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Evaluation of Energy Efficiency and Renewable Energy Generation Opportunities for Small Scale Dairy Farms: A Case Study in Prince Edward Island, Canada

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Abstract

Prince Edward Island (PEI) is the smallest province in Canada measuring about 5700 km^2 in area with a population of around 130,000 people. Small family farm operation is part of the Island's way of life. However, the dairy industry in North America is undergoing significant structural change. Statistics show a significant decline in the small dairy farms industry, while the number of large operations has been increasing. Advantages for large operations include purchasing energy in large quantities with better price margins and the inherent economy of scale created by such breaks. One strategy for small-scale farms to become competitive is to reduce their energy-related operational costs and greenhouse gas emissions. This can be achieved through taking energy efficiency steps, reducing overall energy consumption and generating energy through renewable energy resources and technologies. This paper uses a case study of a small dairy farm in Oyster Bed Bridge, PEI to gain insight into the direct use of energy within small dairy farms. An energy audit methodology is used to determine the energy intensity of the farm as well as energy efficiency opportunities. The paper also assesses the feasibility of meeting part of the energy demand of the farm with renewable energy generation. Energy efficiency recommendations for the case study farm include lighting retrofitting and regular maintenance of refrigeration condenser units. Renewable energy generation findings include the potential use of an anaerobic digester or a 25 kW wind turbine to generate the majority of the operation's energy.

Key Words: Prince Edward Island; dairy farms; energy efficiency; renewable energy

1. Introduction

The existence of small dairy farms in North America is on the decline [1]. The United States Department of Agriculture identified the number of dairy farms in the country in 2006 as 75,000, a decrease of over 80% from the 1970-recorded number of 658,000. During this period, however, an increase of 104% was recorded in the number of large-scale farms with a herd size greater than 2000 [1]. Large-scale farms usually operate 24 hours a day, 7 days a week with continuous milking that results in high volume product output and the advantage of financial capital to create highly efficient operations and facilities. The purchase of industrial equipment in large quantities creates significant advantages to the large-scale operations.

The eastern Canadian province of Prince Edward Island (PEI) is the smallest province in Canada measuring 5684 km^2 in area and consisting of little industry apart from farming and fishing [2]. The farming industry is still a very traditional, family-based industry within the region, with most small operations attempting to remain profitable in the climate of globalization and the trend towards large-scale blanket operations. The energy sources traditionally used on PEI include heating oil, petrol, and electricity [2]. The Island currently contributes 19% of its total electricity supply through wind (18%) and diesel (1%) generation. The remaining 81% is imported from a neighbouring mainland province through two high voltage submarine transmission cables [3]. Approximately 19% of the imported electricity is generated from nuclear sources with the rest derived from carbon intensive resources, mainly coal [4]. In agriculture, the efficient use of energy is one of the priorities for sustainability andagricultural energy use can be classified as either direct or indirect [6]. The primary means of direct energy use on-farm involves the consumption of fuels (diesel, furnace oil, gasoline, and other petroleum products such as propane), electricity and wood. Indirect energy includes the energy used to produce and transport farm inputs such as pesticides and feeds. While indirect energy accounts for about 70% of the energy use in dairy farms [6], it is the direct energy which can be more easily controlled.

2. Research Aim and Objectives

The aim of this paper is to investigate the extent that energy efficiency and renewable energy can assist the economic viability of small-scale diary farms and hence preserve local industry and this traditional way of life. Specifically the objectives of the paper are to:

1) understand the energy consumption profiles of small dairy farms operations within the region of PEI;

2) use an energy audit process to investigate the direct energy use intensity of operation for a small dairy farm case study in PEI; and

3) use the results of the audit to assist in identifying energy efficiency opportunities and possibilities for meeting part of the farm's consumption with renewable energy.

3. Methodology

An investigation of the energy use associated with dairy operation and the feasibility of using renewable energy for the farm's operation requires a broader perspective of the farm's processes and key energy consumption factors as well as the region's energy policy framework and renewable energy resources availability. An energy audit forms the core work of the project. An in-depth energy audit case study of Extondale Farms Ltd., a small family-run dairy farm, in Oyster Bed Bridge, PEI was conducted. Extondale Farms represents the kind of typical small-scale dairy operation found throughout the Atlantic Canadian region and the results of the audit are placed in context through a comparison of energy intensity of the case study farm with farms in the region as well as with global trends. The overall outcome of the audit was to develop a list of recommendations of energy efficiency measures that should be implemented detailing savings, implementation cost and relevant issues of each measure. The RETScreen™ software was used to carry out a portion of the renewable energy feasibility study, investigating the possibility of using renewable energy to meet part of the farm's energy demand.

2.1 Energy Audit Methods

The purpose of an energy audit is to quantify the energy consumption of a facility with the ultimate goal of identifying opportunities for reducing energy use and costs. In Canada, there is no universal standard for energy auditing although numerous professional industry associations have developed their own procedures with varying degrees of application and use [7]. Some of these include the American Society of Heating, Refrigeration and Air Conditioning Engineering (ASHRAE), the Illuminating Engineering Society of North America (IESNA), the Association of Energy Engineers (AEE), and the Canadian Association of Energy Service Companies.

In this study, a three phase energy audit framework, based on the Autralian Government's Energy Management Advisory Booklet [8], was used with the intent of undertaking a structured and systematic approach to energy anaysis upon which benchmarking and energy management opportunities can be clearly defined. This method was chosen based on familiarity of the authors to this audit process. The audit framework is made up of three phases: *Phase I, an audit of historical data*, focuses on the past consumption trends of the facility. *Phase II, the screening survey*, investigates the current operation of the facility and is essentially a screening survey completed in the form of a walk-through audit [8]. In this phase, all energy consuming equipment and process are identified with ratings and estimated operational hours recorded. *Phase III, detailed investigation and analysis*, involves a detailed investigation and further analysis into key areas identified in the *Phase II* analysis with comparison to the results of *Phase I*. Items that may require further examination to determine if efficiency opportunities exist are investigated in detail in *Phase III*.

Facility Description

Extondale Farms Ltd. is a small dairy cattle farm in rural PEI with an active milking herd size of ninety-five (95) cattle. The facility currently consists of one enclosed barn structure of approximately 892 m^2 and is the primary core of all operations and energy consumption on the site. There exist two smaller open-air barns that consist only of lighting energy loads. The three buildings are of wood frame construction with aluminum and wood sidings. The existing lighting fixtures range from incandescent globes, to T8 and compact fluorescent tubes. The primary facility has minimal baseboard electric heating, robust ventilation fans, and a 4500 litre refrigeration tank for milk cooling. Hot water for the tank wash cycle is heated by a propane-fired heating system. A 1.5W electric fence encloses the grazing lands.

Audit Boundary Definition

An audit boundary defines the physical extent or size of the system being audited in terms of the number of sub-systems and components. The boundary of the case study audit encompasses all energy consumption by the primary facility and the two open barns. The defined system boundaries enclose the energy used on the farm for keeping livestock, milking, milk cooling, and cleaning and disinfection. The primary energy sources used in the boundary operations are electricity and propane-fuelled water heating for cooling tank sanitation cycles. The energy used for the transportation of milk to the dairy plant and for packaging are considered secondary (indirect) to the operation of the facility and are therefore considered outside of the audit boundary. Figure 1 depicts the energy audit boundary framework.

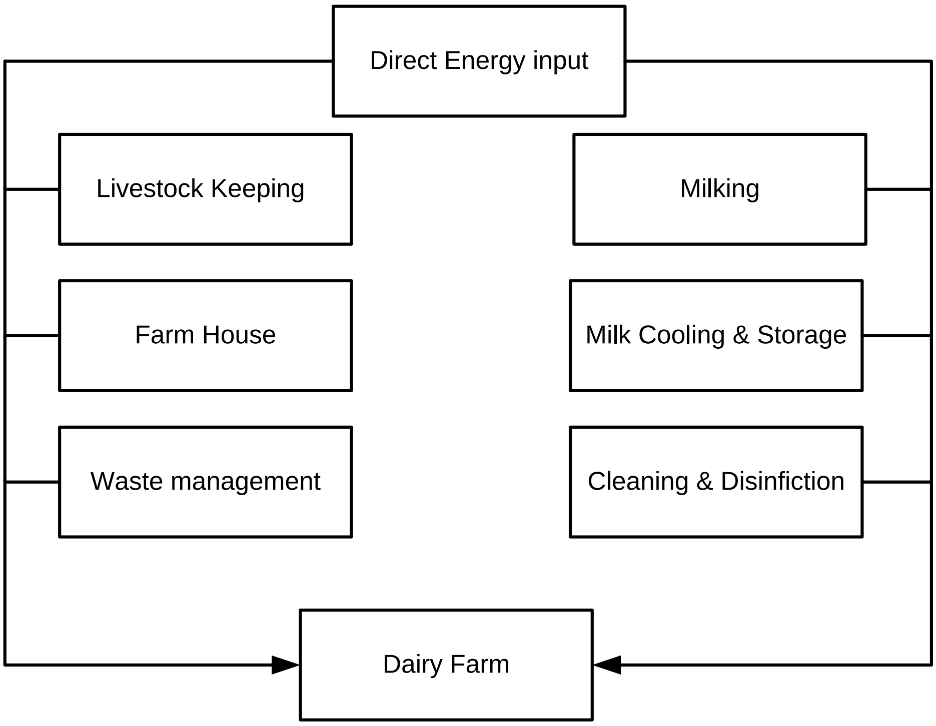


Fig. 1. System boundary and direct energy inflow for the case study farm.

4. Results and Analysis

4.1 Energy Audit Results

This chapter presents the results and analysis of the case study, in which the three phase energy audit approach discussed in the Section 2.1 was applied to Extondale Farms Ltd.

4.1.1 Phase I: Historical Billing Analysis

Electricity and propane are the two primary energy sources consumed within the audit boundary of the case study operation. Historical billing records covering a period of one year were obtained for these two energy sources. An analysis of the billing records dated between November 2010 and December 2011 for the site was undertaken with data normalized to consumption per day for accuracy and comparison purposes. Figure 2 and 3 detail the daily electricity consumption and the daily propane consumption, respectively, over the course of the billing history analysis year.

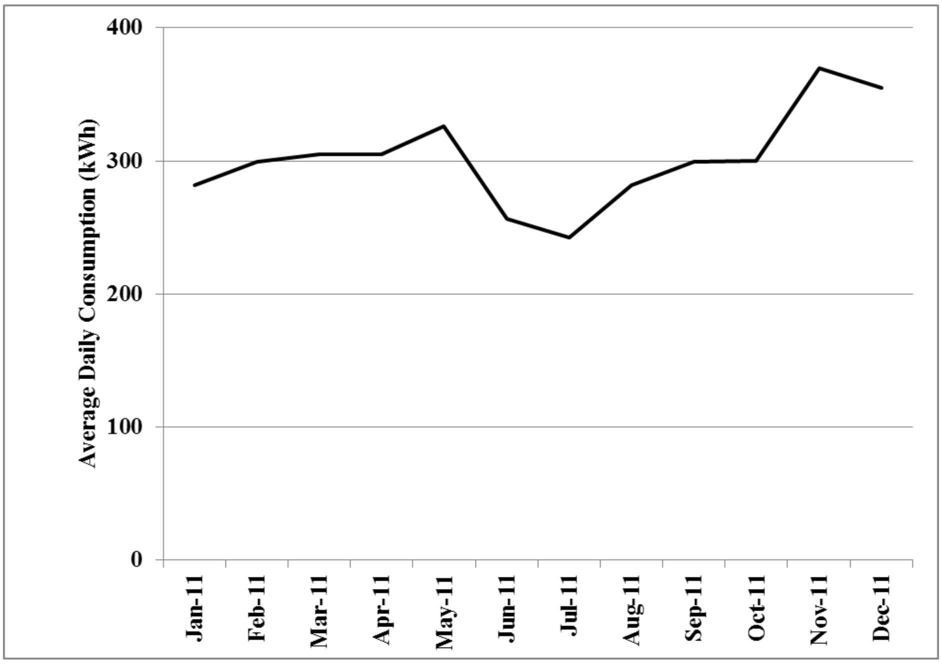


Fig 2. Average daily electricity consumption based on historical billing analysis.

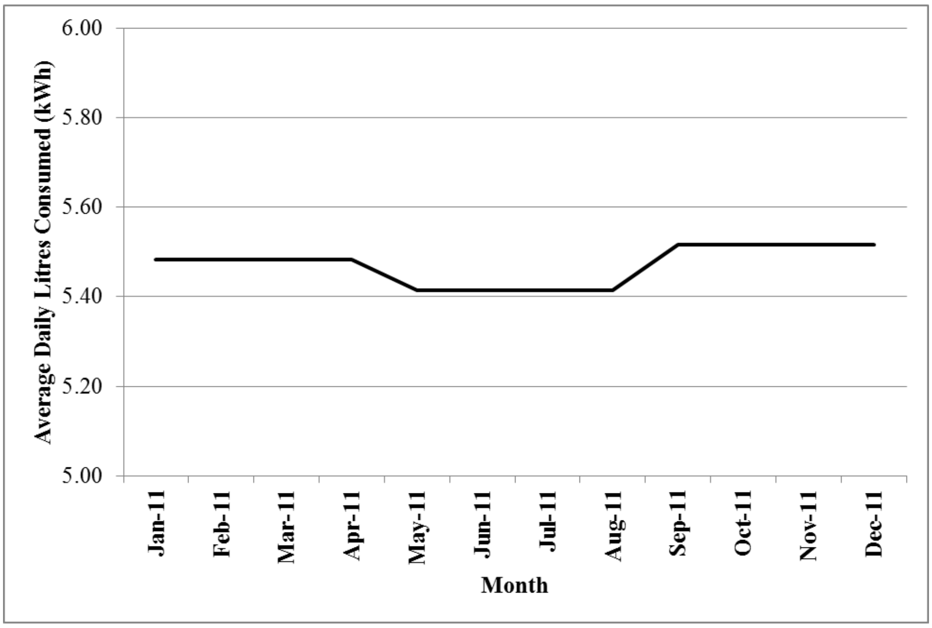


Fig 3. Average daily propane consumption based on historical billing analysis.

The total electricity consumed in the analysis year was found to be 109,678 kWh. The total propane consumed in 2011 was found to be 1,997 litres or 14,034 equivalent kWh. Considering propane and electricity to be the two energy sources within the audit boundary, the total energy consumption of the operation based on historical billing records in 2011 is 123,712 kWh. The percentage of the total consumption accounted for by electricity and propane are 89% and 11% respectively. The energy intensity for the operation is benchmarked as a factor of energy consumption with respect to the herd size. In this case study, the energy intensity is calculated to be 1,302 kWh/head given the total consumption of 123,712 kWh and the herd size of ninety-five (95). This data is key for benchmark comparisons within the industry to assist in future growth and information sharing.

Energy Cost

Extondale Farms Ltd. is a very small operation with one electricity meter encompassing the entire site that includes a previously existing family farmhouse. Given this unique arrangement, the meter's consumption is charged at a Rural Residential rate. Table 1 details the electricity and propane rates at the time of analyzing the historical billing data.

Table 1. Energy rates based on historical billing analysis at Extondale Farms.

Electricity charges	**Rate**
Service Charge	$26.92
Demand Charge	none
Energy Charge	$0.1205 per kWh up to 2000 kWh $0.092 per kWh above 2000 kWh
Propane Charge	**Rate**
Unit Charge	$0.63/Litre

The cost of energy follows a linear relationship with the amount of consumption and therefore does not exhibit opportunities for cost reduction through load shifting. The total annual cost of electricity and propane is $11,097.42 and $1,258.11 respectively, totalling an annual overall energy cost of $12,355.53. The annual cost per head of cattle is therefore $130.06/head.

Energy Consumption Trends and Anomalies

The sanitation cycle, which requires hot water heated by the propane energy source, is a consistent cycle that occurs every 48 hours when the refrigerated milk tank is emptied upon pick-up by the milk purchaser. Variation in propane consumption, though minimal, is evident in Figure 3 and may be the result of seasonal effects. The propane consumption lowers slightly in the summer months, which may be directly related to a rise in the ground water temperature feeding the hot water heating tank. In light of the relatively stable nature of the propane use and it accounting for only 11% of the overall energy consumption, a greater focus will be placed on the electricity consumed.

The electricity consumption over the year does demonstrate some trends and anomalies with respect to external factors such as seasonal changes, which cause operational variances that are evident by reviewing Figure 2. An increase in energy consumption can be identified with the transition to the colder, limited daylight, winter months. December to March is winter within the local region, however the shoulder months surrounding winter can also demonstrate harsh conditions. Figure 4 demonstrates the average daily electricity consumption and the corresponding average temperatures recording during 2011.

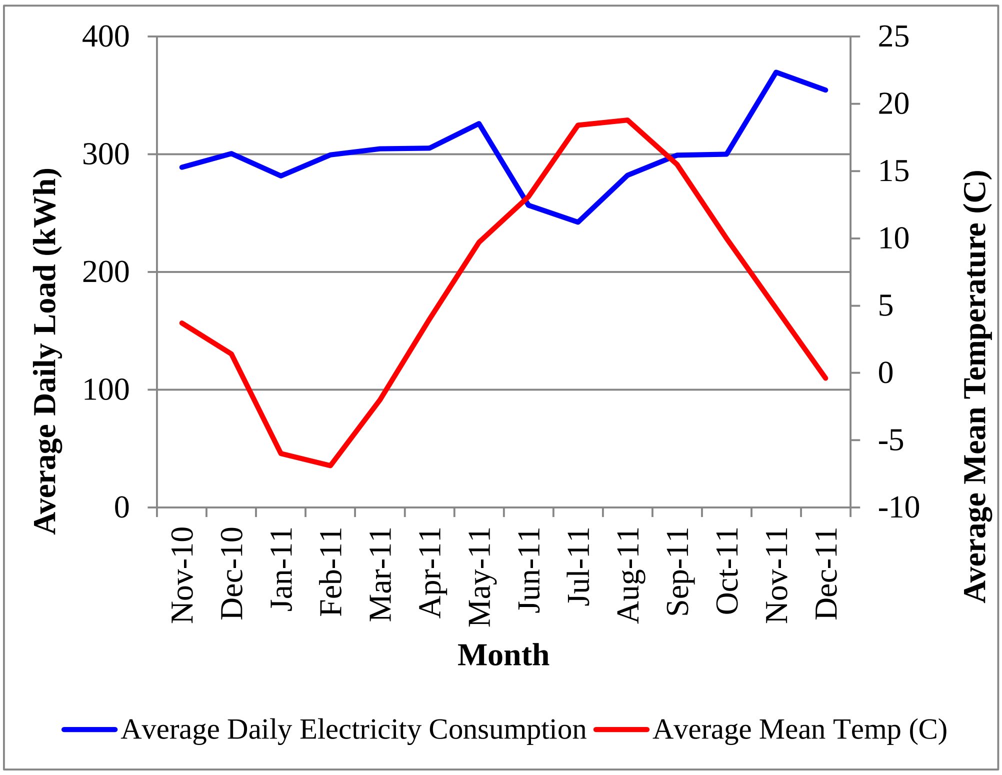


Fig 4. Average daily load and mean temperature trend [22].

An evident reduction in energy consumption is observed during the summer months of June, July, and August. This directly relates to an increase in day-light hours that directly reduces lighting requirements. This, however, does not represent the full story as depicted in Figure 4. The primary factor contributing to the annual electrical consumption trend for the operation is triggered by the changing season, and is associated with the timing in which the herd moves from permanently residing outdoors in the pasture, to permanently residing indoors within the primary facility structure. This is a likely explaination for the two peak consumption periods observed during the months of November and May. In the month of November the temperature begins to fall and freezing temperatures may be experienced overnight and the herd is required to move inside for the winter. However, given that the outside temperature is just at the point of becoming cold, the interior temperature of the barn, filled with the herd, rises much higher than the exterior temperature and therefore the ventilation system functions at its full capacity. This trend occurs again in May prior to the movement of the herd to pasture for the summer months. The ventilation system consists of a wall of fans at the barn's west end and an opposing wall with adjustable air intake panels at the barn's east end. A programmable control system is set to maintain an indoor temperature of 8 degrees Celsius. The ventilation system runs throughout the winter in varying capacities and solely during the 5 hours of milking during the summer months.

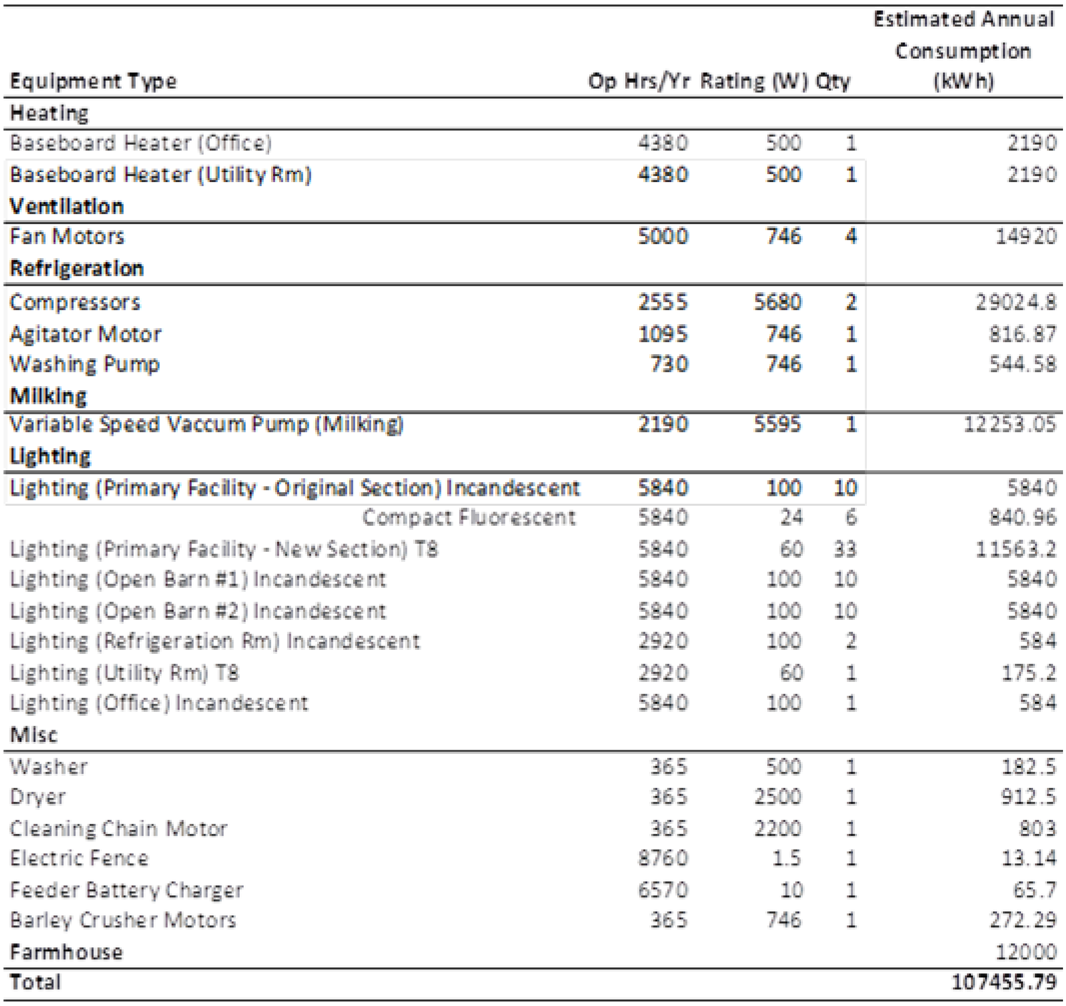
No heating within the main section of the primary facility is therefore required during the winter months. A small office and utility room contain minimal base-board heating, which would also contribute slightly to the increase in electricity consumption during the non-summer seasons.

4.1.2 Phase II: Walk-through Screening Survey

The Phase II Screening Survey was undertaken over the course of five days in November 2011. The process of the operation and consuming equipment were observed for power ratings and operational use trends. The operation requires milking of the herd twice per day at twelve hours intervals. The milk is extracted to the refrigeration tank and remains in holding for pick-up by the local purchaser. The tank is sized at 4500 litres to allow for two days containment or the volume extracted by four milking cycles. One milking cycleproduces approximately 1050 litres of milk. Upon pick-up by the purchaser, the tank undergoes a detailed one-hour sanitation cycle in accordance with local regulations with the purpose of protecting against unwanted bacteria. The 12-hour milking cycle and the two-day milk cooling followed by tank sanitation are the key energy consuming processes that exist within the operation. Table 2 contains the results of the equipment survey and highlights the key energy consumers.

The walk-through audit data listed in Table 2 details the power rating of appliances and the corresponding operational hour estimations, and results in an annual estimated electricity consumption of 107,456 kWh, which is within 2% of the annual electrical consumption of 109,678 kWh found in the facility’s historical billing analysis. The operating hours for each piece of equipment were estimated based upon observation of the facility’s processes and considering seasonal trends that effect operation.

Table 2. Walk-through audit results estimating annual electricity consumption based upon estimated operating hours and equipment ratings.



Equipment Type	Op Hrs/Yr	Rating (W)	Qty	Estimated Annual Consumption (kWh)
Heating				
Baseboard Heater (Office)	4380	500	1	2190
Baseboard Heater (Utility Rm)	4380	500	1	2190
Ventilation				
Fan Motors	5000	746	4	14920
Refrigeration				
Compressors	2555	5680	2	29024.8
Agitator Motor	1095	746	1	816.87
Washing Pump	730	746	1	544.58
Milking				
Variable Speed Vaccum Pump (Milking)	2190	5595	1	12253.05
Lighting				
Lighting (Primary Facility - Original Section) Incandescent	5840	100	10	5840
Compact Fluorescent	5840	24	6	840.96
Lighting (Primary Facility - New Section) T8	5840	60	33	11563.2
Lighting (Open Barn #1) Incandescent	5840	100	10	5840
Lighting (Open Barn #2) Incandescent	5840	100	10	5840
Lighting (Refrigeration Rm) Incandescent	2920	100	2	584
Lighting (Utility Rm) T8	2920	60	1	175.2
Lighting (Office) Incandescent	5840	100	1	584
Misc				
Washer	365	500	1	182.5
Dryer	365	2500	1	912.5
Cleaning Chain Motor	365	2200	1	803
Electric Fence	8760	1.5	1	13.14
Feeder Battery Charger	6570	10	1	65.7
Barley Crusher Motors	365	746	1	272.29
Farmhouse				12000
Total				**107455.79**

The billing analysis may deviate from the walk-through analysis in the area of ventilation energy consumption. It was estimated, based upon seasonal temperature fluctuations and herd location, that the four fans run an estimated 5000 hours per year. This may signify a major error in estimation as the ventilation could theoretically run significantly longer during the year. Most other components of the farm operation are quite cyclical and therefore predictable in their operational trends. Figure 5 represents the breakdown of electricity consumption by the different end-uses as per the results of the Phase II walk-through analysis.

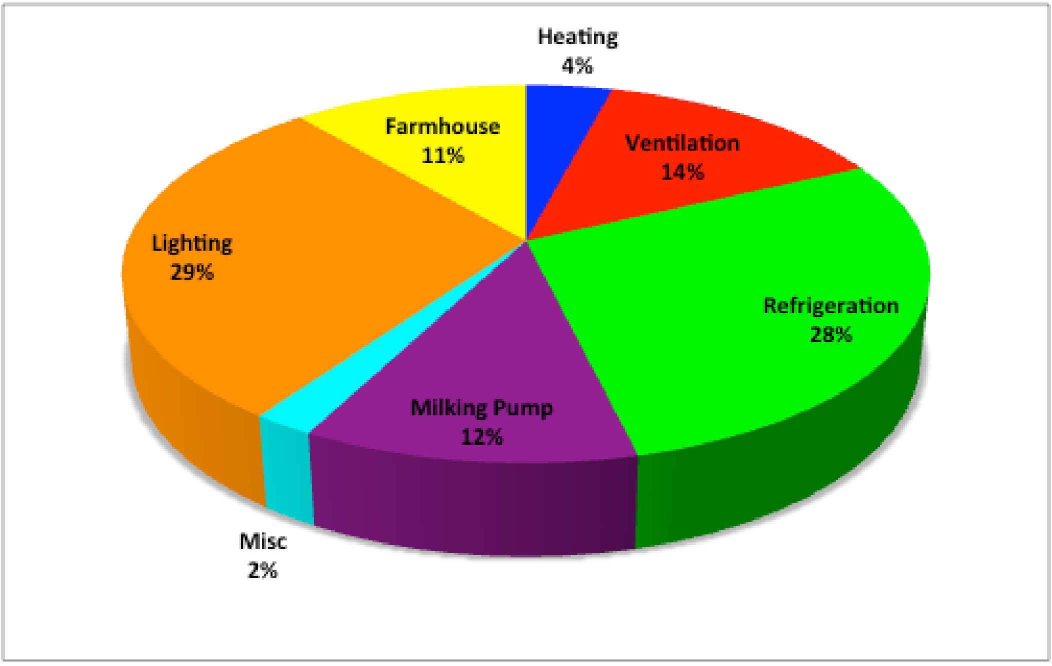


Fig. 5. Phase II audit - electrical consumption breakdown by sector.

Lighting, refrigeration, and ventilation are the three major consumers within the dairy operation as illustrated in Figure 5. No significant anomalies or differing trends are observed upon comparing the billing analysis consumption data with the screening survey data, therefore Phase III will focus solely on the three key consumers.

4.1.3 Phase III: Detailed Investigation

The three key electricity consumers found in the Phase II analysis were the facility's lighting, refrigeration, and ventilation requirements. In this section, we analyse the operation with respect to these key consumers and identify opportunities for reducing energy consumption.

Lighting

The lighting inventory taken in Phase II for the facility exposes opportunities for immediate improvement given that portions of the facility are using incandescent lighting, which consumes a high amount of energy and also emits a high amount of heat. Clarke and House [9] suggest that a dairy facility can experience a 75% reduction in energy costs associated with incandescent lighting by the installation of T8 tube fluorescent lighting fixtures.

The primary facility, within which the herd is housed during the winter months, and milked twice per day, is currently comprised of an old portion and a new section, which was a recent addition to allow for operational growth. The old portion of the primary facility is lit by incandescent lighting, as shown in Figure 6, while the new portion is fitted with T8 lighting as show in Figure 7. An investment in updating the old portion of the facility is a good opportunity for the operation to reduce energy costs, however, Clarke and House [9] also indicate production advantages to improving lighting and extending the light hours experienced by the herd during the winter months.

By retrofitting for T8 fluorescents and extending the current lighting hours from 16 to 18 hours in the primary facility, energy savings and production increases can occur. It can also be proposed that by replacing incandescents, and their inherent heat dissipation of up to 95%, with T8 technology, the ventilation load (one of the three major energy consumers) may be reduced. Research shows that T8 and T5 lighting technology have a favourable heat dissipation value of 73-75% [10].

Fig.6. Original section of the primary facility with incandescent lighting.

Fig.7. New section of the primary facility with T8 fluorescent lighting.

Refrigeration

Refrigeration is a critical component of the dairy operations. The refrigeration cycle is on a two-day pattern, which begins with a sanitized, empty, 4500-litre tank, and proceeds to become ¼ full in the first 12 hours. This requires work from the refrigeration units' compressors to keep the low volume of product in the holding tank cool. After 24 hours the tank is half full and the load on the compressors increase. This load increases further as the produce from the third milking round enters the tank after 36 hours and maximum operational load ocurs after 48 hours when the compressors are working to cool almost 4500 litres of product until pick-up by the purchaser. Figure 8 depicts one of the two compressors that are currently used in cooling and condensing the refrigerant for the holding tank.

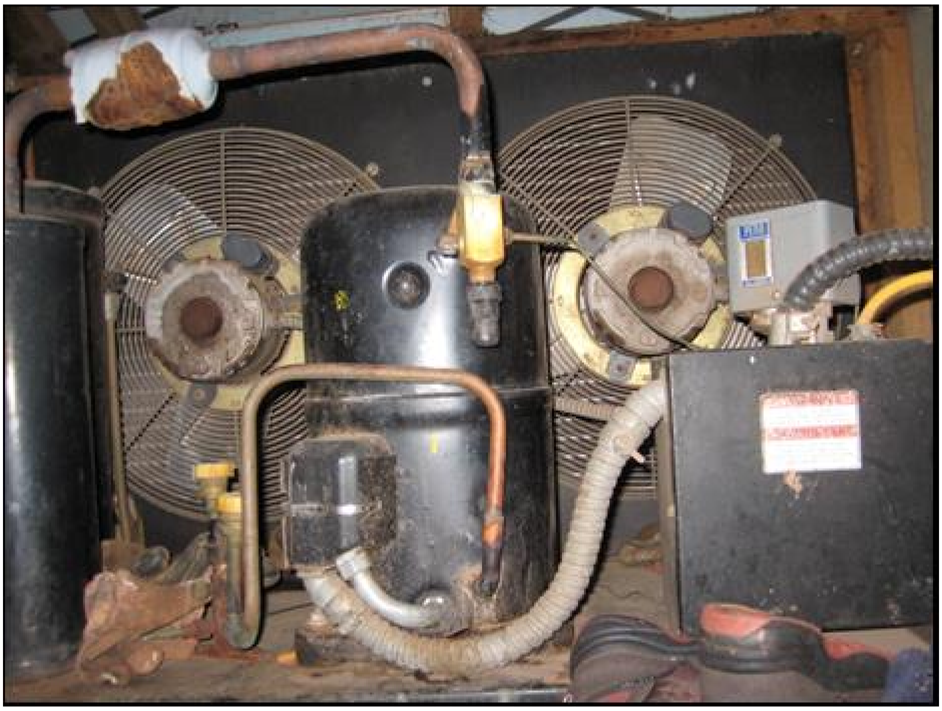


Fig. 8. One of the two 5.68 kW compressor units and corresponding cooling fans used in milk refrigeration.

Given the consistency and size of the operation and the importance of cooling the product, a maintenance program for the condensers and fans would be best suited for this case. Regular cleaning and maintenance of these units would provide some marginal improvement to the current energy consumption.

Ventilation

The ventilation for the primary facility consists of four wall-mounted fans and an automated wall opening at the opposing end of the barn for air flow through the length of the structure. Figure 9 depicts the wall-mounted fans within the facility.

Fig. 9. Four wall-mounted fans for ventilation. Two (below) are active and two (above) are inactive at the time of taking the photograph.

The operation recently installed an automated system, which determines the number of fans required for cooling at each moment. The previous arrangement consisted of all the fans running at the same time or no fans running. Given the recent installation of a management system, the operational trends based upon the seasons may be investigated to reduce energy consumption in this area. A study of further historical billing cycles and historical weather data may provide additional insight into the optimal temperature for the transition of the herd that would reduce or shift the requirement for full ventilation. Such an investigation, however, is beyond the scope of this analysis. The reduction of heat dissipation from incandescent lighting will also ease the load on the ventilation system.

4.2 Energy Efficiency and Conservation Opportunities

There exists several energy efficiency and conservation opportunities for the case study dairy. The simplest and most beneficial opportunity for energy efficiency improvements for the case study dairy lies in upgrading the lighting of the facility given that 29% of the operation’s total electricity consumption is lighting. Some fluorescent lighting is currently in place; however, investment in replacements for the incandescent lighting should become a top priority. T8 fluorescents have become the industry standard, however, the emergence of LED lighting is imminent and approximately 31% more efficient than the standard T8 fixtures [11].

Replacing all incandescent lighting fixtures and lamps currently within the case study facilities with T8 fixtures and lamps is an affordable retrofit with almost immediate payback. Table 3 and 4 detail the economic considerations of replacing the thirty 100 watt incandescent lights currently in use on the farm, with thirty 32-watt T8 lamps. This results in a payback period of approximately one year with a 68% saving in annual electricity cost for this upgrade. A lighting control system would provide further energy efficiency;the lights in non-animal spaces could be motion sensor, while the animal stall areas may have a timer-based system to maximum production and minimize wastage of electricity.

Table 3. Analysis of energy efficient lighting retrofit with T8 tubes.

Replace Incandescents with T8s	Current Incandescent	Proposed T8
Number of Lamps	30	30
Wattage	100	32
Operation Hours	5840	5840
Annual Consumption (kWh)	17520	5606
Annual Energy Savings (kWh)	n/a	11914
Electricity Cost ($)	1,857	594.00
Annual Electricity Cost Savings ($)	n/a	1,263

Table 4. Life Cycle Economic Analysis of the T8 Lighting Retrofit.

T8 Retrofit	Cost
15 Fixtures ($50 per fixture)	-$750
30 Lamps ($3 per lamp)	-$90
Fixture Installation Cost ($25 per fixture)	-$375
Relamping Cost ($4 per lamp)	-$120
Estimated Lamp Life (hours)	33000
Annual Operation (hours)	5840
Analysis Period (years)	20
Discount Rate	10%
Inflation Rate	0
Life Cycle Net Present Value	**$3,520.62**
Annual Electricity Cost Savings	**$1,263**
Annual Energy Savings (kWh)	**11,914**
Simple Payback Period (years)	**1.04**

A heat recovery system could be installed prior to the milk's entrance into the cooling tank, which would extract heat from the milk to reducing the cooling needs. The extracted heat could be used to preheat the water to be used for the sanitation wash cycle. A heat recovery system could also be applied to the outlet of the tank wash line given that the temperature of the sanitation water is required to be at least 82 degrees Celsius. This could also act as a preheating system for the sanitation water to reduce the amount of propane required for heating the water. Regularity in equipment maintenance and in the cleaning schedule would allow all fans, pumps, and motors to function as efficiently as possible. Further analysis of the shoulder season herd transition, as previously mentioned, may also result in a more efficient process through optimization of ventilation systems.

4.3 Case Study Comparison to Industry Baseline

Electricity is the greatest energy consumer in this case study and was surveyed to be the most commonly used energy type among all farm types, in the neighbouring province of Nova Scotia (NS), by Bailey et al. [13]. From this 2008 survey, NS dairy farms were found to have an average annual electricity operational expense of $8338, versus an annual utility expense of $10,195 for Canadian dairy farms, as reported by the Farm Management Analysis Project (FMAP) in 2004 [14]. The total electricity annual expense for the case study farm, Extondale Farms Ltd, was found to be higher than the regional and national average at $11,097. This comparison however is reliant on the price of electricity for the particular region; therefore energy intensity is a more valuable benchmark.

Benchmarking, using the average energy intensity of comparable farm operations, can provide insight into the performance of an individual case within the industry. Benchmarking in this paper is performed on the basis of farm type, which in this case is dairy farms. From a regional comparison, Nova Scotia dairy farms consume an annual average of 1069 kWh of electricity per cow [13], which is 8% lower than the case study farm that showed, through historical billing analysis, an annual consumption of 1154 kWh of electricity per cow. A US and Ontario survey provided a benchmark for electricity intensity of 3146 MJ and 3358 MJ per cow or (874 kWh and 932 kWh) for the regions respectively [15]. Additionally, a New York State dairy farm study in 2003, showed an average electrical use of 781 kWh per cow per year [16]. The case study exhibits energy intensity values that are 32% and 24% higher than the US and Ontario benchmarks, respectively. The higher energy efficiencies in the Ontario and US dairy farm survey may be attributed to larger scale operations, which are becoming the predominant dairy farm structure in those regions [1, 13].

The case study farm appears to be in line with the national average when it comes to production. Reported annual milk production per cow from a Canadian national average was 7700 kg per cow in 1993, which is comparable to the case study's current production of 8335 kg per cow per year (a relative percentage difference of around 8%) [15]. Further, it is suggested that the number of cows milked has a smaller impact on dairy farm energy use compared to the quantity of milk produced [17], therefore energy per 100lbs (kWh/cwt[1]) of milk is considered. As such, Nova Scotia dairy farms used an average of 3.53 kWh/cwt, where Extondale Farms consumed 6.29 kWh/cwt of electrical energy over the historical billing cycle analyzed. Ontario dairy farms report a wide range in this regard, with a minimum of 2.2 kWh/cwt and a maximum of 6.2 kWh/cwt of electricity consumed to milk produced [13]. Again the scale of operation may explain some of the divide with the Ontario region results, however, the Nova Scotia region dairy farms would be expected to compare more favourably to the PEI case study.

The benchmark analysis above supports the argument that small-scale farms must look to reduce their billed energy consumption if they are to be competitive with the larger operations. Thus, the following renewable energy considerations are of great importance to assist in providing options for decreasing the case study farm operating costs.

5. Policies and Feasibility Study of Renewable Energy

All ten provinces in Canada currently provide a form of energy efficiency or renewable energy subsidy program applicable to the dairy farm industry. On a local level, PEI currently has a Renewable Energy Initiative (REI) program in place, which is jointly funded by the Provincial Government and the Federal Government [2]. The program has a three-part approach including a pre-requisite energy audit, system implementation application and installation, and a post-installation energy audit. The energy audit is funded at 75% up to a maximum of $1500. Implementation of a recommended renewable system is

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[1] In Canada, as in the U.S. 100lbs is referred to as one hundredweight or one centum weight (cwt)

funded at 50% up to a maximum of $50,000 per farm. The post-installation energy audit is funded at 100% [2]. PEI utilities allow for net metering, with a retail price credit provided against net electricity usage, which has a 12 month expiration life [18].

This policy framework, in conjunction with PEI's inherent good wind resource, presents a potential opportunity for small dairy farms to use alternative energy generation to supplant operational costs. Given the renewable resources available to the site and the state of development of current technology, an analysis of the renewable energy generation has been undertaken for the case study dairy operation in Oyster Bed Bridge, PEI. Wind options, and biogas energy generation opportunities, and their corresponding financial implications will be assessed for the case study site, and barriers to such opportunities will be discussed.

5.1 Wind Energy Generation

As an island on the outskirts of the Atlantic Ocean, PEI has good wind resources in most locations, and very good wind resources along the northern coast, with successful wind farm developments along the north-western and north-eastern tips of the Island. Given the wind availability, the local utility's net metering program, and the annual electricity consumption of the farm of approximately 110MWh, the implementation of a wind energy system is considered.

A daily load profile of the case study site was compiled through the use of real-time data recording on-site. The total electricity being consumed by the farm was recorded from February 12 to 15 using a Hoiki 3169 power meter resulting in the load profiles shown in Fig 10.

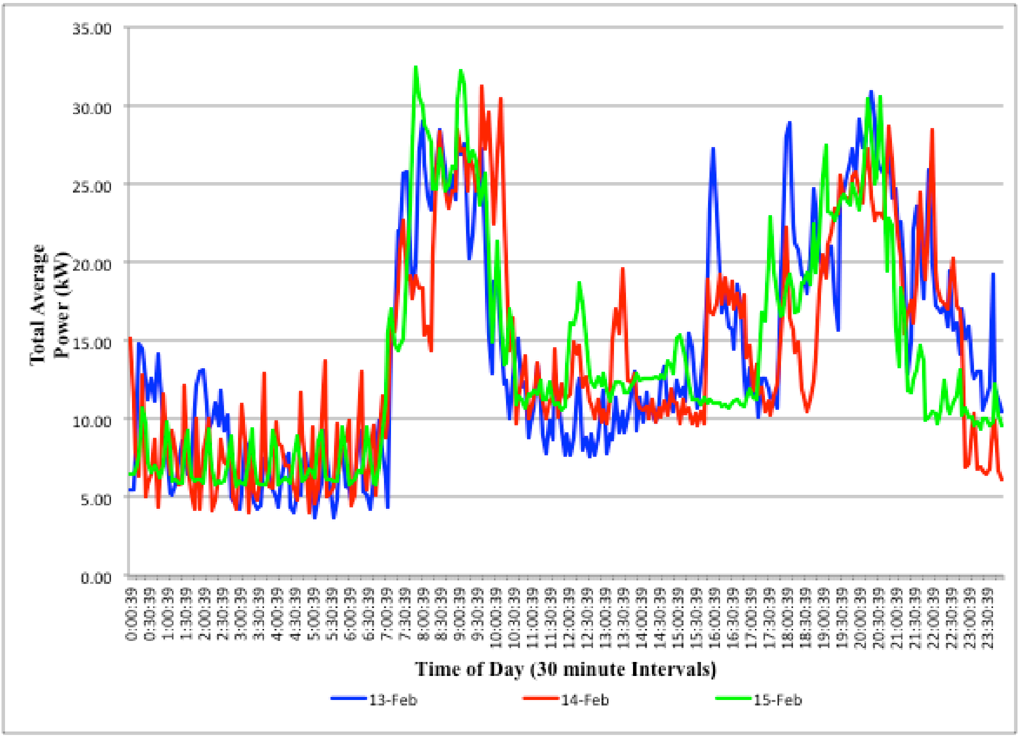

Fig. 10. Daily load profile data recorded at the case study site for February 13 to 15, 2012.

The peak electricity load recorded for the case study during this period was 33 kW, which occurred at 7:50am on February 15, 2012. Given that this peak demand is experienced in February, which is not the highest consumption month, a multiplying factor is considered for estimating the annual peak demand. To estimate a reasonable value for the maximum peak demand over a year, the peak load record in February is divided by the average daily load recorded for February to obtain a percentage of the peak demand with respect to average load. The ratio of 33 kW of peak load versus the average daily load of 12.48 kW for the month of February, results in a factor of 2.64. This factor is then multiplied by the average daily load of the month with the highest electricity consumption, November (see Fig 1),. The average daily load in

November, as per the billing history, was 15.4 kW, which results in an estimated annual maximum peak demand of 41 kW when applying the multiplying factor.

Two wind turbine systems (25 kW and 10 kW) were analyzed separately for the case study site given its load requirements, the site attributes, and the regional energy policies. The annual wind speed data for the case study site is detailed in Table 5, as recorded at the closest data collection point at Charlottetown airport. A wind shear exponent value of 0.11 was used for this analysis due to the farm's abundance of clear, unobstructed, land on which to install a turbine [19]. It was assumed that a Rayleigh distribution is a good approximation for the statistical distribution of wind speeds at the site. Losses considered for this analysis were based upon a single installation configuration, assumed minimal airfoil soiling, 4% or moderate miscellaneous losses, and a 95% availability rating estimation.

A total load of 115 MWh/yr was input into RETScreen™ along with the peak and average monthly load values for the case study. Additionally, the software takes into consideration the potential for greater peak load events to occur throughout a given year. The system was configured to factor in the grid connection and a mean electricity rate of $0.106 was used in the absence of the ability to break down the rate into consumption-related blocks.

Table 5. Wind speed data at 10 m height for the Charlottetown Airport location; Lat. 46.3N and Long. -63.1E [14].

Month	Wind Speed (m/s)
Jan	5.8
Feb	5.8
Mar	5.8
Apr	5.6
May	5.3
Jun	4.7
Jul	4.5
Aug	4.2
Sept	4.7
Oct	5
Nov	5.6
Dec	5.8
Annual Average	5.2

The first turbine analyzed for the case study site, a 25 kW unit, was chosen with respect to the load by adopting a strategy of using the turbine to replace the majority of the electricity consumed by the base load while maintaining a level of plausibility from a financial and scale perspective. The second turbine analyzed for the case study site, a 10 kW unit, was chosen with respect to the loadby adopting a strategy of using the turbine to replace a portion of the electricity consumed by the base load while considering initial costs manageable to the operation and the potential incorporation of other renewable energy generation projects for the site. Table 6 details the specifications of the two wind turbines selected for feasibility analysis through the RETScreen software. The power curves for both units are shown in Figure 11 and Figure 12.

Table 6. Wind turbine specifications for the 25 kW and 10 kW units selected for analysis.

	Option 1	**Option 2**
Power Capacity	25 kW	10 kW
Model	PGE 20/25-31m	ReDriven 10
Hub Height	31 m	18 m
Rotor Diameter	20 m	8 m
Swept Area	314 m²	50 m²

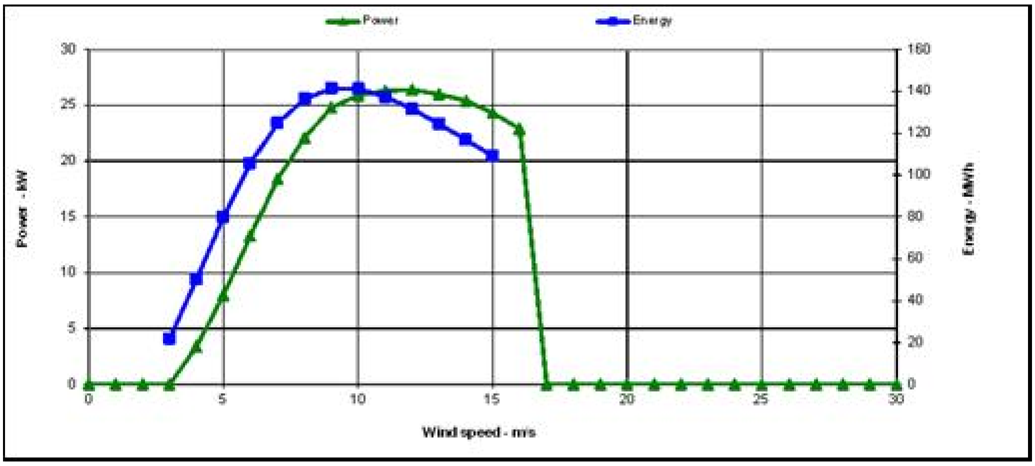

Fig 11. Power and energy curves for the 25 kW wind turbine [14].

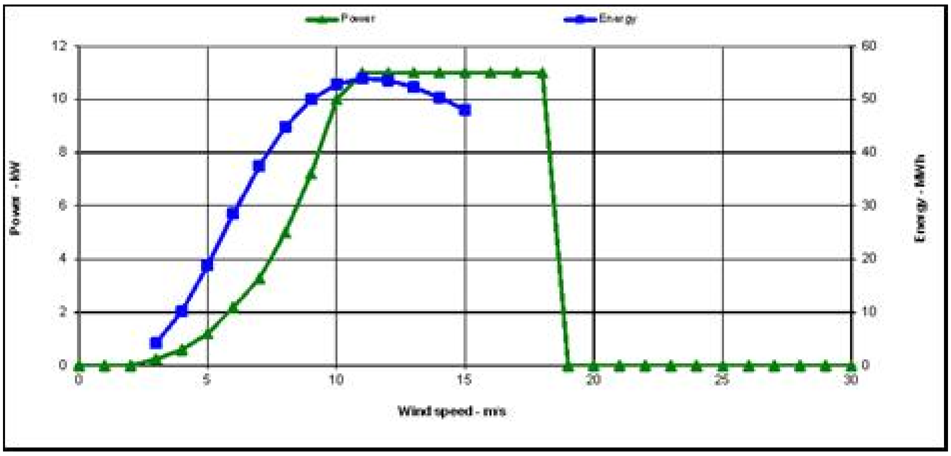

Fig 12. Power and energy curves for the 10 kW wind turbine[19].

Table 7. RETScreen results summary for PGE20/25-31m and ReDriven 10 kW wind turbines at case study site.

	PGE20/25-31m	**ReDriven 10 kW**
Capacity Factor	43.50%	26.10%
Losses Coefficient	0.90%	0.90%
Electricity delivered to load	95 MWh	23 MWh
Electricity delivered to grid	1 MWh	0 MWh
Remaining electricity load required	20 MWh	92 MWh

The results of the analysis of the two turbines under the case study conditions are shown in Table 7. Analysis of the 25 kW unit resulted in the generation of 96 MWh of electricity over a one-year period, with 95 MWh being delivered directly to the case study load. The analysis shows that over 82% of the electrical load is projected to be met by the 25 kW turbine with a remaining 20 MWh of electricity to be purchased through the utility. 1 MWh is shown to be contributed to the grid. This may have occurred during a low load period at the site, such as overnight , with the wind turbine operating at full capacity. This result infers an operational savings of an estimated $10,000, which would have been paid to the utility for the 95 MWh of electricity.

The 10 kW unit results reveal that wind energy can supply a23 MWh annually and would meet just 20% of the overall electricity load.. With this configuration, 92 MWh of electricity would remain to be supplied from the local utility. The results show no electricity being delivered to the grid. The 23 MWh generated by the system equates to savings of $2438, which would otherwise have been paid to the local utility.

5.1.1 Wind Generation Financial Analysis

The financial analysis for the two wind system options was considered over a project lifetime of 20 years,a reasonable estimate for the lifetime of a small wind turbine[20]. Up front wind turbine costs have been estimated for this analysis at $3000/kW equipment cost and $3000/kW for installation and commissioning [20]. A yearly operating and maintenance cost has also been included in the analysis at an annual cost of $1150 per turbine. A future cash flow discount rate of 10% was considered, however, no fuel cost escalation or inflation rates were incorporated in this analysis. A government grant of 50% of the capital cost (up to a maximum of $50,000) was assumed to be approved for the proposed installation and was therefore incorporated in this financial assessment. A summary of the financial considerations for the two wind systems analysed is shown in Table 8.

Table 8. Financial analysis summary for two wind turbines over 20-year period.

	PGE20/25-31m	ReDriven 10 kW
Project Capital Cost	$150,000	$60,000
Annual O&M Cost	$1,150	$1,150
Annual Utility Elect Cost Savings	$ 10,019	$2,428
Discount Rate	10%	10%
Project Life	20 yrs	20 yrs
REI Government Grant	$ 50,000	$30,000
Life Cycle Net Present Value	$ 11,502	-$630
Simple Payback Period	11.3 yrs	24 yrs

The 20-year financial analysis of the two wind turbine systems, including the REI grants funding, result in two very different scenarios. The 25 kW system shows a simple payback period of 11.3 years with a savings of over $77,000 observed for the life of the project, which is equal to a Net Present Value of $11,500. Reinvestment into an upgrade or replacement of the system may be an attractive consideration with the realized savings. However, the 10 kW shows a simple payback period of 24 years, which is outside of the project life span of 20 years. Of the two turbines systems considered, the 25 kW is the more financially viable alternative, however, a large capital cost is required at the initial stage of the project. Note that turbine prices vary frequently and therefore, this financial analysis should be updated regularly.

5.2 Biogas Energy Generation

Energy generation using biogas as fuel to generate electricity for the case study load was considered briefly in this analysis. Successful bio-energy generation systems for farms currently exist using the manure waste from animals in an anaerobic digester for conversion into methane gas to ultimately drive an electricity-producing turbine. The estimated capital cost of an anaerobic digester is in the range of $3700 to $7000/kW with an operating cost of $0.02/kWh [21]. Table 9 presents the potential energy output based upon the annual waste of one animal. This excludes the cost of transporting the waste (collection and feeding into digester).

Table 9. Manure energy potential per animal of different livestock [21].

Livestock Type	Manure Excreted (kg/day)	Biogas Production (m^3/day)	Electricity Potential (kWh/year)	Energy Potential (kWh/year)
Beef	24	1.1	663	3
Dairy	62	2.01	1227	5.5
Piglet	3.5	0.16	98	0.4
Poultry (100 layers)	8.8	0.85	516	2.3

For the case study operation consisting of 95 dairy cows, the potential electricity generation from the herd's manure is 116,565 kWh per year. This exceeds the total annual electricity consumption of the case study operation by approximately 7,000 kWh andtherefore the additional projected output could be used for water heating, displacing a portion of the existing propane system load. This energy generation option appears attractive and therefore a financial analysis was undertaken as summarized in Table 10, assuming a system size of 14.4 kW and the inclusion of an REI grant value to cover 50% of the capital cost.

Table 10. Financial analysis of a 14.4 kW anaerobic digester for the case study site.

Cost component	Value
Project Capital Cost	$101,500
Annual O&M Cost	$2,300
Annual Utility Elect Cost Savings	$12,355
Discount Rate	10%
Project Life	20 yrs
Eligible Grant Value	$50,000
Life Cycle Net Present Value	$149,613.00
Simple Payback Period	6 yrs

With the assistance of the local grant funding, a 6-year simple payback is realized. This analysis results in a favourable system, which would require further investigation and confirmation of unit costs prior to implementation of the project. Note that the sizing of a small-scale system may affect the cost and feasibility of implementing an anaerobic digestion system. This analysis is theoretical in nature; therefore a practical quotation for the small-scale system is required.

5.3 Implementation Opportunities and Challenges

The opportunities assessed result in potential generation systems for the case study dairy farm. Challenges exist in balancing the goal of reducing energy cost through capital cost investment. Efficiency measures should be implemented first to reduce overall consumption. Renewable energy systems may then be considered based upon the reduced, more efficient consumption targets.

The wind and anaerobic digestion systems demonstrate a potential positive impact on reducing energy costs. The 25 kW wind turbine shows good potential production with the challenge of a high initial investment cost. Note that the systems analyzed with RETScreen may not be the best performing systems in the industry at the current time. The systems selected for analysis were based upon the best units available with good performance data records to allow for detailed analysis through RETScreen.

The anaerobic digestion system presents the greatest payback and replaces all of the farm’s current energy needs. The initial cost is quite high however, and may be found to be even higher upon procurement of a system sized for the small scale of the case study. There may be an opportunity within the surrounding farming community to increase the manure input through collaboration with neighbouring farm operations. Resulting waste and other related safety procedures not considered herein may also effect the feasibility of such a system.

It is also noted that the performance and cost of renewable energy systems are continually changing and therefore this feasibility analysis should be reviewed regularly for improvements in generation outputs and decreases in capital cost.

6. Conclusion

This review of the energy framework as it relates to small dairy farms in the province of PEI has produced evidence supporting energy efficiency and renewable energy generation opportunities for the industry.

The case study of Extondale Farm Ltd in Oyster Bed Bridge, PEI resulted in an indication of opportunities currently present to farm operators in the region. Energy efficiency recommendations for the case study farm resulting from this analysis include the following:

1. Replace all incandescent lighting with T8 fixtures and lamps. Compact fluorescent are recommended to be upgraded to T8 as well.
2. Implement a regular maintenance program for cleaning condenser fans to optimize refrigeration energy performance.

Renewable energy generation findings for the case study include the potential use of an anaerobic digester to produce all of the farm’s required electricity while providing an on-site disposal solution for the ever-growing quantity of cow excrement. Wind energy generation was also found to be productive for the case study site while solar hot water heating opportunities may be investigated in the future should the facility wish to eliminate the use of propane fuel. Recommendations for renewable energy generation projects to implement include:

1. Installation of a 25 kW wind turbine dependent on available capital and REI grant approval to provide an estimated 82% of the farm's total electricity consumption.
2. Pursue detailed quotation and design of an anaerobic digester to provide the entire electrical load to the site.

These recommendations are made on the basis that the systems are eligible for the REI grant since the payback periods in all renewable energy generation opportunities analyzed would be double in most cases without the REI grant incentive.

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