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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.

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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 h 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]. PEI's electricity price is one of the highest in Canada [5].

In agriculture, the efficient use of energy is one of the priorities for sustainability and agricultural 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

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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.

3.1. 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 Australian Government's Energy Management Advisory Booklet [8], was used with the intent of undertaking a structured and systematic approach to energy analysis 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.

3.1.1. 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 L refrigeration tank for milk cooling. Hot water for the tank wash cycle is heated by a propane-fired heating system. A 1.5 W electric fence encloses the grazing lands.

3.1.2. 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-fueled water heating for cooling tank sanitation cycles. The energy used for the transportation of milk to the dairy plant and for packaging is considered secondary (indirect) to the operation of the facility and is therefore considered outside of the audit boundary. Fig. 1 depicts the energy audit boundary framework.

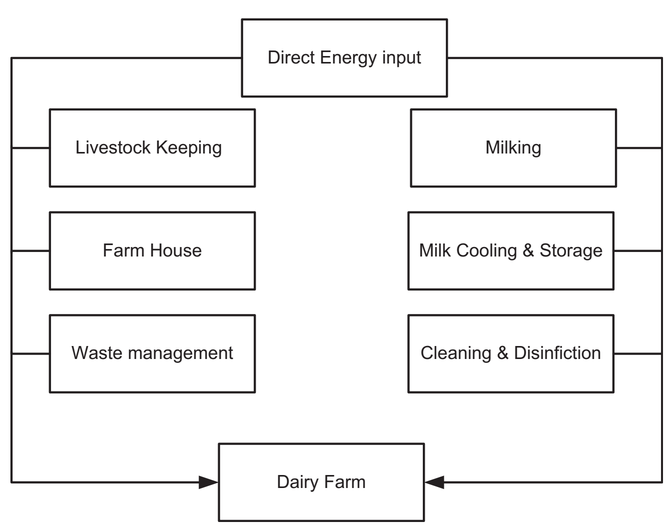

Fig. 1. System boundary and direct energy inflow for the case study farm.

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