Sustainability Applied®

BLOOM CLEAN TECHNOLOGY DEMONSTRATION PROGRAM

CASE STUDY

Demonstrating the Performance of a Small-Scale Anaerobic Digester System at an Ontario Dairy Farm

GREENHOUSE GAS REDUCTION

LOW CARBON ECONOMY

Prepared by:
The Bloom Centre for Sustainability (BLOOM)

SEPTEMBER 2018

CONTACT INFORMATION

BLOOM
Kevin Jones
President & CEO
kjones@bloomcentre.com

Wayside Energy
John Hawkes
Founder
johnhawkes@rogers.com

Harcolm Farms
Robert McKinlay
Co-Owner
rob@harcolm.com

BLOOM CLEAN TECHNOLOGY DEMONSTRATION PROGRAM

CASE STUDY
Demonstrating the Performance of a Small-Scale Anaerobic Digester System at an Ontario Dairy Farm

Program Overview

The objective of the BLOOM Clean Technology Demonstration Program is to demonstrate the commercial application of cleantech and low carbon solutions with a high potential to achieve major greenhouse gas (GHG) emission reductions in targeted sectors.

The outcomes and results from the demonstration Projects are being used to:

- Illustrate to sector stakeholders that viable cleantech and low carbon solutions are commercially available;
- Reduce the perceived environmental, economic, and business risks of adopting cleantech solutions; and
- Bridge the ‘adoption gap’ and increase the market demand for cleantech solutions that can reduce GHG emissions and support the transition to a low carbon economy.

The Challenge

Dairy farms generate considerable quantities of cattle manure. On average, a 1,400 pound lactating dairy cow produces nearly 54,000 pounds of manure annually[1]. The most common practice used by Ontario dairy farmers to manage manure involves the collection and storage of the manure (usually in contained outdoor pits), followed by land application. Manure has beneficial properties that can improve or maintain soil health and provide valuable nutrients for crop production.

However, there are high costs, land base requirements and labour challenges associated with the current practice. Manure management systems in Ontario are highly regulated under the Nutrient Management Act and O. Reg. 267, due to concerns around odour impacts on adjacent property owners, and restrictions on time of year when manure can be land applied to prevent run-off and possible surface and groundwater contamination.

Manure also represents a major source of GHG emissions on a dairy farm. Methane is released as an off-gas when manure is stored in outdoor pits. Methane is a GHG and has 28 to 34 times more global warming potential than carbon dioxide (CO_2).

An alternative option for managing manure is through on-farm Anaerobic Digester (AD) systems. Under controlled operating conditions, these systems biologically break down the organic matter (manure) in the absence of oxygen to produce methane. The produced methane (called biogas or renewable natural gas, RNG) can then be easily captured and 'cleaned' to use in the generation of electricity and heat.

A small number of larger dairy and other livestock farms in Ontario (250 to 1,000 cattle or more) have installed AD systems. Many of these were built to align with Ontario's Feed-In-Tariff program, i.e., systems designed to produce 500 kW of electricity. These systems have high capital costs as well as considerable input feedstock requirements. This requires farmers to import additional organic materials from off-site, to supplement the livestock manure that is generated on-site.

While these larger AD systems have been successful, they are not affordable or practical for the average sized dairy farm operation (80 to 100 cattle), which represent the majority of farms in Ontario. This perpetuates the commonly held belief in the industry that small-scale anaerobic digesters are not a technically and economically viable option.

Methane is a greenhouse gas (GHG) and has 28 to 34 times more global warming potential than CO_2.

It is estimated that methane emissions from manure storage represent on average, 29 kg of methane per cow per year.

Source: National Inventory Report 1990–2016 – Greenhouse Gas Sources and Sinks in Canada: Executive Summary. Environment and Climate Change Canada 2018.

1 http://www.sustainabledairy.org/Documents/DairyCap_GreenhouseGas_FactSheet_Final2.pdf

The Small-Scale Anaerobic Digester Opportunity

The opportunity being demonstrated in this Project was to identify the combined benefits of installing a small-scale anaerobic digester (AD) at an average size dairy farm in rural Ontario, and how this system can support the concept of a 'carbon neutral farm' of the future.

"What we are trying to do is offset every bit of fossil fuel use that the farmer would have."

– John Hawkes, Owner, Wayside Energy

A major benefit of this system is that the design is scaled to fit the size of the farm. This means that the feedstock for the digester is solely supplied by the manure from the on-farm dairy cattle (i.e., avoids the need to 'import' off-farm organics).

Adoption of small-scale AD systems by Ontario's dairy farms can result in a wide range of economic and environmental benefits. The first is a significant reduction in energy costs. The renewable energy produced from the digester can provide all of the electricity needs of the farm and the RNG can be used for space heating in the farm buildings, and as a possible transportation fuel source in farm equipment. **This will allow the farm to be 'energy self-sufficient' and protect it from rising electricity and fuel costs in the future.**

In addition to energy cost savings, there are also benefits in the form of GHG reductions. GHG emissions are reduced in two ways: the reduction of otherwise escaping methane from storage in outdoor manure pits; and the off-setting of CO_2 emissions associated with electricity produced from Ontario's centralized grid and heating fuel for farm buildings (many dairy farms in rural Ontario are not connected to natural gas infrastructure and use propane for heating).

Finally, there are additional benefits through use of the waste by-product of the AD process. This product is called 'digestate' and it is a nutrient-rich slurry with beneficial properties. The liquid digestate can be applied to crop land as a soil amendment and can reduce the cost of chemical fertilizer. The solid digestate can be dewatered through a screw press for use as cattle bedding and can eliminate the cost of sand or other purchased bedding.

In summary, an AD system can provide dairy farmers with an automated and 'closed-loop' energy and manure management solution. It allows dairy farmers to optimize the use of resources and materials that are available on the farm to improve their operations, reduce costs and grow their businesses.

"Getting off-the-grid to generate our own renewable energy and closing the loop in managing our manure just makes sense. This is a self-contained solution where all outputs are captured to make better use of them and add value to our business."

– Rob McKinlay, Harcolm Farms

The Market Adoption Potential

There are more than 3,600 dairy farms in Ontario and just fewer than 11,000 dairy farms in Canada. The majority of these are average-sized dairy farms that have approximately 85 milking cattle, which could benefit from the installation of a small-scale anaerobic digester.

Other livestock operations such as hogs could also benefit from adoption of on-farm AD systems. According to Canadian Pork Council Hog Farm Data, there are 2,500 pig farms in Ontario, averaging about 1,300 pigs per farm (http://www.cpc-ccp.com/hog-farm-data).

2017 Dairy Sector Facts:

Ontario has more than 3,600 dairy farms, 309,000 dairy cows, and 163,100 dairy heifers (young stock).

The average size of a dairy operation in Ontario and Canada is approximately 85 milking cows plus young stock.

In total, there are just under 11,000 dairy farms in Canada with milk shipments, 945,000 dairy cows, and 454,300 dairy heifers.

(Source: Government of Canada, Canadian Dairy Information Centre. Dairy Facts and Figures: Number of Farms, Dairy Cows, and Heifers. 2017)

Investments in an on-farm AD system would allow dairy and other livestock producers to be 'energy independent' and be insulated from future cost-increases, as well as realizing other cost-savings associated with manure management. For smaller farm operations where margins are low, any opportunity to reduce costs and improve the bottom-line is vital for long-term business competitiveness.

However, several key factors would need to converge to allow for widespread market adoption, if dairy farmers are going to change their current energy and manure management practices. At a minimum, the following would have to be achieved:

- The capital cost to install a digester system must be affordable and meet farm equipment Return on Investment (ROI) criteria, which is typically 9 to 11 percent;
- The digester system must be self-contained, reliable, and easy to operate, maintain and service ('plug and play');
- Government policies and regulatory objectives are in place that can act as 'drivers' to incent the installation of AD systems; and
- Flexible financing options are developed that make it economically attractive for dairy and other livestock producers to install AD systems (e.g., operating expense versus capital expense).

The Demonstration

This cleantech demonstration project involved Ontario's 'first installation', commissioning and monitoring of a factory built, small-scale anaerobic digester at an operating dairy farm.

The host for the demonstration was Harcolm Farms, a dairy farm located in Oxford County about five kilometres from Woodstock, Ontario. The farm has a total land area of 200 acres, with about 70 acres of corn. It is currently milking between 70 and 80 cows, with plans to increase this to 200 milking cows. In 2010, the farm was modernized to include a new free-stall barn with a robotic milking system.

The small-scale AD system was built by Biolectric at its manufacturing facility in Belgium. Wayside Energy is the Ontario distributor for this system.

"The innovation space in Ontario has allowed for the first deployment of this technology in North America. This is a great example of a farmer that was willing to take some risk to demonstrate a new technology, with a result that other farmers can see and learn from it."

– Jake DeBruyn, Engineer, New Technology Integration, Ontario Ministry of Agriculture, Food and Rural Affairs

SMALL-SCALE ANAEROBIC DIGESTER AT HARCOLM FARMS

The system consists of two major components: a factory built, pre-packaged 20 foot container; and a reactor vessel made from stainless steel insulated panels.

The components inside the 20 foot container include the engine driven generators (two 10 kW 'gensets'), pumps, mixer drives, a gas purification unit (carbon filter), waste heat recovery manifolds, system controls, switchgear and breakers, and Internet connection. The reactor vessel is a continuous mix mesophilic digester that operates at a temperature of 40 degrees Celsius. The waste heat from the two engine generators will be used to heat the farm buildings.

For the demonstration project, the manure slurry was diverted from the scraper pit inside the cattle barn to the digester tank inside the reactor vessel through use of HDPE pipe and a mast pump.

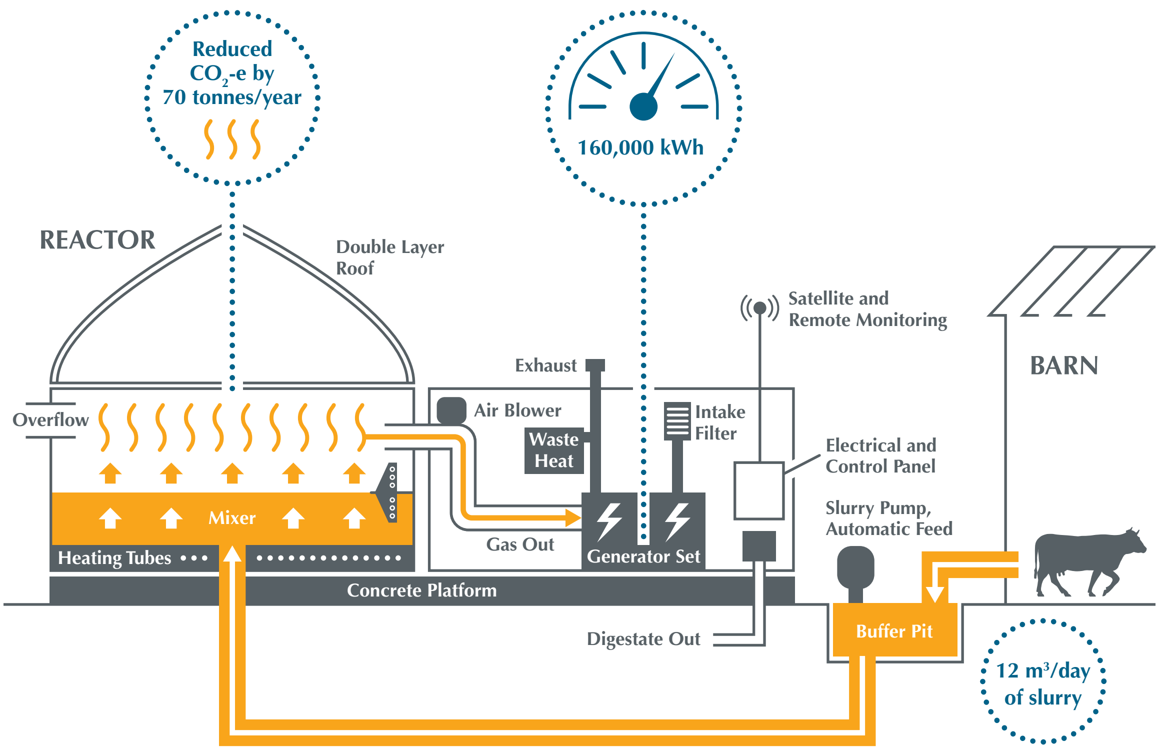
The digestion process releases approximately 80 percent of the available methane, which is routed to the engine fuel injection systems after being cleaned through a carbon filter. The electricity generated provides all of the power needs of the farming operation as well as a residential house on-site. 'Surplus' electricity is sold back into the grid to produce another stream of income for the farm.

Digested slurry is returned to the slurry storage tank and the nutrients are available to the farmer to land apply in three seasons, with the majority of the odour, pathogens and methane removed.

There are plans to install a screw press at the reactor exit to process the straw fibers from the digestate that can be used as animal bedding.

Figure 1 provides a schematic of the various components of the small-scale anaerobic digestion system.

FIGURE 1: COMPONENTS OF THE 20 KW ANAEROBIC DIGESTER SYSTEM



Monitoring

A detailed data collection and monitoring plan for the AD process and system was developed. The key variables, parameters and the measurement frequency for each are shown in Table 1.

TABLE 1: PROJECT MONITORING PLAN

VARIABLES / PARAMETERS	MEASUREMENT FREQUENCY
BIOGAS	
Biogas production – Biogas flow from digester to biogas combustion/control system (engine-generators) (m^3/hr)	Continuous metering
Biogas composition – Fraction of methane in biogas (m^3 CH_4/m^3 biogas)	At least three times during demonstration
Venting events (hr)	Every venting event
Biogas utilization	Continuous if possible through direct metering
SOLID DIGESTATE	
Total volume generated	Each batch or at least monthly
Storage before use	Each batch
Report any treatment before use	Each batch
Use of solid digestate	Each batch
Solid digestate characteristics	Monthly samples
Impacts of bedding on cow behaviour and barn environment	As observed
Disposal of bedding	Each time
LIQUID DIGESTATE	
Total volume generated	Each batch or monthly if continuous production
Use of liquid digestate	Each batch used
Liquid digestate characteristics	Monthly or before land application

Demonstration Results

Installation of the system started in January 2018 and was completed on-site in three days. The system was operational in February following initial testing and system ramp-up. The entire system is fully automated, allowing the operation to be seamlessly managed and monitored from a smart phone.

The system generates a total of 20 kW from two 10 kW 'gen sets'. A key milestone was reached on March 27, 2018 when the farm connected the system to the electrical grid. Harcolm Farms executed two contracts with Hydro One and the Independent Electricity System Operator (IESO):

- A Net Meter contract that provides a cost-avoidance savings of about 20 cents per kWh or $12,000 annually; and
- A MicroFIT contract where the farm sells surplus electricity back into the grid at a price of 25.8 cents per kWh or $20,000 annually.

Based on the operation of the system to date, a pro forma has been developed for future installations, as shown in Table 2.

TABLE 2: PRO FORMA OF THE ANAEROBIC DIGESTER DEMONSTRATION SYSTEM AT HARCOLM FARMS

EXPENSES / REVENUE / COST SAVINGS	EXPENSES ($ CDN)	ANNUAL REVENUE / COST SAVINGS ($ CDN)
Capital and installation expense	$395,000	
Annual operating and maintenance expenses (including labour)	$15,000 to $20,000	
Electricity sales (MicroFIT contract)		$20,000
Electricity displaced purchases (Net Meter contract)		$12,000
Heat displaced purchases (propane)		$10,000
Cost savings on manure handling		$8,000
Cost savings on animal bedding		$15,000
Cost savings on chemical fertilizer		$3,000

As shown in Table 2, the estimated annual revenue and cost-savings from the AD system is approximately $68,000. While this is attractive and provides a dairy farmer with energy independence and a ‘closed-loop’ manure management system, the business case would need to be improved to increase broader market adoption.

GHG Impact Quantification

The BLOOM ‘Impact Quantification’ methodology, known as BLOOM IQ, was used to quantify the ‘net’ GHG emissions reductions that can be realized over the entire life-cycle of the small-scale anaerobic digester system.

Elements that are included in any GHG quantification must be relevant, differ relative to the baseline, and have available quantification methodologies in order to calculate GHG emission reductions. Further details are provided in Appendix A.

To conduct the GHG impact quantification, a credible baseline must be established. Without a credible baseline or benchmark, accurate estimations of potential GHG emission reductions cannot be attributed to a particular Project. The baseline should represent the current business as usual, i.e., what would have occurred in the absence of the Project.

For this demonstration project, the ‘baseline scenario’ is the current status quo dairy farm, where the ‘inputs’ are electricity from the Ontario grid, propane fuel for heating and sand for cattle bedding, and the outputs are the collection, storage and land application of manure and all of the associated GHG emissions.

The ‘project scenario’ is the AD system, where the inputs are parts and equipment to manufacture and assemble the system as well as the dairy cattle manure, and the outputs are the electricity and heat produced, the liquid digestate that is land applied and the solid digestate that is used as cattle bedding.

The associated GHG emissions for the baseline and project scenarios are shown in Figures 2 and 3, respectively.

FIGURE 2: GHG EMISSIONS FROM FARM OPERATION AND MANURE STORAGE ONLY

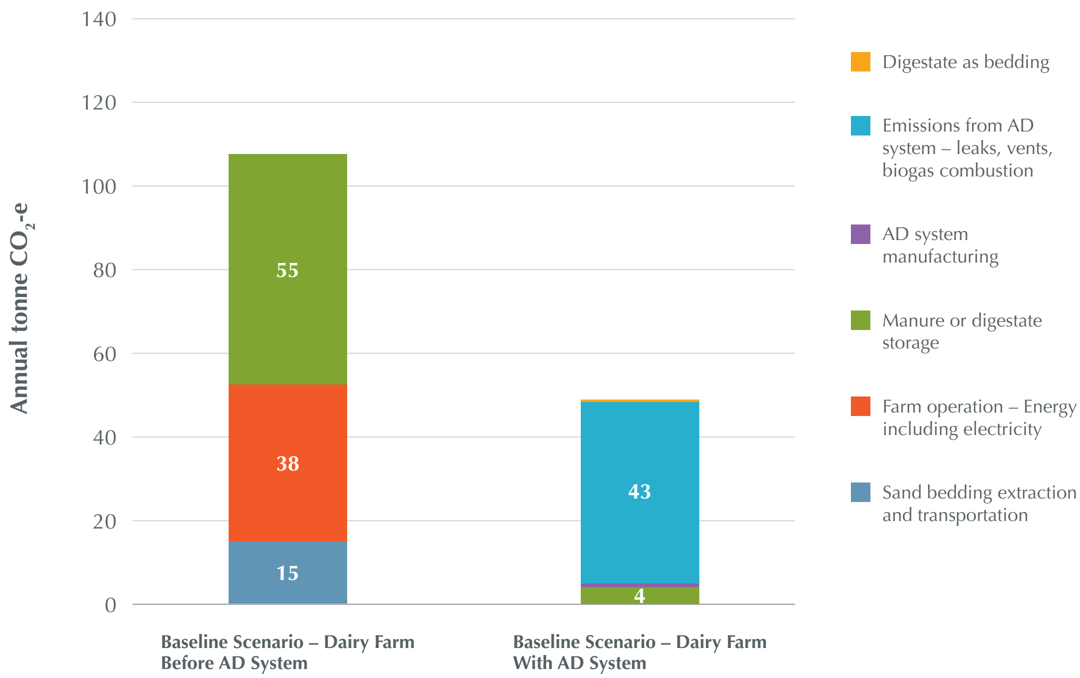
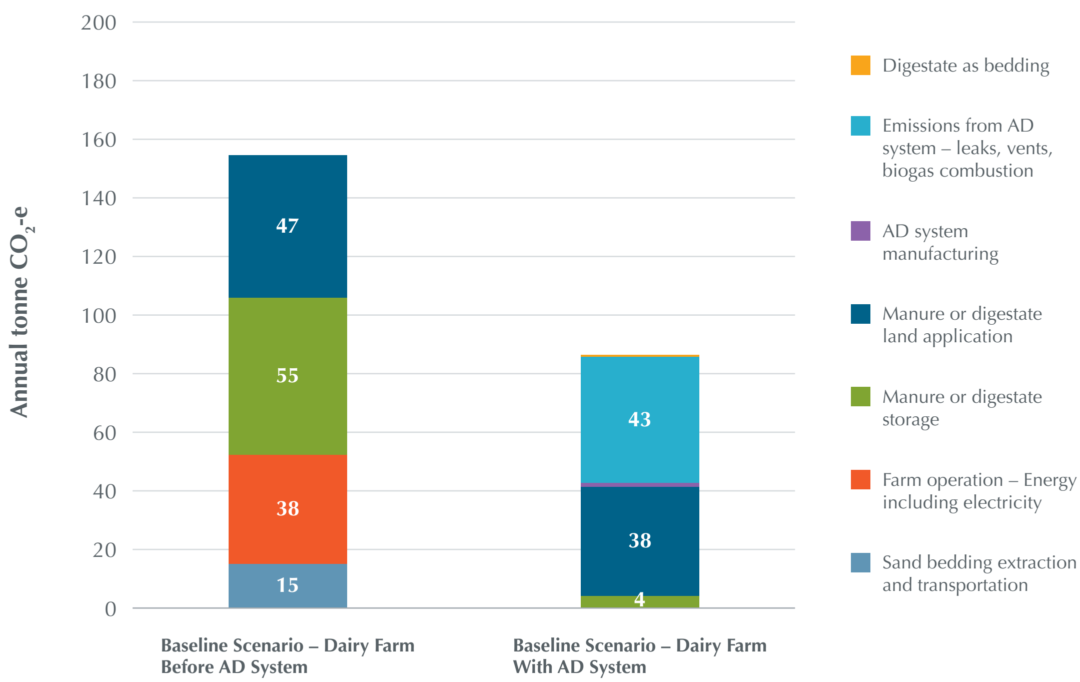


FIGURE 3: GHG EMISSIONS FROM FARM OPERATION, MANURE STORAGE AND LAND APPLICATION



GHG quantification for the farm with and without the AD was completed. The results showed a potential annual reduction of 60 tonne CO_2-e (Carbon dioxide equivalent) per system in Ontario, with potential annual additional reduction of 10 tonne CO_2-e per system when including nitrous oxides (N_2O) emissions from land application.

Figures 4 and 5 illustrate the potential cumulative reductions in GHG emissions from adoption of a small-scale system in Ontario and Canada, respectively. The data is based on an annual one percent adoption rate in the first five years and a two percent adoption rate annually after that, over a 10 year period.

The projected curves show a potential cumulative net GHG emission reduction of 34,450 tonnes in Ontario and 115,241 tonnes in Canada within 10 years. This is equivalent to more than 7,377 and 24,677 passenger cars[2] being taken off the road annually, respectively.

FIGURE 4: CUMULATIVE GHG REDUCTIONS IN ONTARIO

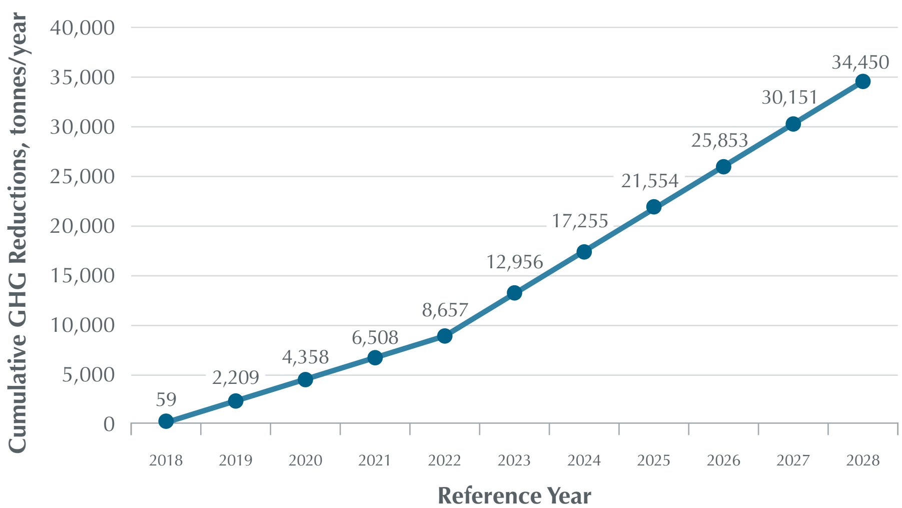
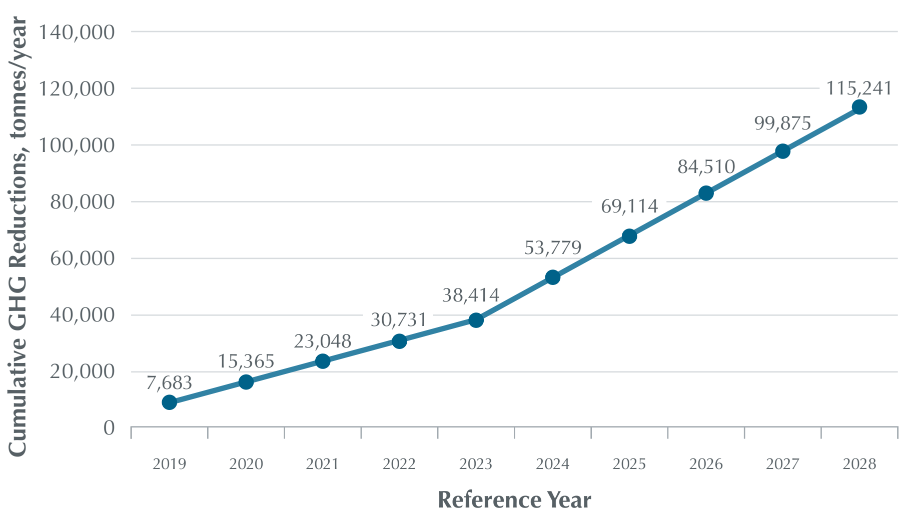
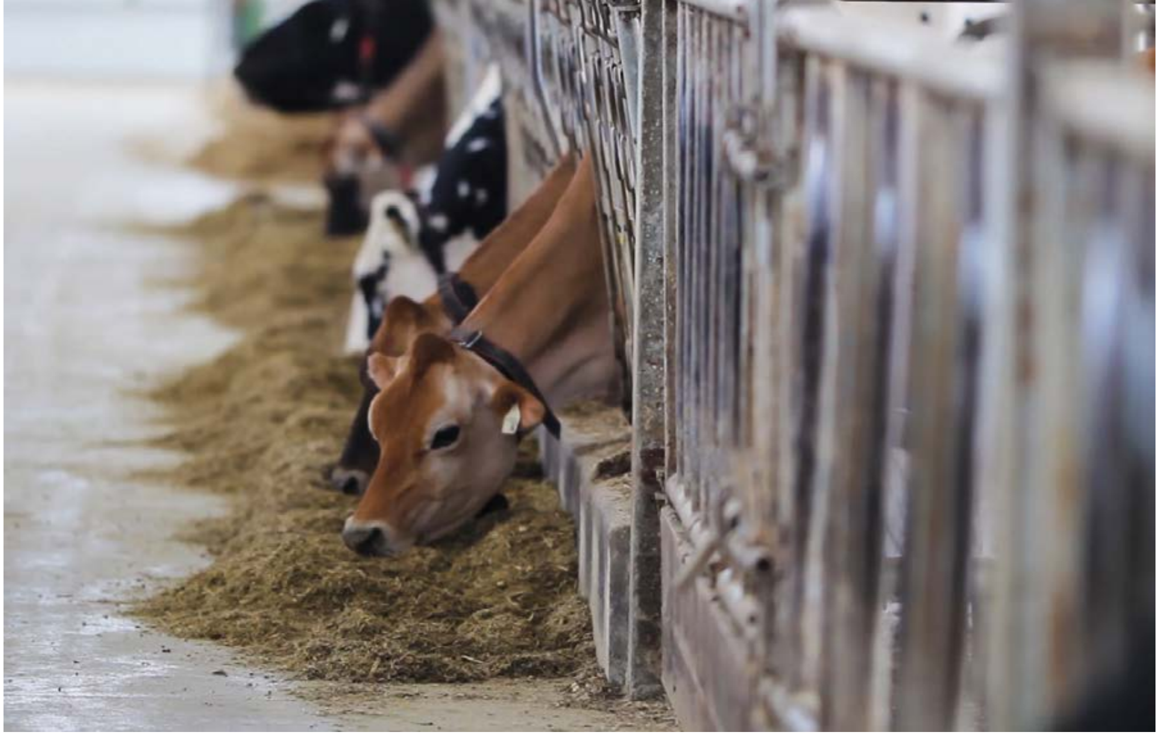


FIGURE 5: CUMULATIVE GHG REDUCTIONS IN CANADA



2 https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator



Sector-Wide Adoption – Positioning for the Future

Reducing Costs and Becoming Energy Self-Sufficient

Dairy farms of any size must be vigilant in controlling and reducing the costs of their operations to remain competitive. This is even more important for smaller farms where margins are tighter due to factors such as limited buying power and higher relative fixed costs.

A small-scale AD system enables dairy farmers to 'get off the grid' and become energy self-sufficient. The AD system also functions as an automated manure management system that can lower these costs, as well as cost avoidance of chemical fertilizers and bedding materials through the reuse of the digestate by-product.

Fitting into the Low Carbon Economy

Governments from around the world are implementing climate change policies as part of the transition towards a low carbon economy. A relevant example is in Sweden where the average CO_2 emission per capita is 4.25 tonnes. Approximately 10 percent of Sweden's total electricity generation is from co-generation systems powered by biogas.

An operator of an AD system in Sweden is paid 0.4 Swedish Krone per thermal kW of biogas that is produced as financial compensation for reducing GHG emissions. This is equivalent to more than $50,000 CDN per year, which would support the ROI for dairy farmers.

On-farm, small-scale AD systems can be a key component in creating the 'Carbon Neutral Farm' of the future.

Enhancing Local Community Relations and Rural Economic Development

Dairy and other livestock farmers that install on-farm digester systems can promote to their customers, policy-makers and local communities that their operations are carried out in an environmentally sustainable manner and significantly reduce GHG emissions.

For instance, in the Township of South-West Oxford, where Harcolm Farms is located, the Township has a long history of supporting and implementing energy conservation and other programs that have a positive impact on the environment. The Township strongly supports the County of Oxford's goals to be on 100 percent renewable energy by 2050.

The Township also recognizes that with more than 300 local dairy farms in the County, there is considerable potential to install on-farm digesters to capture methane gas and generate a cleaner and reliable local supply of renewable energy, while at the same time supporting a competitive dairy industry that can contribute to regional economic development and job creation.

Pre-Competitive Business Issue

Energy and manure management are common 'pre-competitive' business and environmental issues that face all farmers in Ontario's dairy and other livestock industries.

This project has demonstrated the wide ranging economic, environmental and societal benefits that can be realized from more widespread adoption of small-scale, on-farm AD systems.

However, increasing broader market adoption is not going to happen, unless there are proactive, concerted and coordinated actions from key stakeholders in Ontario's dairy industry. These include individual dairy farmers, industry associations such as the Dairy Farmers of Ontario and Canadian Biogas Association, regional and local communities, private investors and financial institutions, and government agencies at the federal, provincial and municipal levels that can each develop supportive policies.

A major need is to identify and develop innovative models to finance the installation of on-farm AD systems across Ontario. These could include traditional models such as a revolving loan fund that could provide farmers with capital at zero interest rates, or a 'service as a solution' model where farmers could pay a lease cost for a system and finance it over a longer period of time through their annual operating budgets.

The Power of the Cumulative to Achieve GHG Emission Reductions

This on-farm AD system is an example of an often overlooked approach to achieve GHG emission reductions. The approach takes advantage of a large number of potential installations to multiply the relatively small GHG savings achieved through an individual dairy farm installation versus the significant cumulative GHG savings achieved through higher rates of market adoption over a 10-year period.

With more than 3,600 dairy farms in Ontario and almost 11,000 in Canada, on-farm, small-scale AD systems have the potential to make a major impact in reducing GHG emissions in the dairy and other livestock industries, while providing other benefits to support sustainable growth and regional economic development.

Appendix A: GHG Quantification Scope and Boundaries Approach

Procedures for Identification Elements and Boundaries

The project and baseline boundaries and elements were identified using the following process:

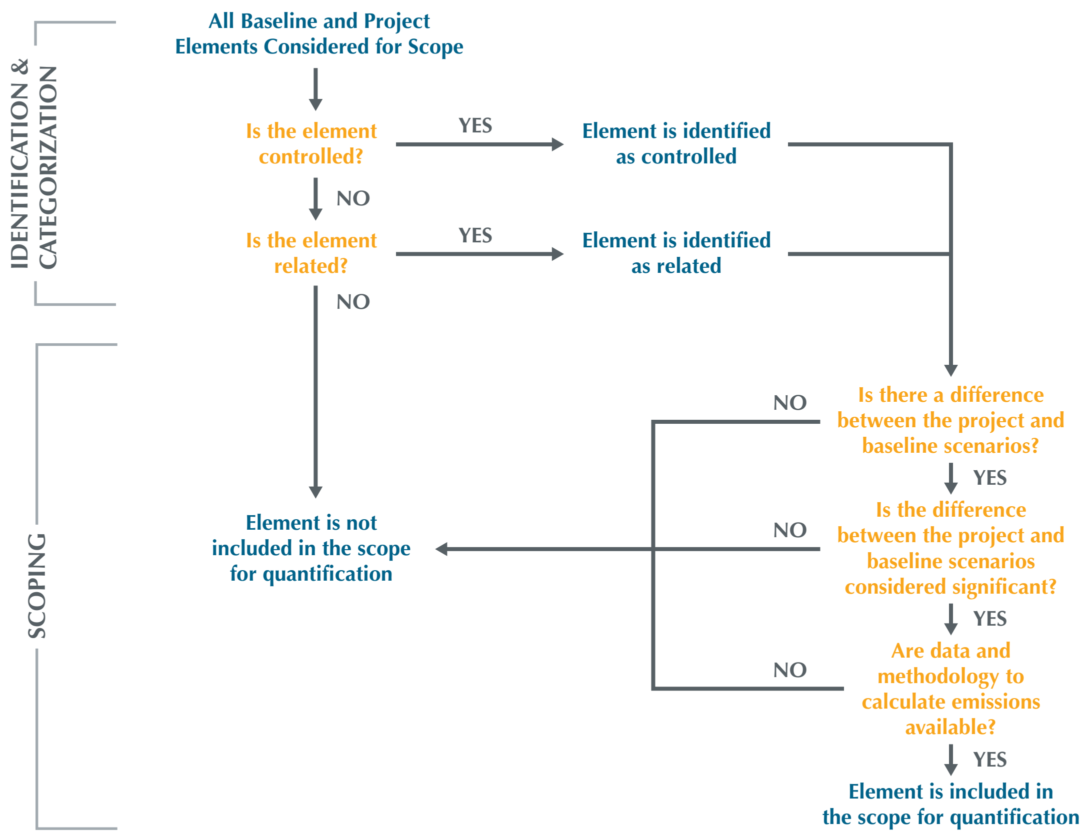
1. Identify the elements for the system (i.e. those directly controlled or owned in the project), including the related (i.e., those elements that are related to the project by energy or material flows) and affected elements (i.e. those elements that cause changes in markets or activity outside the project boundary that are not connected to the project through material or energy flows);

2. Define system boundaries; and

3. Determine if elements are in scope by assessing relevance, significance, and practicality.

All elements identified earlier are either directly or indirectly related to the project or the baseline. In order to determine whether these elements should be included in the scope of the project and would be part of the environmental impacts quantification, the methodology presented in Figure 4 was used.

FIGURE 6: GENERAL METHODOLOGY FOR ELEMENT SELECTION



The Bloom Centre for Sustainability

1540 Cornwall Road, Suite 213
Oakville, ON Canada L6J 7W5

t: 905.842.1115

info@bloomcentre.com
www.bloomcentre.com