.	Redwater	Alberta	175,625.61
213	Grand Lake Generating Station	NB Power Generation Corporation	Newcastle Creek	New Brunswick	175,000.00
214	Coal Valley Mine	Coal Valley Resources Inc.	Edson	Alberta	174,438.21
215	Minnedosa Ethanol Plant	Husky Oil Operations Ltd	Minnedosa	Manitoba	174,376.66
216	INEOS NOVA Ltd - Sarnia Site	INEOS NOVA LLC	Sarnia	Ontario	173,305.03
217	Terrace Bay Facility	Terrace Bay Pulp Inc.	Terrace Bay	Ontario	172,222.07
218	Sarnia Fractionation Plant	BP Canada Energy Company	Sarnia	Ontario	170,066.26
219	MacKay River, In-Situ Oil Sands Plant	Petro-Canada	Fort McMurray	Alberta	169,464.23
220	Prentiss Manufacturing	MEGlobal Canada Inc.	Lacombe County	Alberta	169,114.04

	Facility				
221	Mine de Mont-Wright	ArcelorMittal Mines Canana	Fermont	Quebec	169,092.61
222	Niagara Waste Systems Limited	Niagara Waste Systems Limited	Thorold	Ontario	168,588.27
223	Essex County Landfill No. 3	Essex-Windsor Solid Waste Authority	Lakeshore	Ontario	168,536.95
224	Joliette	Graymont (QC) Inc.	Joliette	Quebec	167,881.29
225	Windfall 8-17 GP	SemCams ULC	Whitecourt	Alberta	167,586.23
226	Burrard Generating Station	British Columbia Hydro and Power Authority	Port Moody	British Columbia	167,490.35
227	Fort Nelson Generating Station	British Columbia Hydro and Power Authority	Fort Nelson	British Columbia	167,132.88
228	Irving Paper	Irving Paper Limited	Saint John	New Brunswick	165,137.66
229	Crofton Division	Catalyst Paper Corporation	Crofton	British Columbia	162,149.80
230	Cavalier Power Plant	EnCana Corporation	Strathmore	Alberta	158,996.82
231	Exshaw	Graymont Western Canada Inc.	Exshaw	Alberta	157,820.99
232	AV Nackawic	AV Nackawic Inc.	Nackawic	New Brunswick	157,801.80
233	Faulkner	Graymont Western Canada Inc.	Faulkner	Manitoba	157,582.15
234	Whitby Cogeneration	Whitby Cogeneration L.P.	Whitby	Ontario	156,492.50
235	Great Divide	Connacher Oil and Gas Limited	Fort McMurray	Alberta	155,603.80
236	Rio Tinto Alcan-Usine Beauharnois	Rio Tinto Alcan-Usine Beauharnois	Melocheville	Quebec	155,101.09
237	ATCO Pipelines	ATCO Gas and Pipelines Ltd.	Edmonton	Alberta	152,572.37

238	Gathering	Spectra Energy Transmission	Fort St. John	British Columbia	152,155.50
239	Wildboy Gas Plant	Penn West Petroleum Ltd	Helmut	British Columbia	151,367.12
240	Thebaud Platform	ExxonMobil Canada Properties	Offshore	Nova Scotia	151,274.84
241	Highland Valley Copper	Highland Valley Copper	Logan Lake	British Columbia	151,234.84
242	Lake Superior Power	Lake Superior Power	Sault Ste. Marie	Ontario	150,706.67
243	Elk Falls Division	Catalyst Paper	Campbell River	British Columbia	149,357.19
244	Hinton Pulp	West Fraser Mills Ltd.	Hinton	Alberta	148,331.30
245	Coal Mountain Operations	Teck Coal Limited	Sparwood	British Columbia	145,877.65
246	Mine Raglan	Xstrata Nickel - Mine Raglan	Rouyn-Noranda	Quebec	143,465.66
247	East Crossfield Gas Plant 9-14-28-01W4	PrimeWest Energy Inc.	Crossfield	Alberta	143,240.43
248	Silicium Bécancour inc.	Silicium Bécancour inc.	Bécancour	Quebec	140,635.53
249	Kidd Metallurgical Site	Xstrata Canada Corporation	Timmins	Ontario	138,771.01
250	Aciérie - ArcelorMittal Contrecoeur	ArcelorMittal Montréal Inc.	Contrecoeur	Quebec	138,048.41
251	W12A Landfill	Corporation of the City of London	London	Ontario	137,090.25
252	Gerdau AmeriSteel Whitby	Gerdau AmeriSteel Whitby	Whitby	Ontario	135,922.23
253	Centrale de cogénération de Kingsey Falls	Fonds de revenus Boralex Énergie	Kingsey Falls	Quebec	132,526.84
254	Wildcat Hills Gas Plant	Petro-Canada Oil & Gas	Cochrane	Alberta	132,242.31

255	Prince George Refinery	Husky Oil Operations Ltd	Prince George	British Columbia	128,263.70
256	Oshawa Car Assembly Plant	General Motors of Canada Limited	Oshawa	Ontario	125,305.23
257	Orion Complex	Shell Canada Limited	MD of Bonnyville	Alberta	125,206.54
258	Centrale de Cap-aux Meules, Îles-de-la-Madeleine	Hydro-Québec	Cap-aux-Meules	Quebec	124,644.63
259	Mohawk Street Landfill	The Corporation of the City of Brantford	Brantford	Ontario	124,441.00
260	Northwood Pulp Mill	Canfor Pulp Limited Partnership	Prince George	British Columbia	123,825.00
261	Eurocan Pulp and Paper Co.	West Fraser Timber Co.	Kitimat	British Columbia	122,799.48
262	Copper Cliff Nickel Refinery	Vale Inco Limited	Copper Cliff	Ontario	121,955.36
263	Bienfait Mine	Prairie Mines & Royalty	Bienfait	Saskatchewan	120,324.79
264	Cancarb Ltd.	Cancarb Ltd.	Medicine Hat	Alberta	120,205.06
265	Wapiti Gas Plant	Devon Canada Corporation	Grovedale	Alberta	120,145.02
266	Casco Inc. - London Plant	Canada Starch Operating Company Inc.	London	Ontario	119,927.80
267	Prince George Pulp and Paper and Intercontinental Pulp Mills	Canforpulp Limited Partnership	Prince George	British Columbia	119,277.13
268	Becancour Power Plant	TransCanada Energy Ltd.	Bécancour	Quebec	117,500.34
269	Line Creek Operations	Teck Coal Limted	Sparwood	British Columbia	117,397.15
270	Pavilion	Graymont Western	Cache Creek	British Columbia	116,567.30

		Canada Inc.			
271	Essex County Regional Landfill	Essex-Windsor Solid Waste Authority	Essex	Ontario	116,212.13
272	Nevis Gas Plant	Keyera Energy	Stettler	Alberta	115,252.68
273	Peace River Pulp Division	Daishowa-Marubeni International Ltd-Peace River Pu	MD of Northern Lights	Alberta	113,585.44
274	Wolverine Group- Perry Creek Mine	Western Canadian Coal Corp.	Tumbler Ridge	British Columbia	113,191.20
275	Olds Gas Plant	Pengrowth Corporation	Olds	Alberta	112,965.42
276	Domtar Pulp and Paper Products Inc. - Dryden Mill	Domtar Pulp and Paper Products Inc.	Dryden	Ontario	112,223.20
277	Alberta-Pacific Forest Industries Inc. Pulp Mill	Alberta-Pacific Forest Industries Inc. acting as a	County of Athabasca	Alberta	111,863.77
278	Norman Wells Central Processing Facility	Imperial Oil Resources	Norman Wells	Northwest Territories	111,166.01
279	Goldboro Gas Plant	ExxonMobil Canada Properties	Goldboro	Nova Scotia	110,865.20
280	Duffin Creek Water Pollution Control Plant	Regional Municipality of Durham	Pickering	Ontario	108,954.42
281	Domtar Inc., Espanola Mill	Domtar Inc.	Espanola	Ontario	108,102.03
282	Kamloops Pulp Mill	Domtar Pulp and Paper Products Incorporated	Kamloops	British Columbia	108,063.34
283	Wabush Mines - Scully	Wabush Mines	Wabush	Newfoundland & Labrador	107,261.75
284	Summit Road Landfill	City of Winnipeg, Water & Waste Department	Winnipeg	Manitoba	106,491.00

285	Xstrata Nickel Sudbury Smelter	Xstrata Canada Corporation	Falconbridge	Ontario	106,083.57
286	SFK Pâte	SFK Pâte S.E.N.C.	St-Félicien	Quebec	105,430.04
287	Pétromont - Usine de Varennes	Pétromont s.e.c.	Varennes	Quebec	105,160.40
288	Port Mellon	Howe Sound Pulp and Paper Limited Partnership	Port Mellon	British Columbia	104,803.20
289	Kruger Wayagamack inc.	Kruger Wayagamack inc.	Trois-Rivières	Quebec	104,372.93
290	Joffre LAO Plant	INEOS Canada Partnership	Joffre	Alberta	103,802.83
291	Grande Prairie Operations	Weyerhaeuser Company Limited	Grande Prairie	Alberta	103,800.96
292	Cheviot Mine (Cardinal River Operations)	Cardinal River Coals Limited (Teck Coal Limited)	Hinton	Alberta	102,613.98
293	Cariboo Pulp and Paper	West Fraser Mills Ltd	Quesnel	British Columbia	102,535.85
294	Irving Pulp & Paper Ltd.	Irving Pulp & Paper Ltd.	Saint John	New Brunswick	100,948.83
295	North Tangleflags Facility	Canadian Natural Resources Limited	Bonnyville	Saskatchewan	100,547.82
296	Kapuskasing Power Plant	EPCOR Regional Power Services Limited Partnership	Kapuskasing	Ontario	100,223.50
297	Tunis Power Plant	EPCOR Regional Power Services Limited Partnership	Tunis	Ontario	100,184.77
298	Lloydminster Ethanol Plant	Husky Oil Operations Ltd	Lloydminster	Saskatchewan	99,262.10
299	Cavendish Farms	Cavendish Farms Corporation	New Annan	Prince Edward Island	98,589.00

300	Terasen Gas	Terasen Gas Inc	British Columbia	British Columbia	98,344.43
301	BFI Usine de triage Lachenaie Ltée.	BFI Usine de triage Lachenaie Ltée.	Terrebonne	Quebec	97,226.01
302	Works 84, Owen Sound Flat Glass Plant	PPG Canada Inc.	Owen Sound	Ontario	96,804.36
303	CEPSA Chimie Montréal, s.e.c.	CEPSA Chimie Montréal, s.e.c.	Montréal-Est	Quebec	94,751.23
304	Quirk Creek Gas Plant	Imperial Oil Resources	Millarville	Alberta	92,791.64
305	Greater Toronto Airports Authority	Greater Toronto Airports Authority	Mississauga	Ontario	91,957.62
306	East Calgary Landfill	City of Calgary	Calgary	Alberta	90,431.50
307	Brazeau Gas Plant	Keyera Energy	Drayton Valley	Alberta	89,409.67
308	Brazeau Gas Plant	Blaze Energy Ltd.	Drayton Valley	Alberta	88,447.11
309	Sierra Gas Plant	ExxonMobil Canada Ltd	Fort Nelson	British Columbia	88,093.10
310	Dyno Nobel Nitrogen Inc.	Dyno Nobel Nitrogen Inc.	Maitland	Ontario	87,778.04
311	Varennes Plant	Greenfield Ethanol Inc.	Varennes	Quebec	86,536.36
312	Division des papiers pour publications	Kruger inc.	Trois-Rivières	Quebec	83,414.92
313	Brock West Landfill	City of Toronto	Pickering	Ontario	81,724.50
314	Cochrane Generating Station	Northland Power Inc.	Cochrane	Ontario	81,169.70
315	Bowater - Thunder Bay Operations	Bowater Canadian Forest Products Inc.	Thunder Bay	Ontario	81,154.15
316	Mazeppa Sour Gas Plant	Mazeppa Processing Partnership	High River	Alberta	80,720.21
317	Bear Creek Power Plant	TransCanada Energy Ltd.	Grande Prairie	Alberta	79,119.53
318	Carstairs - Crossfield Gas Plant	Bonavista Petroleum Ltd.	Carstairs	Alberta	76,536.29

319	Usine Laurentide	Compagnie Abitibi Bowater du Canada	Grand-Mère	Quebec	74,840.00
320	FS1 EOEG	MEGlobal Canada Inc.	Fort Saskatchewan	Alberta	73,402.49
321	Havelock	Graymont (NB) Inc.	Havelock	New Brunswick	73,325.69
322	Terasen Gas Vancouver Island	Terasen Gas (Vancouver Island) Inc.	British Columbia	British Columbia	70,113.04
323	Caribou North Compressor Station	EnCana Oil & Gas Co. Ltd.	Bonnyville	Alberta	64,382.95
324	Harmac Pacific Operations	Nanaimo Forest Products Ltd.	Nanaimo	British Columbia	54,921.85
325	Bonnie Glen Gas Plant	Imperial Oil Resources	Thorsby	Alberta	51,825.49
326	Prentiss Manufacturing Facility	Dow Chemical Canada ULC	Lacombe County	Alberta	38,009.46
327	Port Alberni Division	Catalyst Paper Corporation	Port Alberni	British Columbia	36,521.70
328	Powell River Division	Catalyst Paper Corporation	Powell River	British Columbia	34,439.20
329	Rainbow Lake Generating Station (Units 1-3)	Alberta Power (2000) Ltd.	Rainbow Lake	Alberta	29,565.61
330	Umicore Autocat Corp	Umicore Autocat Corp	Burlington	Ontario	23,153.60
331	Transfer Station No. 2	Essex-Windsor Solid Waste Authority	Kingsville	Ontario	21,080.54
332	Tiverton Plant	Greenfield Ethanol Inc.	Tiverton	Ontario	20,411.37
333	Poplar Hill Generating Station	ATCO Power Canada Ltd.	Grande Prairie	Alberta	18,154.04
334	Usine de fluorure	Rio Tinto Alcan Métal Primaire	Jonquière	Quebec	13,558.89
335	Portlands Energy Centre	Portlands Energy Centre LP	Toronto	Ontario	12,553.21

336	Electrolux Canada Corp.	Electrolux Canada Corp.	L'Assomption	Quebec	10,960.40
337	Usine de Bécancour	Société PCI Chimie Canada	Bécancour	Quebec	7,958.93
338	Valleyview Generating Station	ATCO Power Canada Ltd.	Valleyview	Alberta	7,682.77
339	Grande Praire Combined Heat and Power Plant	Canadian Gas and Electric	Grande Prairie	Alberta	7,680.26
340	Paper Recycling Division	Catalyst Paper Corporation	Coquitlam	British Columbia	6,095.45
341	Delta Plant	Buckeye Canada	Delta	British Columbia	4,465.62
342	Bayer CropScience Inc. Formulation Facility	Bayer CropScience Inc.	Regina	Saskatchewan	2,515.31
343	Wheat City Metals	General Scrap Partnership	Regina	Saskatchewan	2,137.62
344	General Scrap	General Scrap Partnership	Winnipeg	Manitoba	1,892.00
345	Navajo Metals	General Scrap Partnership	Calgary	Alberta	1,862.31
346	Lakehead Scrap Metal	General Scrap Partnership	Thunder Bay	Ontario	1,075.78
347	GenAlta Recycling Inc.	General Scrap Partnership	Edmonton	Alberta	678.66
348	Metal Systems of Canada	Metal Systems of Canada	Dundalk	Ontario	0.52
349	Courtenay Bay Generating Station Unit #2	Irving Paper Limited	Saint John	New Brunswick	0.00
350	Sturgeon Generating Station	Alberta Power (2000) Ltd.	Valleyview	Alberta	0.00
Total				0	262,564,631.91