Energy Substitution Rates and Energy Policy Analysis on Nova Scotia Dairy Farms

by

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ABSTRACT

This paper analyzes energy substitution rates on dairy farms in Nova Scotia (NS), Canada. A transcendental logarithmic cost function is used to find the elasticities of substitution which are utilized to determine the substitutability of total farm energy and to determine feasible renewable energy (RE) technologies. Wind turbines are found to be the only feasible RE technology for dairy farms within the region, at this time. A review of on-farm RE production and the associated feed-in tariff (FIT) policies in Germany, USA, Canada, Denmark and the Netherlands are examined. The NS FIT policy is used as a case study to assess the effect policies may have on wind turbine implementation by NS farms. Several scenarios are developed based on the existing policy structure to provide a critical review of the policy and to identify methods to provide an increase in the implementation of wind turbines on NS dairy farms.

LIST OF ABBREVIATIONS AND SYMBOLS USED

AES	Allen/Uzawa partial elasticity of substitution
AWEA	American Wind Energy Association
BMP	Best management practices
CEDIF	Community economic developments investment fund
CES	Constant elasticity of substitution
CF	Capacity factor
COMFIT	Community feed-in tariff
CPP	Canada pension plan
DFNS	Dairy Farmers of Nova Scotia
e.g.	For example
EI	Employment insurance
EGSPA	Environmental goals and sustainability prosperity act
FIT	Feed-in tariff
GHG	Greenhouse gas
GW	Gigawatts
GWh	Gigawatt hour
i.e.	That is
IRR	Internal rate of return
kW	Kilowatt
kWh	Kilowatt-hour
MES	Morishima elasticities of substitution
MC	Marginal cost
MP	Marginal product
MRTS	Marginal rate of technical substitution
MW	Megawatt
MWh	Megawatt hour
MES	Morishima elasticity of substitution
NDP	New Democratic Party
NS	Nova Scotia
NSDA	Nova Scotia Department of Agriculture
NSPI	Nova Scotia Power Inc
PV	Photovoltaic
RE	Renewable energy
RES	Renewable energy standards
RET	Renewable energy technology
ROI	Return on investment
Translog	Transcendental logarithmic
USA	United States of America

ACKNOWLEDGEMENTS

CHAPTER 1: INTRODUCTION

Dairy farming is one of the primary sources of income from Nova Scotia's agricultural sector. Milk is the primary product sold from dairy farms, and milk supply has remained relatively stable over the past thirty years due to the national supply management policy which regulates milk and milk product supply to meet domestic demand. Although total milk production within the province has remained relatively stable, input costs have had increasing trends, especially in recent years. Electricity prices have also increased and since electricity is imperative in the milking process, it is difficult for NS dairy farmers to reduce their electrical consumption. This current trend of increases in energy and electrical prices is impacting the bottom lines of NS's dairy farms.

Two main research issues are presented in this thesis. The first relates to energy and the question of whether there are substitution possibilities between inputs, especially the energy subgroup, which consists of the three main energy users on dairy farms: electricity, heating fuels and diesel and auto fuels. Secondly, current energy programs and policies are reviewed to determine if the current policies in place are sufficient to encourage the implementation of renewable energy technologies by NS dairy farmers. Policy recommendations are presented, based on the findings of this research.

It is argued, based on the empirical results of this research that energy is highly substitutable on NS dairy farms, which encourages implementation of renewable energy sources. Electricity and heating fuel are the short term substitution possibilities, but it is also argued that in the long run, due to technological development, diesel could be

considered as a substitution possibility for electricity. This would make the overall

benefit of switching from conventional to renewable electricity even more appealing to

dairy farmers. Regarding the second issue, the current renewable energy policy is

reviewed to determine its impact on the agricultural sector in NS and the possibility of

energy substitution in the long term.

1.1 INTRODUCTION TO NOVA SCOTIA'S DAIRY SECTOR

Nova Scotia is a small eastern Canadian province with a population of just under

one million (Statistics Canada, 2011a). NS's agricultural sector plays a considerable role

in Canadian agriculture, with the provincial agricultural GDP accounting for 2.2% of the

total Canadian agriculture and agri-food sector GDP (Agriculture and Agri-Food Canada,

2007). There are approximately 250 dairy farms across NS, producing annually over 165

million litres of milk, which is primarily used as fluid milk (DFNS, 2012). Cash receipts

from the NS dairy sector accounted for 23% of total farm cash receipts in NS in 2002

(GPI Atlantic, 2008a) and were the largest of all the major agricultural products produced

in the province, including dairy, poultry, floral/nursery, fruit, beef and hog, forest

products and eggs, vegetables, potatoes, turkeys, grain, and sheep. These cash receipts

represent farm revenues of approximately $120 million per year and create over 550 on-

farm jobs (DFNS, 2012).

The dairy industry in Canada is regulated through supply management policies,

meaning quotas are needed for dairy farmers to sell milk. The amount of quota available

in Canadian provinces is set by the Milk Marketing Boards. As well, the quantity of

quota available is directly related to the demand for milk and milk products by consumers

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in the individual provinces. The milk marketing boards only allow enough quota to be available to satisfy consumer demand. Since there is no excess quota (and therefore production), milk prices tend to be relatively high and stable for Canadian dairy farmers.

1.2 INPUT USE ON NS DAIRY FARMS

Energy has become an important topic worldwide due to the limited supply of oil, increasing energy prices, scarcity and other environmental concerns such as greenhouse gas emissions that are associated with utilization of conventional energy products. These concerns have increased the awareness and use of renewable energy sources as a means to address energy and environmental issues.

Farms within Canada are not exempt from these energy trends. The number of dairy farms in Atlantic Canada has been decreasing, while at the same time average farm size has increased (Statistics Canada, 2011b). Although larger farms often obtain economies of scale, larger farms also often use larger quantities of energy. This, combined with trends of increasing energy prices, has heightened the importance of on farm energy efficiency and renewable energy implementations.

The cost of direct energy inputs (electricity, heating fuels, and diesel and auto fuels) on dairy farms within the province of NS has increased substantially since 1995 (Figure 1). This could be due to the global trend of increasing fossil fuels prices, since NS's primary source of electricity is generated by fossil fuels (Centre for Energy, 2012). Other trends causing a rise in energy costs could be due to an increased dependence upon electronic technologies on farms, such as electronic milkers, feeders and manure scrapers. Another cause may be the trend of fewer, but larger dairy farms within the province

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(Statistics Canada, 2011b), which can lead to larger equipment, and as a result more fuel usage. Whether the increase in energy costs is due to an increase in energy prices or an increase in consumption, the fact is that higher costs are impacting the net income of the region's dairy farmers. Figure 1 presents the annual energy costs for NS dairy farms.
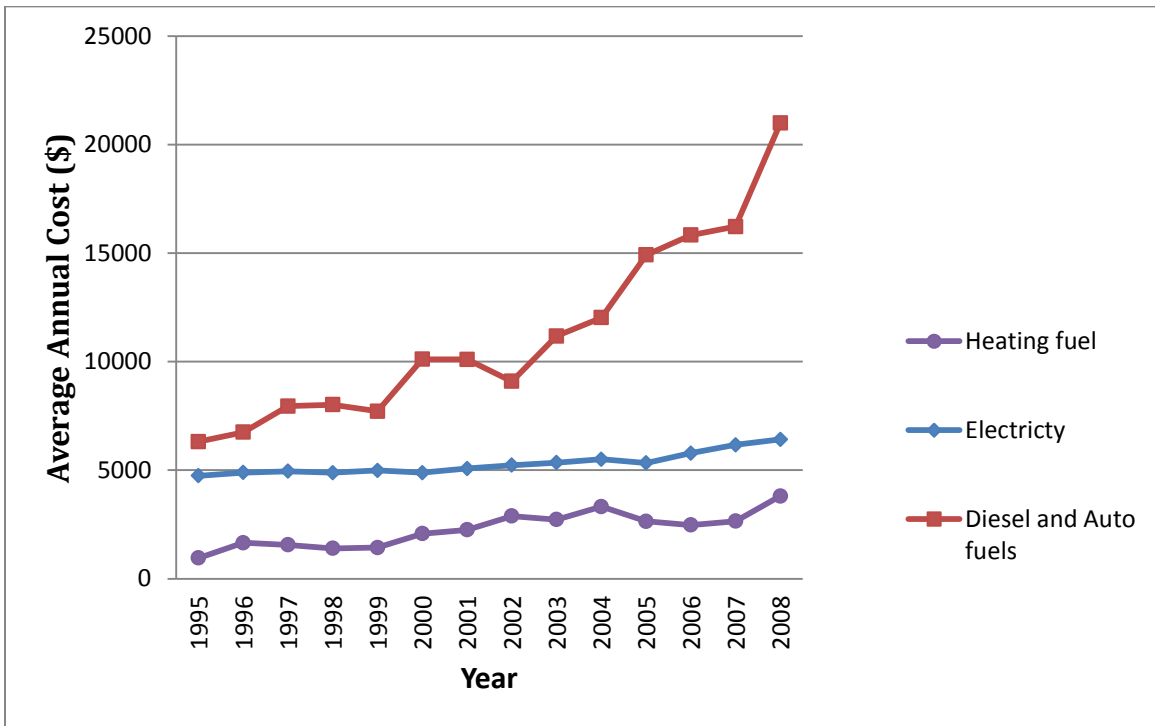
Source: Canadian Farm Financial Database, 2011.
Figure 1: Annual energy costs on NS dairy farms

Figure 1 shows increasing trends for all dairy farm energy costs in Nova Scotia. The average amount spent on heating fuel has nearly quadrupled since 1995 from $954.44 to $3,805.36 in 2008. The costs of diesel and auto fuels to dairy farmers have more than tripled since 1995, increasing from $6,314.20 in 1995 to $20,984.58 in 2008. The amount spent on electricity has been relatively more stable, with an increase in average annual spending of from $4,743.55 in 1995 to $6,413.00 in 2008.

Energy use can be separated into two types within the agricultural sector: direct and indirect (Pervanchon et al., 2002). Direct energy use consists of the consumption of fuels such as diesel, oil, gas, electricity, wood and other heating fuels, which can be measured directly on farm. Indirect energy, however, is not used directly on farms. For example, this would include energy used to transport or produce inputs that are used on the farm, which can include, but is not limited to, pesticides, fertilizers, feeds, seeds, machinery and equipment. Of the total energy used on dairy farms, 70% is attributed to indirect energy (Meul et al., 2007). Although the amount of indirect energy used on farms is high, it is difficult to measure and therefore challenging to control the quantity used.

Direct energy usage is simpler to measure and therefore control. Diesel and electrical energy use are the main sources of direct energy on dairy farms, with diesel being the primary energy source (Meul et al., 2007; Bailey et al., 2008). Yet, electrical energy is pertinent to dairy farms due to the modern technologies used during the milking process. The three main electrical loads on dairy farms are milking, feeding and manure handling (Dyer et al., 2006). NS data revealed the highest user of electricity on NS dairy farms is attributed to lighting (26%), followed by milking (20%), cooling (18%), water heating (14%), feeding, ventilation and manure (12%) and other uses (10%) (Farm Energy Nova Scotia, 2011). Although lighting is found to be the highest electrical energy user on dairy farms in NS, total electrical demand is very high during the milking process. High electrical demands are due to most of the equipment being used simultaneously for the milking process, which can create electrical loads up to eight to ten times higher than the minimum load (Dyer et al., 2006). Since most milking equipment is used simultaneously, it can be difficult to decrease electrical loads during

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the milking process; therefore, it is important to incorporate energy efficient technologies to lower electrical loads during these peak periods. Energy efficient technologies relevant to industrialized dairy farms include variable speed pumps, plate coolers and free heaters (Farm Energy Nova Scotia, 2011).

In this thesis, two stage budgeting is used to assess energy costs (Deaton and Muellbauer, 1980). Figure 2 demonstrates the separation relationships associated with the two stage process with specific focus on the energy input. Total energy costs are assumed to be part of a farm's total cost and a farm has a limited amount of money it can spend on all inputs (e.g. capital, labor, feed, energy etc.). Each of these inputs are broad categories (upper level) that can be broken down into more detailed components (lower level). The upper level capital input could be separated further into machinery, buildings or land categories, whereas the energy input could be separated into electrical, diesel and auto fuels or heating fuel components. In this thesis, the broad categories (capital, energy etc.) are referred to as the "upper level". Each individual lower level category such as electricity, diesel and auto fuel or heating fuel can further be divided into the individual technologies that generate these lower level categories. For example, electricity could be generated by solar, wind or anaerobic technologies, whereas heating fuels could include oil, grass pellets, corn etc.. The concept of two stage budgeting is further discussed in chapter three of this report.
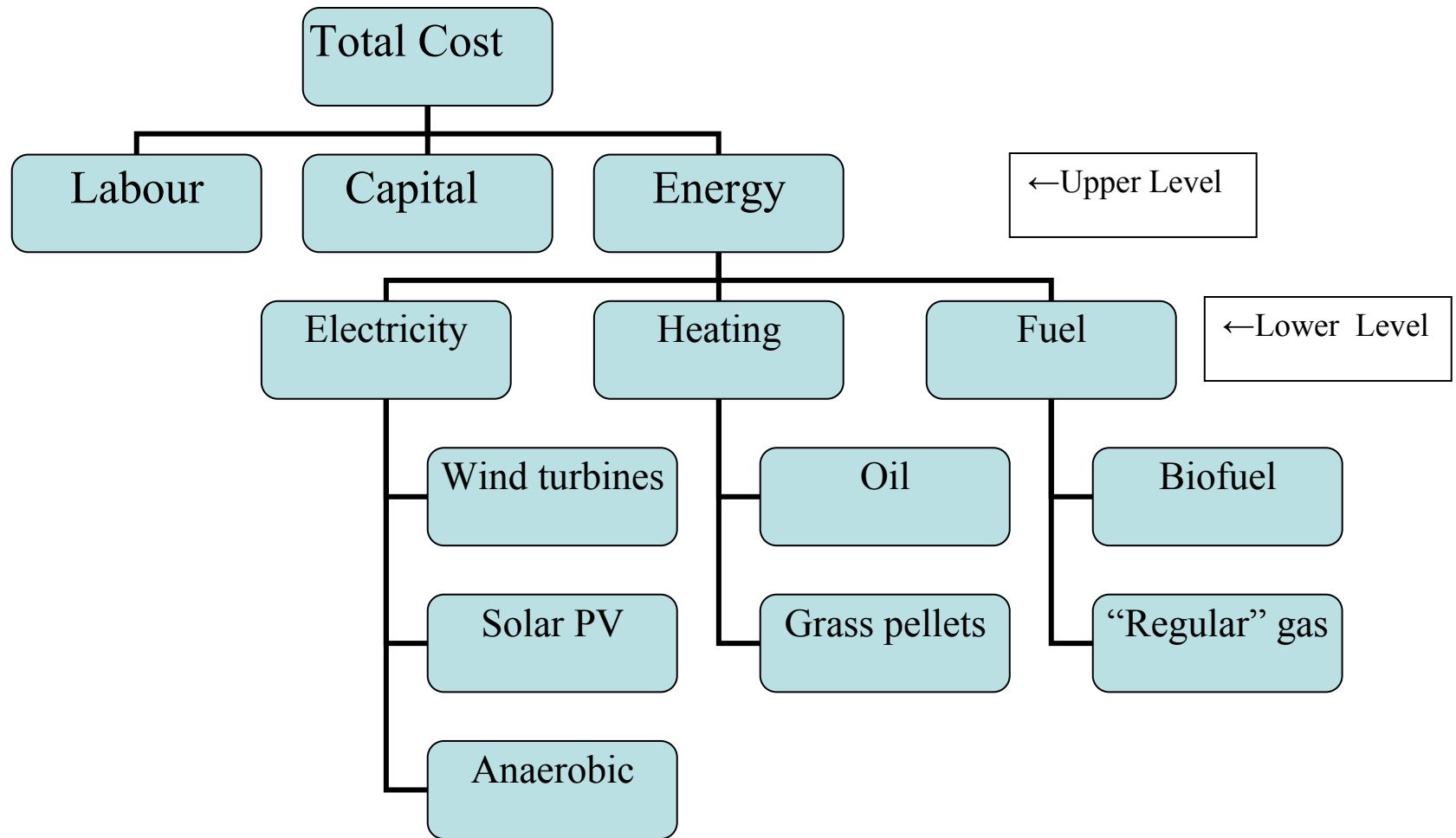
Figure 2: Example of upper and lower level groups used for aggregate energy input used in the cost function

*Note: lower level list is not inclusive of all available renewable energy technologies

1.3 CURRENT ENERGY PROGRAMS IN NS

The provincial government and the NS Department of Agriculture (NSDA) have begun to focus attention on energy conservation on farms by implementing a renewable energy policy through the Renewable Electricity Plan (Province of NS, 2010), and by providing additional programs and incentives to farmers to conserve energy or increase the energy efficiency of their operations. There are two main programs with a focus on energy within the NSDA. The first is the Energy Conservation Program (NSDA, 2011a), provided through the federal Growing Forward initiative; and second is the Beneficial Management Practices within the Homegrown Success Program (NSDA, 2011b).

1)   The Energy Conservation Program attempts to reduce greenhouse (GHG) emissions and protect the environment by implementing alternative energy systems and energy conservation. The NSDA has employed a farm energy specialist to perform on-farm energy assessments that evaluate the current energy management practices and electrical equipment on farm (e.g. motors, lighting and heating sources). From this assessment, the specialist determines opportunities where energy can be conserved or used more efficiently within the farm's operation. This program aims to educate farmers on their energy use and management practices while highlighting opportunities where energy can be conserved. Through this program, pilot projects are also used as educational tools to demonstrate energy conservation and efficiency technologies (NSDA, 2011a).

2)   *The Homegrown Success Program* is a bilateral agreement between the federal and provincial governments to implement the Growing Forward policy framework. This policy has three visions of the agricultural sector of the future, hoping it will be:

"A competitive and innovative sector; a sector that contributes to society's priorities; and a sector that is proactive at managing risks"(NSDA, 2011b).

The program uses Beneficial Management Practices (BMPs) to provide incentive for energy conservation and technology. There are three BMPs associated with farm energy: BMP 35 focuses on energy efficiency assessment, BMP 36 focuses on energy efficiency implementation and BMP 37 focuses on alternative (green) energy systems.

BMP 35 – Energy Efficiency Assessment- provides incentive of 75% of the cost of an energy assessment to be paid for by the federal government, with a maximum cap of $2,000.

BMP 36 - Energy Efficiency Implementation- provides incentive of 50% of the cost of the following technologies to be paid for by the provincial government: heat curtains, reverse osmosis systems, plate coolers, heat exchangers, variable speed drives, infrared heaters, creep heat pads, energy efficient shatterproof lighting, insulation, biomass (or pellet) boilers, thermostats, energy efficient motors, fans and pumps.

BMP 37 – Alternative (green) energy systems - provides incentive of 50% of the cost of the following technologies to be paid for by the provincial government: ground source heat pumps, wind assessments and wind power generation, solar air, solar hot water heating, and solar panels.

Annually, there is a provincial cap of $10,000 per farm and a federal cap of $50,000 on all BMPs combined.

Along with programs supported through the NSDA, there are other federal and provincial programs that farmers in NS are capable of accessing. These include 1) EcoEnergy programs, 2) Efficiency NS programs, and 3) Accelerated Capital Cost Allowance program.

1) **Eco Energy Programs –** includes the following three sections:

    a) EcoEnergy for Renewable Power program (Government of Canada, 2011) – provides incentives of $0.01 per kWh for up to 10 years on low impact renewable energy generation.

    b) EcoEnergy for Biofuels program (Government of Canada, 2011) provides fixed declining incentives starting at $0.10 per liter for ethanol and $0.26 per liter for biodiesel.

    c) EcoAgriculture Biofuels Capital Initiatives – was implemented to help accomplish the federal government's goal of reaching 5% renewable content in gasoline by 2010 and 2% renewable content in diesel fuel and heating oil by 2012. This program will cost share projects producing biofuels from agricultural feedstocks. More details for these programs are provided by Agriculture and Agri-food Canada (2011).

2) **Efficiency Nova Scotia**

    Efficiency Nova Scotia is an independent corporation aiming to reduce energy use and improve energy efficiencies within NS. The programs that are currently offered that may encourage energy conservation or efficiencies on the province's dairy farms include:

a) Commercial Solar Program - Conserve NS provides a 15% rebate on the installation cost of solar hot water and solar air heating, up to a maximum of $20,000 (Efficiency NS, 2011).

b) Business Energy Rebates for Agribusiness – This program provides financial rebates for eligible technologies which can include products in the following categories: lighting, high efficiency fans, livestock waterers, agriculture heat pads, timers, motors and variable speed drives as well as dairy-specific technologies such as dairy scroll compressors, heat reclaimer units and milk pre-cooler systems (Efficiency NS, 2011).

c) Small Business Energy Solutions program – This program consists of free onsite assessments of current lighting and provides up to 80% of the cost of installing new, energy efficient lighting. As well, Efficiency NS looks after all arrangements (assessment, materials, electrical contractor and disposal of old materials). A financing option is also available, with payment at 0% over a period of up to two years through Nova Scotia Power Inc., with payments added to the customer's current bill (Efficiency NS, 2011).

3) **Accelerated Capital Cost Allowance Program**

a) This program was implemented by the federal government and is designed to increase the rate at which renewable or efficient energy technologies can be depreciated for tax purposes (Industry Canada, 2009).

1.4 PROBLEM STATEMENT

It is obvious from the available programs and the new energy policy implemented in the province of NS, through the NS Renewable Electricity Plan (see chapter 5) (Province of NS, 2010), that there are many possible opportunities for dairy farms to lower their energy costs. Increasing costs of inputs, such as electricity or diesel and auto fuels, can have a major impact on farm income since farmers tend to be price-takers and thus, they have little impact on the price paid for their products. Therefore, an increase in input prices, such as electricity prices, is a direct loss to a dairy farmer's income, unless costs can be mitigated through management changes or reduction in consumption. Since electrical energy is needed for the milking process on dairy farms, it is often difficult for dairy farmers to lower their energy use via changes in management practices (due to the fact that many of the energy consuming systems are used simultaneously during the milking process).

There are options that can improve energy efficiency during the milking process, such as installing variable speed drives, high efficiency compressors, plate coolers and/or heat exchangers. These technologies are more energy efficient than conventional technologies. With the new NS Renewable Electricity Plan being implemented, there are also many opportunities for farmers to take advantage of installing renewable energy technologies on their farms, which could not only be used to reduce energy bills, but also has the potential to be an additional source of income, through payment for excess generation put back onto the electrical grid. Farmers tend to have the resources needed renewable energy technologies, such as available land or waste products such as manure or organic material, which implies that farmers can have a major role in the production of

renewable energy (Lipp, 2008). This research aims to determine the best renewable energy technology options for various sized (small, medium and large) dairy farms to implement in NS, based on the current policies and costs of the technologies.

In order to assess the potential and feasibility of using renewable energy technologies on NS dairy farms, production costs, technology costs and energy costs were evaluated using a cost function approach. Internal rate of return (IRR) was used to determine investor attractiveness. The current renewable energy policy is critically analyzed to determine what impact it has on the substitutability of energy sources in the NS dairy sector. Policy suggestions are recommended, since informing policy makers on the best technology options for on-farm energy production can allow for amendments or implementations of policies that can help NS attain its renewable energy goals through increased renewable energy production by farms.

1.5 OBJECTIVES

While it is possible to use renewable energy on farms (Lipp, 2008), it has not been specifically established whether there is the potential on dairy farms within NS, or whether the new policies implemented through the renewable electricity plan could make renewable energy systems feasible investments for NS dairy farmers. There has been limited research in determining energy substitution rates in any area of the Canadian agricultural sector, with no research on energy substitution rates specific for dairy farms within NS. With the programs and policies currently in place, it may be feasible for NS dairy farmers to invest in renewable energy technologies. However, it is important to analyze the potential for NS dairy farms to change their energy supply mix on farm.

Hence, the first objective of this thesis can be formulated as follows:

Objective 1

To establish the upper level elasticities of energy substitution within the NS dairy sector.

The first objective is achieved through pursuing the following goals of the first section (chapters 2 and 3) of this thesis: 1a) Literature review to determine what research has been performed on input substitution in the agricultural sector, specifically related to energy substitution; 1b) Determine the profile of the NS dairy sector in terms of farm size as identified through the data by annual revenue from dairy products; 2) Given the time series data available on costs of production for NS dairy farms, the appropriate modeling technique is chosen from the family of time series tools. This technique is chosen with no *a priori* restrictions on the model and relevant theory is discussed, given the choice of the technique used; 3) Based on the modeling technique chosen, the energy substitution rates on NS dairy farms are determined and analyzed; 4) From the determined energy substitution rates at the upper level, conclusions are drawn on the possibility of using renewable energy technologies on NS dairy farms.

Objective 2

To determine which renewable energy technologies are feasible for dairy farms to use as substitutes for conventional energy forms.

The second objective of this research is achieved through pursuing the following goals of the second section of this thesis (chapter four): 1) A review of the current electrical use within NS is presented, followed by an overview of the NS renewable energy plan; 2) Subsequently, the possibility of implementing renewable energy technologies on NS dairy farms is discussed; 3) Finally, a case study is presented to determine the feasibility of implementing wind turbines, using payback periods and IRR as measures to determine if they are feasible.

After the upper level energy substitution rates are determined, and the feasibility of various renewable energy technologies is discussed, the focus of this thesis shifts to the policies surrounding renewable energy implementation, which leads to the third objective:

Objective 3

To analyze and review the NS renewable electricity plan to assess the impacts it may have on promoting renewable energy within the province's agriculture sector and more specifically the dairy sector. The associated greenhouse gas emissions saved from the substitutions will be determined to assess the environmental benefit that would be obtained from switching out of conventional energy into the renewable energy technologies that are currently feasible for NS dairy farmers.

The third objective of this research is achieved through pursuing the following goals of the third section of this thesis (chapter 5): 1) A review the current energy policy implemented in the province in presented 2) Issues that may affect uptake of the policy

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by farms are addressed; 3) Feasibility of dairy farmers implementing wind technologies on farms is assessed using internal rates of returns and payback periods; and 4) Conclusions and policy recommendations are drawn based on the results of the research. While analysis for objective three is distinctively different from the analysis used in objectives one and two, all objectives are focused on the potential of renewable energy technology implementation on NS dairy farms

1.6 THESIS OUTLINE

The remainder of the thesis is structured in the following manner. Chapter two introduces the relevant literature. Following the literature review, the upper level substitution rates are presented for NS dairy farms in chapter three with its own introduction, theory, data, model, empirical results, discussion and conclusion sections. Following chapter three, chapter four presents the feasibility of current renewable technologies and the viability of substituting between energy sources without any policy interference. Subsequent to chapter four, a critique of the current renewable electricity plan, specifically the community based feed-in tariff policy, and the impact it has on the NS dairy sector is presented. Based on the findings of chapter three through five, general conclusions and policy recommendations are presented in chapter six.

CHAPTER 2: THEORY AND LITERATURE REVIEW

2.1 PRODUCTION THEORY

This section provides an overview of basic production theory, focusing on input substitution, which leads into the discussion of the model used for analysis in this research. Readers are referred to Pindyck and Rubinfeld (2005) for a complete and thorough explanation of production theory.

A production function is the highest level of output a firm can produce, given specific input combinations. There are two common time periods associated with production functions: the short term and the long term. The short term production function refers to a time period when at least one of the inputs is fixed. For example, a firm may have a five year equipment lease which is non-negotiable, and therefore at least for the short term, the cost of the input (equipment) is fixed. Technology may also limit short term production functions as technology does not evolve overnight. On the other hand, long run production functions allow all inputs quantities to be variable, including technology.

An isoquant is a curve that represents all combinations of inputs for a given level of output. Figure 3 demonstrates three isoquants for three different output levels (Q1, Q2 and Q3). The level at which input X can be reduced from using an additional unit of input Y, while holding output constant is the marginal rate of technical substitution (MRTS). Marginal product (MP) is the extra output that can be produced by using one additional unit of an input, while MRTS is equivalent to the ratio of the marginal products of Y and X, which is also equivalent to the slope of the isoquant:

$$MRTS = -\Delta Y / \Delta X \qquad\qquad (2.1)$$

$$= MPy / MPx$$
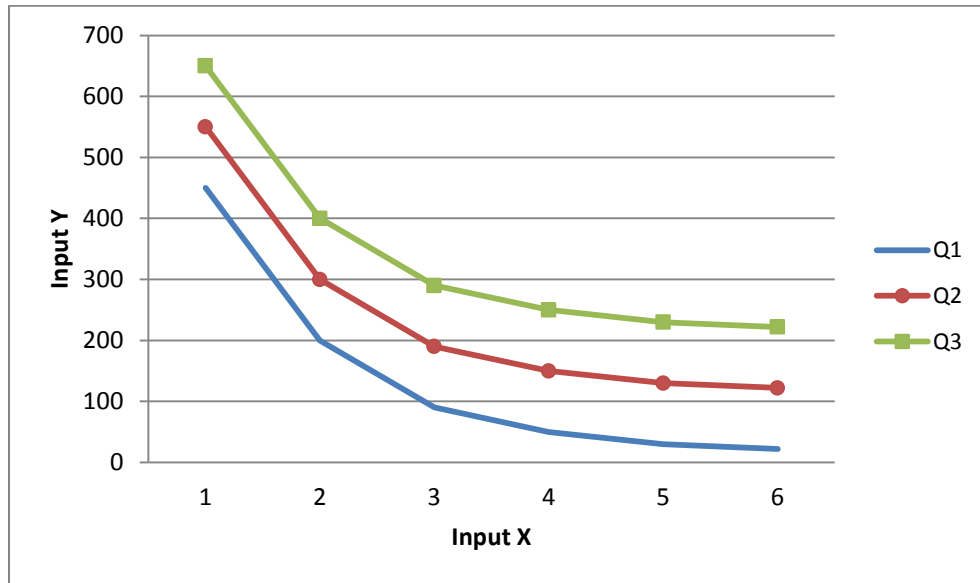
Figure 3: Isoquants for given output levels, Q1, Q2 and Q3

Inefficient and unattainable situations can occur with isoquants. Firms are producing inefficiently if more inputs are used than necessary to reach a given production level. For example, Figure 4 shows an unattainable point (point A), for the given isoquants, because if the firm were operating at the Q3 level of production, they are not using enough inputs to reach the production level of point A. An increase in input quantities used of either X or Y, or any combination of the two could allow the Q3 level of production to be extended (i.e. to a higher isoquant at "Q4 level") and possibly reach point A. However, at point B, the firm is inefficient because more inputs than necessary are used to reach the Q1 level of output. If operating at Q1, firms could decrease the amount of input X and/or Y used to become more efficient and reach point B.
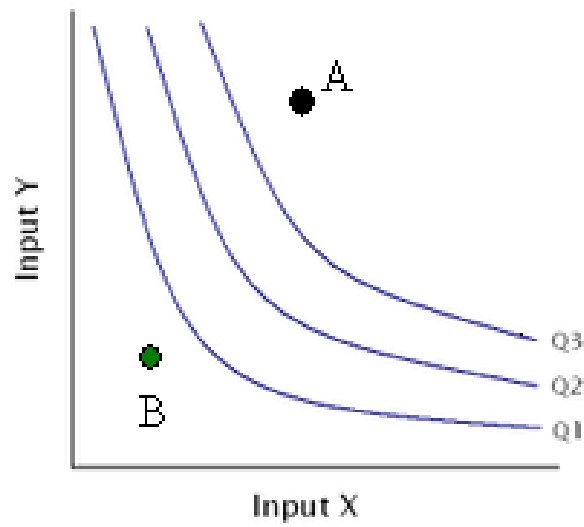
Figure 4: Inefficient and unattainable points on an isoquant

There are two special cases that can occur with isoquants: perfect substitutes and fixed proportions. Perfect substitutes occur when the MRTS is constant for all points along an isoquant and occurs when the isoquant is linear (Figure 5). For example, perfect substitutes would occur if for every unit of labour, one pair of safety boots were needed, then the labour to boot substitution ratio is 1:1, or 1. This creates a linear isoquant.
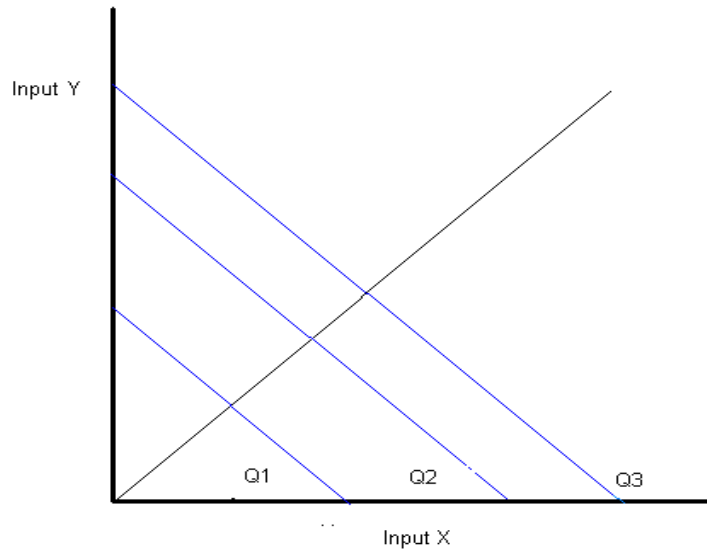
Figure 5: Perfect substitutes for given levels of output, Q1, Q2 and Q3

On the other hand, fixed-proportion production functions occur when it is impossible to substitute among inputs and occurs when MRTS is infinite (Figure 6). For example, if for every unit of capital exactly three labor units are needed, production requires a capital to labor ratio of exactly 1:3. Thus it is inefficient to hire seven laborers if only two capital units are in production, as the seventh labor unit is redundant.
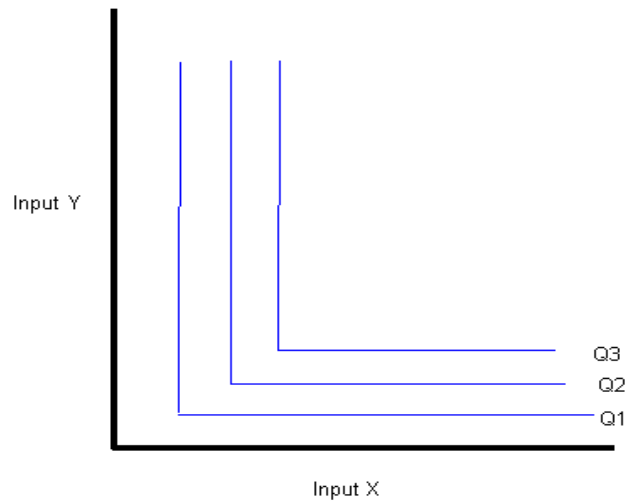
Figure 6: Fixed Proportions for given levels of output, Q1, Q2 and Q3

Although many factors affect the decision making process used to decide on input usage, input cost tends to be one of the major factors when selecting inputs used in production. It is commonly assumed that firms attempt to minimize costs, to allow for profit maximization. An isocost line shows all possible combinations of inputs that can be utilized for a given cost level (Figure 7). Marginal cost (MC) is the change in total cost associated with using one additional unit of input. The minimum cost for a firm is at the intersection of the isoquant and the isocost lines. For example, in Figure 7, if a firm were operating along isocost Q1, the desired level of output cannot be reached since the Q1 does not intersect the isoquant. This indicates that more inputs are needed to increase output and reach the desired level of production.

Using the same example, if a firm were using inputs to produce at isocost Q3, the desired level of production is attainable using this combination of inputs, because the

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isoquant and the isocost intersect (point A). However the intersection of Q3 and the

isoquant does not occur at the lowest cost, because the intersection is not at the lowest

point along the isoquant. This demonstrates that if the firm used a different combination

of inputs, it would allow for the same production level to be reached, but at a lower cost.

Therefore the firm in Figure 7 would want to operate along isocost Q2, which will allow

for the least amount of inputs to be used to attain the desired level of output. This is

shown in Figure 7 where the isoquant intersects Q2 at its minimum (point B).

Input price changes cause isoquant lines to vary in slope. For example, if in Figure

7 the price of input X increases, the isocost line becomes steeper and cost minimizing

firms would decrease quantities of input X used and increase quantities of input Y. Hence

they would substitute from the relatively more expensive input X, to the cheaper input Y.

This is also true for the reverse. If the price of input Y increases, the isocost becomes

flatter and a cost minimizing firm would use more input X and less input Y.
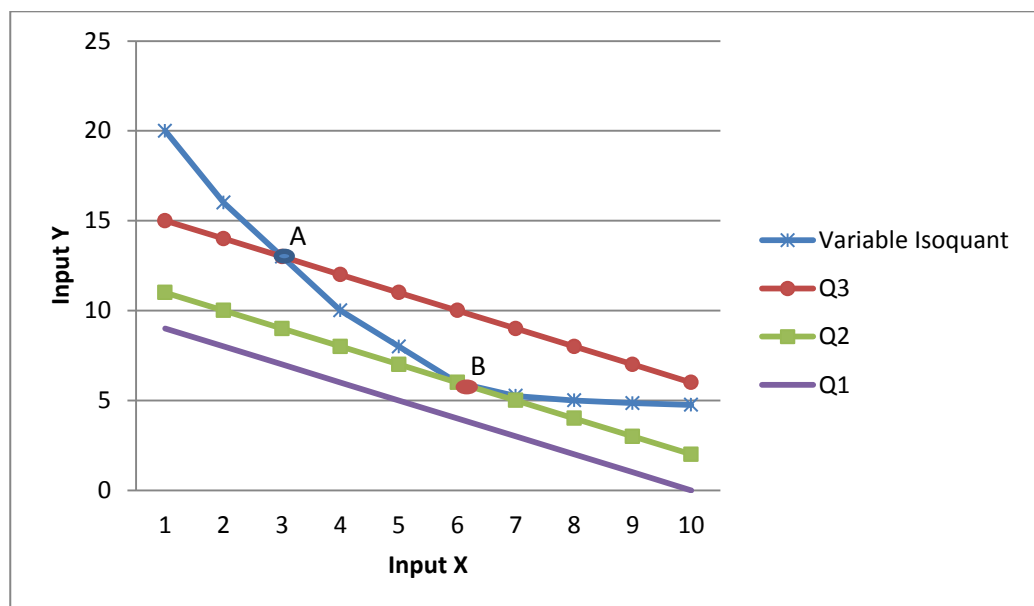
Figure 7: Examples of isocost curves for various input prices

This concept of input substitution is the basis of the economic theory used in this research to analyze the energy substitution rates on NS dairy farms. The next section presents a literature review on input substitution – primarily related to energy substitution as well as a literature review specifically on input substitution within the agricultural sector.

2.2 INPUT SUBSTITUTION

There have been numerous studies on empirical production functions, yet, energy substitutability was not considered a major issue until after the first oil crisis in the 1970's. Since then, there have been various empirical studies using energy as an input factor in both constant elasticity of substitutions and flexible form production functions. Energy costs have been a main focus in both the manufacturing and the agricultural sectors, since both industries tend to be energy intensive. The primary substitution focus has been on capital-energy and labor-energy substitutions and results have varied widely across the literature. In general, input substitution occurs when input prices change, technology advances or production scale varies. Berndt and Wood (1975) found that the demand for inputs, including energy, is a derived demand, based on output, input substitutability and technology use. They also found energy demand to be price responsive. In the agricultural industry, expansion tends to lead to an increased sensitivity of output prices to changes in input prices for regulated commodities such as the supply managed commodities of dairy, eggs and poultry within Canada (Lopez and Tung, 1982). This implies that increasing cost of production can lead to higher prices and therefore decreased output. Lopez (1980) found that aggregate cost functions as well as aggregate production functions exist within Canadian agriculture. Other literature on input

substitution in agriculture include Thompson and Yeboah (2007), who found that in American corn production, fuel was slightly elastic between 1975-2005.

It has also been found that labor is often the best substitute for energy (Lopez and Tung, 1982; Griffin and Gregory, 1976), however there appears to be some debate on the substitutability of energy and capital. Griffin and Gregory (1976) found energy and capital to be substitutes, while Berndt and Wood (1975), Fuss (1977), Hudson and Jorgenson (1974) and Magnus (1979) found these two inputs to be complements. Many others have debated the issue. It seems that the *a priori* restrictions imposed by the method of evaluation affected if energy and capital were found to be substitutes or complements. For a more complete review of the literature relating specifically to energy substitution elasticities see Thompson (2006).

Most prior studies examined the substitutability of energy with another input, such as labor or capital. Field and Grebenstein (1980) and Cameron and Schwartz (1979) both found that substitution estimates vary substantially across different industries and countries. There is limited research specifically on energy substitution in the agricultural sector, and virtually no research on substitutability of different energy inputs, such as between electricity and heating fuel, specifically within the agricultural sector.

There is some literature on the ability of electricity to substitute within the cost function in other industries. Caloghiro et al. (1997) found electricity to be a weak substitute for capital and labour Greek manufacturing. Barnett et al. (1998) found the same results within major industries in Alabama.

There is some substitution literature on the ability to substitute between different fuel sources (e.g. electricity, diesel fuel, oil etc.) outside of the agricultural sector, such as

the work done by Mahmud (2000) who found that in the Pakistan manufacturing sector, there was weak substitution in aggregate energy and other inputs and weak substitution between electricity and gas.

Yeboah et al. (2011) examined the substitution potential between renewable energy and conventional energy sources and found that there are very low substitution possibilities between types of energy inputs. Yeboah et al.(2011) also found the potential for renewable energy to substitute for conventional energy forms is higher than the potential for the conventional energy forms to substitute within themselves, for all energy forms except natural gas. However, the bulk of studies in the literature have examined energy substitution with fixed proportions in mind. For example, for heating, oil and electricity are two common methods of heating and literature is available on substitution rates between the two (e.g. Yeboah et al. 2011). In the long run, technological advances could increase the substitutability between electricity and diesel fuel substitutes, if electric tractors and equipment were to become readily available to dairy farmers. If this were to occur, the potential for dairy farms to switch from their conventional energy sources to renewable sources increases dramatically since substitution rates would no longer only encompass the possibility for direct energy substitutions based on currently available technologies, but it would also include substitution possibilities for total farm energy because in the long term, technological advances should allow substitution possibilities between inputs that aren't currently possible (e.g. between electricity and diesel). This is the factor that takes what has been reported in the literature a step further, to determine the overall substitution potential in the long term, if total energy substitution

possibilities are assessed on farm, not just for substitution possibilities that are currently available.

The research project varies from that of Lopez (1980) and others who have looked at input substitution in agriculture: this study is more specific and only considers the NS dairy sector, rather than Canadian agriculture as a whole. Therefore, the scope of this research is narrower and more detailed than what has been previously discussed. The next section of this thesis introduces the theory used to examine energy substitution on dairy farms in NS. In order to demonstrate the relevance of the theory used, the following sections are introduced: 1) Cost functions the transcendental logarithmic (translog) functional form; 2) Concepts of aggregation and separability of cost functions are discussed; and 3) Substitution theory including Allen/Uzawa elasticities and Morishima elasticities are explained.

CHAPTER 3: UPPER LEVEL INPUT SUBSTITUTION

3.1 INTRODUCTION

This chapter presents the analysis of the upper level substitutions for the cost function for NS dairy farms. First, a review of cost functions is presented, followed by a discussion of duality theory and the transcendental logarithmic (translog) functional form. Two types of elasticities of substitution are presented: Allen/Uzawa elasticities and Morishima elasticities. The concepts of aggregation and separability are discussed, then the model used is presented which consists of a translog cost function with one output variable and seven inputs variables, of which three are energy related. The non-energy input variables include: i) fertilizer and lime; ii) feed supplement, straw and bedding; iii) machinery; iv) salaries (including CPP and EI); and the energy input variables include: v) net fuel expenses, machinery, truck and auto; vi) net electricity (farm share); and vii) heating fuel (farm share). The output variable used is revenues from dairy products and subsidies. The substitution rates between these inputs are found using time series expenditure data and price indices. The empirical results are then presented with both Allen/Uzawa and Morishima elasticities of substitution for the NS dairy sector.

3.2 COST FUNCTIONS

The ability to estimate production parameters can be established through two approaches: primal and dual. The primal approach uses distance functions and Antonelli elasticities of substitution to estimate parameters, while the dual approach uses cost functions and Allen/Uzawa elasticities of substitutions. The information contained in both approaches is identical, typically allowing preference to be decided given data

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availability (Clark et al., 2010). If data is cross-sectional in nature, distance functions are often used because there is little or no variation in prices among producers, making it difficult to estimate a cost function. However, if data is time series in nature, cost functions are typically used because there is price and expenditure data available (e.g. Lopez, 1980). Ideally, if all data are available, preference would be given to simultaneous estimation of both equations, but in general the dual method is typically used when prices are exogenous and quantities are endogenous (Clark et al., 2010).

A major advantage of using cost functions includes not having to impose homogeneity to the degree one on inputs, as necessary in other methods, since cost functions are homogeneous in prices. This implies that input ratios will not change when input prices change, because applying homogeneity in degree one on prices does not apply homogeneity on input quantities (Binswanger, 1974). Another benefit of using costs functions over distance functions occurs when using primary time series data, when costs and expenditures may be the only data available. The estimation of a cost function is simple with only cost and expenditure data, whereas data on input use is needed for the estimation of a distance function and is often difficult to find at the producer level in agriculture, making distance functions more difficult to estimate. Using a cost-function approach eliminates variation because it allows for the estimation equation to use prices rather than quantities as the independent variable (Lopez 1980). This accounts for variations in input combinations due to management or technology differences or fixed capital in the short term. However, the use of cost functions allows the same variable to be examined across all farms, since it is assumed that costs of inputs are the same for each farm within a region (assuming the law of one price holds). This allows for

estimation of a cost function without imposing *a priori* restrictions on the data. This is

supported by Berndt and Wood (1975) who found that for the firm level, the supply of

inputs may be elastic with fixed prices. Yet, at the industry level, input prices are less

likely to be exogenous.

Cost functions are relationships between a vector of input prices (r) a vector of

input quantities (x) and output (Y), which can be defined as:

$$C = C(r,Y) \tag{3.1}$$

Assuming that farms act like typical profit maximizing businesses, then the

behavioral assumption is made that farmers always attempt to minimize cost. The cost

minimization equation is as follows:

$$\min C\ r_i, Y\ =\ \sum_{i=1}^{n} x_i r_i\ \ i=1,2,...n \qquad\qquad \text{s.t. } Y=f\ x_i...x_n \tag{3.2}$$

Where:

    C is total cost

    r_i are the input prices

    x_i are the input quantities

    Y is output

Using the Langarian multiplier (£), the cost minimizing point can be found at:

$$C\ r_n, \lambda\ =\ -\ \sum_{i=1}^{n} r_i\ x_i\ +\ \lambda\ f\ x_i...x_n\ -Y \tag{3.3}$$

The first order conditions associated with the minimized cost function are as follows:

$$\frac{\partial C}{\partial x_i} = r_i - \lambda \frac{\partial f}{\partial x_i} = 0 \tag{3.4}$$

$$\frac{\partial C}{\partial \lambda} = Y - \lambda \; f \; x \; - Y \; = 0 \tag{3.5}$$

$$f \; x \; \geq Y \tag{3.6}$$

There are both necessary and sufficient conditions of well-behaved cost functions. The necessary condition is that cost functions are non-decreasing in output and concave in input prices, while the sufficient condition is that marginal cost curve is upward sloping. The properties of a well behaved cost function are that it is homogenous of degree one in input prices, concave in input prices and non-decreasing in output.

The restrictions placed upon the cost function include first order conditions stating that the change in the cost function with respect to the change in inputs must be zero: ($\partial C/\partial x_n$=0) and that the change in the cost function with respect to marginal cost is also equal to zero ($\partial C/\partial MC = 0$).

Two other restrictions that are often placed upon costs functions include the negativity and symmetry restrictions. The symmetry restriction is that the ratio of the increase (decrease) in one input when there is decrease (increase) in the price of another input must be equivalent to the decrease (increase) in ratio of the second input to the first inputs price, or $\partial x_i/\partial r_j = \partial x_j/\partial r_i$. This must be true for a given output level. The negativity restriction is that since the cost function is concave in prices, then $\partial x_i/\partial r_i < 0$, for concavity to hold. The remainder of this section will focus on the transcendental logarithmic functional form of a cost function and the associated elasticities of substitution.

3.3 THE TRANSCENDENTAL LOGARITHMIC FUNCTIONAL FORM

The transcendental logarithmic (translog) functional form is one type of a cost function, developed by Christensen, Jorgensen and Lau (1973). This method is a general form and a second order approximation to an arbitrary twice differentiable cost function (Christenson et al., 1973; Berndt and Wood, 1975). Translog cost functions are typically used when *a priori* restrictions on the model (specific functional form) are unknown. This is a convenient form of duality theory to use when the type of production function is unknown, as in the NS dairy sector, since there has been little previous economic analysis performed on that specific sector. Other benefits of using the translog model are that it imposes no restrictions, such as homogeneity or symmetry, on the cost function which allows the results to be unbiased.

The translog functional form is a function of input prices (r_i) and output (y):

$$Ln\ C\ =\ \alpha_o + \sum_{i=1}^{n+1} \beta_i \ln r_i + \frac{1}{2} \sum_{i=1}^{n+1} \sum_{j=1}^{n+1} \beta_{ij} \ln r_i^* \ln r_j^* \ ; \qquad and\ \beta_{ij} = \beta_{ji} \quad (3.7)$$

Where:

Ln C is the natural logarithm of the cost function

Ln r_i^* is a vector of the natural logarithms of input prices and output, where r_i*=[ln r_1, ln(r_2), … ln(r_n), ln(y)].

r is a vector that includes [r_1, r_2…, r_n]

n is the number of input variables

The properties of the translog cost function are that it is homogeneous of degree one in r, concave in r and non-decreasing in y (e.g. Shephard, 1970). There are two major restrictions imposed on the translog cost function model which include a homogeneity restriction and a symmetry restriction.

The homogeneity restriction of the translog cost function are:

$$\sum_{i=1}^{n} \beta_i = 1 \quad \text{and} \quad \sum_{i=1}^{n} \beta_{ij} = 0 \tag{3.8}$$

This implies that if the entire function changes proportionately, there will be no net effect on the function. The symmetry restriction is as follows:

$$\frac{\partial x_i}{\partial r_j} = \frac{\partial x_j}{\partial r_i} \tag{3.9}$$

This implies that the proportional change in one input is equivalent to the proportional change in another input. This means as the price of an input (r_1) increases, a producer would buy less input x_1, and would have to increase use of a second input (x_2) by a proportional amount to keep output levels constant.

Using Shepherd's lemma and differentiating equation 3.7, the following share equation is found:

$$S_i = \beta_i + \sum_{j=1}^{n} \beta_{ij} \ln r_j + \beta_{iy} \ln Y \tag{3.10}$$

Where:

$$S_i = \frac{\partial \ln C}{\partial \ln r_i} \tag{3.11}$$

Where:

S_i is the share of total cost

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r$_i$ are input prices, and

C is total cost

Using Shepherd's Lemma, optimal input levels (x*) occur at:

$$x_i^* \; r_i Y \;\; = \;\; \frac{\partial C \; r_i, Y}{\partial r_i}$$ (3.12)

and

$$C \; r_i, Y \;\; = \;\; \textstyle\sum r_i \, x_i^* \; r_i, Y$$ (3.13)

The share equation (3.11), is used when calculating elasticities of substitution as a proportion of the input with respect to total cost. This is the method that is used for calculating elasticities in this analysis. Although the translog cost function itself is not calculated, but only used as a means to calculate elasticities, there are many benefits of using this functional form, including that it can be used for any twice differentiable cost function that is linear in logarithms and also for any twice differentiable aggregate production function that relates to the flow of gross output and inputs used (Berndt and Wood, 1975; Binswanger, 1974; Griffin and Gregory, 1976). The translog method also does not imply homothenicity, meaning expansion is not necessarily linear therefore input combinations can vary. This avoids the necessity of restricting the elasticities of substitution (Woodland, 1975 and Berndt and Wood, 1975). Estimation of a translog cost function has been used frequently in analysis of input substitution in agriculture by Binswanger (1974), Lopez (1980), Clark and Youngblood (1992) and Clark et al. (2010).

Although the translog functional form is a commonly used method of analysis, there are some concerns associated with it, specifically around input aggregation and

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separability. This is because in the aggregate, prices and quantities of both inputs and outputs can influence one another (Christensen et al., 1973).

Composite commodity theorems were created for easier estimation of utility and cost functions, through aggregation of primary commodities. For example, let r and x be vectors of input prices and quantities of inputs used on dairy farms, for i=1,…,n and I is the index of groups of inputs. For example the set of i ε I for the aggregate input group of "feed" could include all grains (barley, corn etc.), forages (hay, silage, grasses, etc.), and supplements (salt, minerals, soybean meal etc.). Incorporated in this study, the set of i ε I for "energy" could include electricity, heating fuel and diesel and auto fuels. R and X would then be vectors of group prices for inputs and quantities.

Historically in economics there have been two common ways to aggregate commodities for analysis. The first was using the Hicks-Leontief composite commodity theorem which was developed by Hicks (1936) and Leontief (1936). This involves prices having a correlation equal to 1, where $w_i= \log(p_i/P_I)$, so w_i is the logarithm of the ratio of the price of the commodity p_i to the price of the group, P_I, where X minimizes a cost function given the group prices, P, is constant. This indicates that either the price or the quantity ratios of every i in the group I must move in exact proportion over the data sample. Although prices tend to be correlated over time, a correlation equal to one is not realistic. Therefore aggregation errors in this model are generally accepted as unknown errors (Davis et al., 2000). The benefits of this model are that it imposes no restrictions on preferences and the parametric model utilized does not have to be established, and it allows prices to be collinear (Davis, 2003).

The second way to aggregate commodities was using the separability theorem which was developed for producer theory by Leontief (1947). This method uses separability and two-stage budgeting by assuming producers are rational and minimize prices and quantities of each individual input, which causes the price and quantity of the aggregate input to also be minimized. This is done through two stage budgeting. First it is assumed that tradeoff between inputs is independent of the quantity of other inputs and therefore is completely dependent upon costs. The second step is to aggregate inputs into independent broad categories such as feed or energy as mentioned previously. The inputs within the broad categories must be independent and separable into individual commodities for the separability assumption to hold. This can be stated as:

$$\frac{\frac{\partial x_i}{\partial r_i}}{\frac{\partial x_j}{\partial r_j}} = 0 \tag{3.14}$$

For a strongly separable assumption the above equation must hold for all i ε I_s, j ε I_p, and k∉I_s ∪ I_r where I_r is another subset of I. For a weak separablility assumption, the above equation must hold for all iε I, jε I, kε I where I is a subset of the set of input factors I= (1,2,…, n).

This method imposes very restrictive measure on technology (Davis et al., 2000) because separability is a strong assumption that is difficult to test due to multicollinearity and disaggregate prices (Lewbel, 1996). The main concern associated with using

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separability is that even imposing weak separability implies strict restrictions upon the elasticities equality of groups (Davis et al., 2000).

Lewbel (1996) proposes a generalized composite commodity theorem that has weaker restrictions imposed on the model. This is accomplished by allowing the model to have a well behaved error term in the aggregate groups. This denotes the ratio of individual inputs to group input prices (p_i/P_I) can vary and enforces only that the input price ratio be independent of group price levels, allowing weak separability conditions. This is the method that is used for analysis in this research. The subsequent section will discuss the two types of elasticities of substitution used for the empirical analysis.

3.4 ALLEN/UZAWA AND MORISHIMA ELASTICITIES

The theory of elasticity of substitution shows a firm's changes in quantities of two inputs as a response to a relative change in the ratio of the prices of those inputs. The relationship between inputs is important to determine since it demonstrates how changing the quantity of one input will affect the quantity of others. Inputs are found to be substitutes if the change in input quantity with respect to input price is greater than zero ($\partial x_i/\partial r_j > 0$), but, if the change in input quantity with respect to input price is less than zero ($\partial x_i/\partial r_j < 0$), then inputs are determined to be complements. Although some inputs can be complements, meaning that as more of one input is purchased, so is more of the other, not all inputs can be complements. This is because if all inputs were complements it would violate the basis of substitution theory, which states that overall output cannot be held constant, if all inputs are complementary. To ensure that output is held constant at least some inputs must be substitutes, meaning that as more of one input is used, less of

another is used. If all inputs were complements and none were substitutes, then more and more of each input would be used which in turn would increase output and violate the basis of the cost function which is determined for a given, *constant* output level.

There are two generally accepted types of long run elasticities of substitution, with the first being created by Hicks (1932) and updated by Allen (1938) called the Allen partial elasticity of substitution (AES). The Allen/Uzawa partial elasticity of substitution is used to measure substitution possibility between two inputs in a cost function. This can be shown as:

$$\sigma_{ij} = \frac{C \frac{\partial^2 C}{\partial r_i \partial r_j}}{\frac{\partial C}{\partial r_i} * \frac{\partial C}{\partial r_j}} \tag{3.15}$$

Where:

C is a cost function where regularity conditions hold, meaning C is continuous, non-decreasing, linearly homogeneous, concave in r, increasing in output, twice continuously differentiable in r, and Cij is a restricted cost function that holds fixed all factors other than i and j and satisfies the same conditions as C. r_i and r_j are input prices, and i and j are partial derivatives where i=1…k and j=1…k. The results of the Allan/Uzawa elasticities of substitution determine relationships between inputs. Inputs are determined to be superior substitutes if elasticity is found to be greater than one. Inputs will act normal if elasticity is between zero and one, and inputs are inferior if elasticity less than one. However AES does not provide insight to relationships between factor shares (Blackorby and Russell, 1989), but it does inform on own price elasticities.

The associated Morishima elasticity of substitution (MES) (Blackorby and Russell, 1989 and Morishima, 1967) between inputs x_i and x_j are found intuitively by subtracting the diagonal element (σ_{ij}), of the jth row of the AES matrix from equation 3.13 and can be defined as:

$$MES_{ij} \ r, x \ = \ S_j \sigma_{ij} - S_i \sigma_{ii} \qquad (3.16)$$

Equation 3.16 is the difference between the cross price elasticity and own expenditure and demonstrates the properties of the MES meaning they are not required to be symmetric or constant. The MES is solely a measure of the ease of substitution which can be used to evaluate the factor shares as a result of a change in price or quantity ratios (Blackorby and Russell, 1989).

3.3 DATA

The data used in this research is secondary time series data from the Canadian Farm Financial Database's taxation data program (CFFD, 2010), which is a joint program between Statistics Canada and Agriculture and Agri-food Canada. The data runs from 1997 through 2008 for dairy farms in the province of NS, Canada. The data required for this research are expenditures for the seven inputs. The non-energy related inputs were: i) fertilizer and lime; ii) feed supplement, straw and bedding; iii) machinery; iv) salaries (including CPP and EI); while the three energy related inputs were: v) net fuel expenses, machinery, truck and auto; vi) net electricity (farm share); vii) heating fuel (farm share); and gross revenues from one output: i) dairy products and subsidies. The data is segregated into three groups by revenue class, which is used to determine farm size. The

farm sizes included small dairy farms, defined as NS dairy farms generating under $250,000 annually; medium dairy farms generating between $250,000 and $499,999 annually and large dairy farms generating more than $500,000 annually. Price indices were also required for the seven inputs and one output and were found using Statistic Canada's farm input price index (Statistics Canada, 2008) and the farm product price index (Statistics Canada, 2011c), to correspond with the seven inputs and one output variables. All indices were normalized for 1992 using price indicies. The following section will present the data used for analysis and demonstrate the two-stage budgeting and translog cost function approach.

3.4 MODEL

3.4.1 TWO-STAGE BUDGETING AND TRANSLOG COST FUNCTIONS

This paper uses two-stage budgeting as a method to analyze the elasticities of substitution within the NS dairy sector. A translog cost function is estimated with seven aggregate input categories: i) fertilizer and lime; ii) feed supplement, straw and bedding; iii) machinery; iv) salaries (including CPP and EI); v) net fuel expenses, machinery, truck and auto; vi) net electricity (farm share); vii) heating fuel (farm share); and revenues from one aggregate output: i) Dairy products and subsidies. Figure 2 shows the two-stage budgeting approach used with specific reference to the energy sub-groups.

In this section, a translog cost equation is created for NS dairy farms. The translog model is written in matrix form to allow for simple demonstration of a multiple input model. A translog cost function is used, as in equation (3.15), where:

$$Ln\ C\ =\ \alpha_o\ +\ \sum_{i=1}^{n}\beta_i\ \ln r_i\ +\ \frac{1}{2}\ \sum_{i=1}^{n}\ \sum_{j=1}^{n}\beta_{ij}\ \ln r_i^*\ \ln r_j^*\ +\ \ln y \qquad (3.17)$$

Where:

$$\beta_{ij} = \beta_{ji}$$

LnC is the natural logarithm of the cost function for NS dairy farms

$\ln r_i^*$ is a vector of the natural logarithms of the seven inputs and one output,

where:

r_1 = fertilizer and lime

r_2 = feed supplement, straw and bedding

r_3 = machinery

r_4 = salaries (including CPP and EI)

r_5 = net fuel expenses, machinery, truck and auto

r_6 = net electricity (farm share)

r_7 = heating fuel (farm share)

y_1 = dairy products and subsidies

This model was created as a means to determine the Allen/Uzawa and Morishima

elasticities of substitutions, using equations 3.15 and 3.16 applied to the translog model,

as presented above in equation 3.17.

Simple bootstrapping was used to estimate the regularity conditions of the model

(i.e. concavity and negativity) for each year. Bootstrapping has been used by Chalfant et

al. (1991) as well as in many other economic studies such as Eakin et al. (1990), Ryan and Wales (2000), Dissou and Ghazal (2010) and Gervais et al. (2008). The bootstrap is used for the estimation of partial elasticities of a cost function because in a typical model, it is assumed that parameters are normally distributed. However, since the cost function is a nonlinear model, the parameter estimates will not necessarily be normally distributed. Regularity conditions of cost functions are often calculated at the mean of a data set, but due to the nonlinearity of the function, the regularity conditions may not hold true for a mean of a flexible form function, such as the translog cost function because so many parameters (multi-inputs in this model) are estimated. Anderson and Thursby (1986) suggest that there is no reason for one to expect the Allen elasticities of substitution to follow normal distributions. The bootstrap method estimates the regularity conditions at each data point, rather than at the mean of the sample. This allows the functional form to continue to be flexible. The assumptions associated with the translog cost function in this application are as follows:

1. No restrictions imposed on the first and second order derivatives, which allows scale and substitution measures to vary as inputs and outputs change

2. Cost minimization implies that the cost function is linearly homogenous with respect to input prices while Young's theorem (Jehle and Reny, 2011) implies symmetric second cross partial derivatives.

3. Other regularity conditions such as monotonicity, concavity and non-negative marginal costs cannot be imposed without a great loss in functional form flexibility. Instead these conditions are checked at each data point.

With this method, the properties of the cost function are tested at each data point,

rather than at the mean of the entire data set. For example, instead of estimating a

translog cost function for the entire data set and testing concavity for the average cost

function, rather, concavity is estimated at each data point within the sample to see if each

individual point is concave. If it is not, these points are not used in the estimation of the

overall cost function, implying the overall cost function must be concave, since only

concave data points are utilized in the estimation of the function. With this method, a

translog cost function was used to estimate both the associated Allen/Uzawa and

Morishima elasticities of substitutions calculated for each of the three farm sizes: small,

medium and large.

3.5 EMPIRICAL RESULTS

The results of the empirical analysis are presented in the following tables:

Table 1: Allen/Uzawa elasticity of substitution matrices for energy group of small farms

	Price ($)		
Quantity	Fuel – diesel and auto	Electricity	Heating
Fuel – diesel and auto	-9.92	-0.79	-14.49
Electricity	-0.79	-20.93	-0.83
Heating	-14.49	-0.83	-1004.39

Source: Own calculations

Table 1 presents the Allen/Uzawa elasticity of substitution matrix of the energy

sub-group for small dairy farms in NS. The entire farm elasticity of substitution matrix

for small farms can be found in Appendix A. The Allen/Uzawa elasticities show that for

small farms the law of demand holds, demonstrated by negative own price elasticity

estiamtes. As well, own price complementarity is considerably high for heating fuel, at

-1004.39.

Table 2: Morishima elasticity of substitution matrices for energy group of small farms

	Price ($)		
Quantity	Fuel – diesel and auto	Electricity	Heating
Fuel – diesel and auto	0.00	3.26	-0.36
Electricity	1.58	0.00	1.59
Heating	77.56	358.17	0.00

Source: Own Calculations

Table 2 presents the Morishima elasticity of substitution matrix for the energy sub-group for small dairy farms in NS. The whole farm elasticity of substitution matrix for small farms can be found in Appendix A. The Morishima elasticities demonstrate that complementarity is eliminated, since all inputs are found to be net substitutes, except for the complementary estimate between diesel and auto fuel and heating, where the value is estimated to be – 0.36. This could be due to the fact that the primary farm auto fuel source within the province is diesel and a common heating source within the province is oil, and both of these inputs are dependent upon the price of oil. Therefore, when the price of oil increases (decreases), the usage of these two inputs decreases (increases) relatively, and there is no substitution between the two inputs due to a price change. Another point of interest is that heating fuel has very high estimates for both the Allen/Uzawa and Morishima elasticities, indicating that it is very elastic. This result could be due to heating fuel having such a small share of total farm expenditures, or the fact that technology is currently available to allow for easy substitution between heating fuel and the other energy sources.

Table 3: Allen/Uzawa elasticity of substitution matrices for energy group of medium farms

Quantity	Price ($)		
	Fuel – diesel and auto	Electricity	Heating
Fuel – diesel and auto	-13.58	-2.44	-23.86
Electricity	-2.44	-34.23	-6.25
Heating	-23.86	-6.25	-70430.26

Source: Own calculations

Table 4: Morishima elasticity of substitution matrices for energy group of medium farms

Quantity	Price ($)		
	Fuel – diesel and auto	Electricity	Heating
Fuel – diesel and auto	0.00	4.49	-0.63
Electricity	2.13	0.00	1.70
Heating	4714.41	28362.28	0.00

Source: Own calculations

Table 3 and Table 4 demonstrate the Allen/Uzawa and Morishima elasticity of

substitution matrices for the energy sub group of medium sized dairy farms in NS. The

entire elasticity of substitution matrix for medium sized dairy farms can be found in

Appendix B. Both the Allen/Uzawa and the Morishima elasticities are presented. The

Allen/Uzawa elasticities show that for medium sized dairy farms the law of demand

holds, demonstrated by negative estimates for own price elasticities, for each of the three

inputs. As well, own price elasticity is extremely high for heating fuel at -70430.26. The

Morishima elasticities demonstrate that complementarity is eliminated, since all inputs

for medium sized farms are also found to be net substitutes, except again, there is

complementarity between heating fuels and diesel and auto fuels (-0.63), which is

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probably due to their dependence upon the price of oil, as explained previously.

Electricity-diesel substitutions (4.49) are quite elastic as well as electricity-heating fuels

(1.70). Heating fuel was also found to be extremely elastic for medium sized dairy farms,

which intuitively, if the technologies are readily available for substitution, then heating

fuel would be elastic for any farm size.

Table 5: Allan/Uzawa elasticity of substitution matrices for energy group of large farms

	Price ($)		
Quantity	Fuel – diesel and auto	Electricity	Heating
Fuel – diesel and auto	-14.75	-3.07	-32.53
Electricity	-3.07	-37.99	-9.94
Heating	-32.53	-9.94	-4054.67

Source: Own calculations

Table 6: Morishima elasticity of substitution matrices for energy group of large farms

	Price ($)		
Quantity	Fuel – diesel and auto	Electricity	Heating
Fuel – diesel and auto	0.00	4.40	-1.04
Electricity	2.44	0.00	1.64
Heating	281.15	1524.70	0.00

Source: Own calculations

Table 5 and Table 6 demonstrate the elasticity of substitution matrices for large

dairy farms in NS. The entire elasticity of substitution matrices for large farms can be

found in Appendix C. Both the Allen/Uzawa and the Morishima elasticities are presented.

The Allen/Uzawa elasticities show that for large farms the law of demand holds,

demonstrated by negative estimates for own price elasticities. Again, the Morishima

elasticities demonstrate that complementarity is eliminated, since all inputs for medium

sized farms are also found to be net substitutes. Again, heating fuel was found to have

large estimates for own price complementarity and is very elastic and heating fuels and

diesel and auto fuels were found to be the complements (-1.04).

3.6 DISCUSSION

Heating fuel was found to be extremely elastic for all farm sizes. This could be

due to the small factor share of heating fuel relative to the total farm expenditure. It is

also thought that heating fuel is elastic because the technology is available for

substitution from heating fuel into electricity and diesel. Diesel and heating fuel were

complements for all farm sizes, with small farms having smaller complementarity and

large farms with the highest complementarity. As mentioned previously, this is probably

due to the fact oil, which is a common heating source within the province is dependent

upon the price of oil and so is diesel, the main fuel source; therefore, higher price

complementarity would occur for larger farms that use higher quantities of heating fuel.

Electricity is the most substitutable input within the aggregate energy category

and was in the second top substitutable input for the entire farm, following feed (see

appendices A through C). This indicates that an increase (decrease) in the price of

electricity, farmers will tend to purchase less electricity and increase (decrease) on-farm

electrical use.

On medium and large farms feed was most substitutable with electricity, diesel

fuel and fertilizer. This make sense because if feed prices increase (decrease) farmers

decrease (increase) expenditures on purchased feeds and increase (decrease) on-farm

production of feeds which will increase (decrease) use of inputs such as diesel fuel and

fertilizer. A decrease in purchased feed prices would also increase electricity use, possibly due to increased motor use of augers and feed lines.

These results are in agreement with Lopez and Tung (1982) who determined energy and energy based inputs to be substitutes with labor and capital, however complements between themselves. They also agree with Clark et al. (2010) who found substitution between machinery, fertilizer and labor. However these results disagree with Webb and Duncan (1979), who determined energy and energy based inputs to be substitutes. These results also vary from Lopez (1980) who found the highest substitution between labor and capital. They also vary from Binswanger (1974), who found fertilizer-labor and fertilizer-machinery substitutions to be complementary within the United States of America (USA).

As demonstrated by the Allen/Uzawa and Morishima elasticity of substitution matrices presented (tables one through six), it is shown that electricity is highly substitutable within the energy subgroup, indicating that either heating fuel or diesel fuel could be substituted for (or into) electricity, if the technologies were available. These results were expected due to the fact that there currently are renewable energy technologies available to allow electric users to switch from conventional electric generation into renewable energy sources.

3.7 CONCLUSIONS

This chapter demonstrated the use of a translog cost function as a means to estimate share equations and Allen/Uzawa and Morishima elasticities of substitution for small, medium and large dairy farms in NS, to determine if price complementarity or

substitution existed between inputs. A transcendental logarithmic functional form was used for the empirical analysis and consisted of seven inputs: i) fertilizer and lime; ii) feed supplement, straw and bedding; iii) machinery; iv) salaries (including CPP and EI); three energy inputs consisting of: v) net fuel expenses, machinery, truck and auto; vi) net electricity (farm share); vii) heating fuel (farm share); and one output: i) dairy products and subsidies. Both Allen/Uzawa and Morishima elasticities of substitution were determined. Results indicated that within the energy group, heating fuel and diesel and auto fuels were complementary for all farm sizes, and heating fuel was very elastic for all farm sizes. Feed, electricity and fertilizer were found to be the most substitutable inputs across all farm sizes.

The subsequent chapters will discuss the lower level substitutions between technologies that can substitute for conventional electricity (e.g. renewable electricity sources), conventional heating fuel (e.g. grass pellets etc.) and conventional fuel - diesel (e.g. biodiesel) (see Figure 2). The resources within the province of NS are evaluated for potential renewable generation. Policy implications will then be evaluated to determine how policy is currently, or could potentially, impact the uptake of renewable energy production.

CHAPTER 4: LOWER LEVEL INPUT SUBSTITUTION

4.1 INTRODUCTION

This chapter presents the analysis of the lower level substitution for the cost function for dairy farms in NS. First, a review of the current electrical use within NS is presented, followed by an overview of the NS renewable energy plan. Subsequently, the possibility of implementing renewable energy technologies on NS dairy farms is discussed. Finally, a case study is presented to determine the feasibility of implementing wind turbines, using payback periods as measures to determine if they are feasible.

4.2 CURRENT ENERGY USE IN NOVA SCOTIA

4.2.1 ELECTRICITY

In 2008, NS used 12,164,400 megawatt hours of electricity (Statistics Canada, 2009a). Nova Scotia Power Inc. (NSPI) is the main supplier of electricity, supplying 97% of the province's electricity requirements. This accounts for an annual average of 2.2 GW of electrical power generation, transmission and distribution (NSPI, 2009a).

The electricity capacity of NS is primarily from fossil fuel plants using coal (47.5%) and petroleum coke (8.4%). Other electrical capacity comes from natural gas (17.1%), hydro (13.6%), wind turbines (10.8%) and tidal power (0.7%) (Centre for Energy, 2012). Total generating capacity is given in Table 7. There is also an interprovincial connection between NS and New Brunswick, with a total capacity of about 350 MW (NSDE, 2009).

Table 7: Electric generating capacity in NS in 2009

Energy Source	Number Installed	Installation Capacity
Petroleum fired	3	222
Natural Gas fired	1	450
Coal Fired	4	1252
Hydro	33	360
Wind	161	283.3
Tidal	1	20
Biomass	3	46.2
Total		**2633.5**

Source: Centre for Energy, 2012.

The demand and the price of electricity in the province have been increasing. In 2003 an average consumer used 8.84 MWh per year, and had an average annual electrical bill of $874.34. While in 2007 the average use was 10.38 MWh per year, at a cost of $1,131.27 (Statistics Canada, 2007). This increasing trend in electricity demand is expected to continue over the next decade, from a provincial total of 12,539 GWh demand in 2008, to a predicted 13,241 GWh in 2018 (NSDE, 2009a). Specific to agriculture, it was found by Bailey (2007) that the average annual energy cost by dairy farms within the province was $22,026 with 37.9% of that allocated to electrical energy and 29.4% to diesel fuel. The other types of energy use included gas (17.3%), oil (9.7%), wood (3.8%) and other petroleum products (1.8%).

NSPI supplied an average of 2,293 MW of electrical power to NS consumers in 2008 (Nova Scotia Power Inc., 2009a), and with demand increasing, NSPI is approaching its total electrical generating capacity of 2,983.5 MW (if the provincial interconnection of 350 MW is used strictly for imports). This potential shortage in electrical generating capacity, combined with increasing electrical prices (NSPI has proposed a 3% annual increase of electric rates over the next two years (Nova Scotia Power Inc, 2012)) and a

concern with environmental impacts from fossil-fuel generated electricity has spurred the provincial government to consider renewable energy sources for electrical generation.

4.2.2 RENEWABLE ENERGY POLICY IN NS

Before April 2010, there was no true renewable energy policy in NS. However there were acts within the province that impacted the energy industry, such as the Renewable Energy Standard (RES) Regulations (Province of Nova Scotia, 2007a) and the Environmental Goals and Sustainability Prosperity Act (EGSPA) (Province of Nova Scotia, 2007b).

The EGSPA sets forth regulations regarding environmentally friendly economic growth. This encompasses regulations involving all types of environmental management, including management of pollution, emissions, and environmental resources. The major regulation that affects energy consumption is that greenhouse gas (GHG) emissions must be at least 10% below the 1990 level by the year 2020. To accomplish this, GHG emissions from electrical generation must not increase (Province of Nova Scotia, 2007a). The RES also stated the goal to have 18.5% of the total electricity needs of NS generated from renewable energy sources by the year 2013. However the NDP government updated the renewable energy standard regulations to increase this goal to generate 25% of the total electricity needs of the Province obtained from renewable energy sources by the year 2015 (Province of NS, 2010).

Although there was no comprehensive energy policy in the province, NSPI had a net metering regulation in place for small scale renewable energy options, which allowed consumers to implement small renewable energy projects and the electricity generated from the renewable energy source could offset their energy consumed. Therefore, the

consumer paid for the "net" (electricity purchased from the grid less electricity produced) annual amount used (NSPI, 2009b). This is essential for generation variable supply. If a consumer produced more electricity than they consumed in a given year, the consumer was not compensated for their over production. However, if a consumer produced less than their total usage, the extra electricity needed was supplied by NSPI, at a cost to the consumer (electricity was supplied at the current electrical rate for the period).

On April 23rd, 2010 the Provincial Government announced the Renewable Electricity Plan that outlined the methods by which the government will move forward with regards to electricity generation (Province of Nova Scotia, 2010). Three scales of renewable electricity generation were addressed in this plan. Small scale generation was supported through enhanced net metering, community scale generation was supported through a community feed in tariff (COMFIT) and large scale generation through contracts between NSPI and independent power producers (NSDE, 2011a). Enhanced net metering applies to projects of less than 1MW to be connected to the distribution network, but the consumer cannot install a generator greater than the energy consumed on the site. COMFIT applies to projects under 5 MW in size, for a provincial cap of 100 MW total generation, connected to the distribution network; and medium and large scale renewable projects continue as they traditionally have with the Utility and Review Board overseeing NSPI's proposed projects and independent power producers bidding for projects through requests for proposals (Province of Nova Scotia, 2010).

4.2.3 ENHANCED NET METERING

The enhanced net metering policy was implemented to address small scale renewable energy generation, which updates NSPI's previous net metering regulation that was enforced by NSPI. An issue with NSPI's previous net metering regulation was that it only applied to small projects with a generating capacity of less than 100 kW and did not provide payment for excess power generated. This policy also did not allow excess electricity generated to be supplied to surrounding community members, as the renewable source could only be used for individual consumption. Therefore, it only approved very small projects for individual customers who were not compensated for any excess generation (Nova Scotia Power Inc., 2009a).

However, with the new enhanced net metering policy, the maximum generation capacity was increased to 1 MW. This is a significant improvement upon the historical net metering regulation, for it allows larger projects to be considered. In addition, payment is now provided at current electricity rates for any surplus electricity produced annually and generators are able to supply electricity to multiple meters, provided they remain within the 1MW production limit (Province of Nova Scotia, 2010). The improvement to this regulation has given the potential for farms to install small scale renewable energy technologies for their own consumption and receive another source of income for any excess electrical generation.

4.2.4 COMMUNITY FEED-IN TARIFF

Medium scale renewable energy generation was addressed through the creation of the community based tariff (COMFIT), which applies to projects under 5 MW in size, for

a provincial total of 100 MW total generation, connected to the distribution network (Province of Nova Scotia, 2010). These projects must be community owned, meaning that farmers would have to form a co-operative with at least 25 members, all residing within the same municipality, to implement a renewable energy system of this size. This presents a hurdle for any farmer interested in medium scale renewable energy generation.

4.2.5 REQUESTS FOR PROPOSALS

Medium to large scale renewable projects continue as they traditionally have with the Utility and Review Board overseeing NSPI's proposed projects and independent power producers bidding for projects through requests for proposals (Province of Nova Scotia, 2010).

A critical analysis of the entire renewable energy policy in NS with respect to farm implementation is presented in chapter five.

4.3 POTENTIAL FOR RENEWABLE ENERGY GENERATION ON NS DAIRY FARMS

In 2008, NS farmers spent a total of $9,883,000 on electricity, equivalent to about 89.8 GWh, accounting for an average 2.4% of total farm expenses as reported by Bailey (Bailey et al., 2008a; Statistics Canada, 2009b). On-farm generation of renewable energy creates two potential benefits for farmers. First, it can provide energy and financial security by increasing the stability of operating costs and second, it has the potential for diversification of farm production. Farms are typically located in rural areas and, depending on the farm type, have access to land for the installation of large wind turbines, often in the COMFIT scale, or for the growth of energy crops. Such crops could be used to provide energy for a farmer's own operation or for sale for further processing

as a consumer product. Although the exact amount of unused agricultural land in NS is unknown, estimates are in the hundreds of thousands to over a million hectares of land that is currently not being used for crop production which would be suitable for energy crops (GPI Atlantic, 2008b). Biomass, under the COMFIT regulations can consist of primary forest products, agricultural energy crop residues, sawmill and wood processing residues, farm based biogas, liquid, solid and gaseous fuels made from biomass, and biosolids.

The regulations farmers have to observe when considering wood biomass options include:

- a provincial annual limit of 350,000 dry metric tons of sustainably harvested primary forest products to be used annually for biomass

- sawmill and wood processing residues are preferred to harvesting forest biomass

- it is recommended that agricultural energy crops and residues from short rotation woody crops and herbaceous energy crops are produced, grown and harvested according to the NS Environmental Farm Plan and Nutrient Management Planning programs (NSDA, 2010);

- farms can use their own feedstock for biogas systems;

- all projects must be sold from a combined heat and power plant and comply with air emission and efficiency standards (Province of Nova Scotia, 2010).

In addition to biomass and wind options, small, run-of-river tidal could have potential for implementation on farms, depending on the land and water resources available.

Table 8 shows the average amount NS dairy farmers spent on electricity and total direct energy use of their farms for the given time period.

Table 8: Average energy use on NS dairy farms

Farm size	Average electrical usage (kWh)	Annual electricity expenditure($)	Annual total energy expenditure ($) (electricity, heating and diesel fuel)	Electricity as a percentage of total energy expenditure (%)
Small	22042	2865.47	9734.33	29.44
Medium	42393	5511.12	17446.14	31.59
Large	63953	8313.86	28384.50	29.29

Source: CFFD, 2010

As shown in Table 8, as farm size increases, so does the amount spent on total energy. This demonstrates that as farms grow, which is the trend in the NS dairy sector, more electricity and overall energy will be used per farm unless measure are taken to reduce or conserve energy usage. Electricity use accounts for approximately 30% of total on farm energy use. Therefore, one third of total energy use could be reduced by switching from electricity to renewable electricity sources.

Electricity can be generated by many renewable sources, including solar photovoltaic (PV), hydro, tidal, anaerobic digesters and wind technologies. However all of these technologies are not suitable to be installed on NS dairy farms to generate electricity. Solar PV technologies are still relatively new to Canada, and prices for them are quite high. For example, Ontario's FIT policy attempted to provide a similar return on investment for all renewable technologies, including solar PV, which resulted in high FIT rates for solar technologies. The FIT rate required for rooftop solar PV in Ontario ranged

from 54.9 ¢/kWh for projects under 10kW to 48.7 ¢/kWh for projects over 500 kW in size. The range for ground mounted solar projects is 44.5 ¢/kWh for projects under 10 kW to 34.7 ¢/kWh for projects greater than 5 MW in size. For comparison, the Ontario FIT rate for wind turbines is 11.5 ¢/kWh (Ontario Power Authority, 2012). Yet, in NS, the COMFIT provides no incentive for any type of solar PV. With no incentive from the province to encourage this technology, it is thought that it would not be feasible for NS dairy farms to install solar PV at this time.

In-stream tidal is another means of generating renewable electricity and the NS COMFIT policy does promote small scale in stream tidal technology with a rate of 65.2 ¢/kWh. However tidal technologies are also relatively new and therefore it is thought that the high rate for tidal is to encourage research and development in this area. As well, tidal technology is not commercially available and thus, NS dairy farmers would not be able to install this technology at this point in time. Alsol, tidal is very site specific and not all dairy farms within the province would have the resources necessary to install run-of-river tidal technology. Hydro technologies face the same deterrents, with hydro also being very site specific and with no incentive in the COMFIT policy to promote hydro, NS dairy farms are unlikely to install this technology.

Although there are also no incentives for NS dairy farms to produce biogas through anaerobic digesters, dairy farms would have the resource available, through the manure produced by their cows, to install an anaerobic digester. However previous research in the area by Brown et al. (2007) found that without incentives, anaerobic digesters were not financially feasible for dairy farm in Nova Scotia, unless the farm was milking over 500 cows. In 2011, the average size of a dairy farm within the province was

74 milking cows (Statistics Canada, 2012). Therefore anaerobic digestion was not considered a feasible technology to explore as a renewable energy source to generate electricity.

Wind turbines, however, are a potentially feasible option. The technology is readily available in NS and wind turbines can easily be substituted for conventional electricity generation. As well, the COMFIT rate for small scale wind technology of under 50 kW capacity is 49.9 ¢/kWh. The large scale rate is 13.1 ¢/kWh. As well, there is potential for more farms to have a wind resource available than a tidal or hydro resource, and presently, there are 52 farms within the province of NS interested in using wind energy (NSFA, 2012). Therefore the remainder of the analysis presented examines the possibility of using wind technology for electricity generation.

The available power by wind is determined based on the wind mass (m) where:

$$m = p * v * A \qquad (4.1) \text{ Where:}$$

m is the wind mass

v is average wind velocity

p is the air density

A is the swept area of the turbine blades

t is time

And:

$$p = \ 0.5\ mv^2 \qquad (4.2)$$

Where:

m is wind mass

v is wind velocity

Assuming wind is distributed using a Rayleigh distribution, with a Rayleigh factor of 1.91, the power available in the wind can be found by substitution equation 4.2 into equation 4.1, where:

$$Wind\ power = 0.5 * p * 1.91 * A * v^3 \qquad (4.3)$$

As noted in equation 4.3, velocity is the driving factor behind the available power in the wind since velocity is cubed. Therefore the wind speed will be a major determinant in the feasibility of wind turbines to NS dairy farms. Using the NS Wind Atlas (NSDE, 2012) the average wind speed for NS is assumed to be 5.5 m/s, and this average speed will be used in all feasibility calculations for the various turbines presented.

4.4 CASE STUDY

Using the data presented in Table 8, if an average NS dairy farm were to switch from conventional electricity to utilizing a wind turbine to generate electricity, the electrical savings would be equal to their current electrical expense, or $2,865.47 for small farms, $5,511.12 for medium farms and $8,313.86 for large farms. This would account for a substantial reduction of their total energy expenditure, up to about 30% for all farm sizes. Although this appears to be a considerable amount of savings, wind turbines also tend to be expensive to implement and can range in price anywhere from tens to hundreds of thousands of dollars, depending on the size of the turbine

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(Woofenden and Sagrillo, 2010). As well, investment in wind energy tends to be a long term investment with long payback periods. Therefore the electrical cost savings obtained by implementing a renewable energy source, may or may not offset the cost of implementing a renewable energy source. To explore this further, the following section will analyze three wind turbines: the Gaia-Wind 133-11.8 (Gaia-Wind Limited, 2012) Halus Power System's V-17 turbine (Halus Power Systems, 2012) and Endurance Windpower's E-3120 (Endurance Windpower, 2011). These turbines were selected to represent turbines that could be implemented by all farm sizes to meet their individual electric needs.

A case study of these three turbines, sized to be capable of producing the average amount of energy used for each farm size, will be evaluated to demonstrate the likely simple payback and internal rate of return (IRR) if farmers opted to install a turbine to substitute for their electrical energy purchased from NSPI. IRR is often used to determine the attractiveness of a capital investment to an investor. The higher the IRR, the more attractive the investment is. Simple payback shows how long it takes to recoup the initial capital investment cost. The following assumptions are used to calculate the results:

1. An average wind speed of 5.5 m/s in Truro, NS.

2. Turbine costs came from the 2010 Wind Generator Buyer's Guide (Woofenden and Sagrillo, 2010).

3. Turbine cost is only the initial capital investment cost and does not account for installation, maintenance, hook-up fees or any other cost associated with turbine installation or maintenance.

4. IRR is based on 20 years of generation, with no inflation or change in electrical consumption or usage.

5.   The life of a turbine is assumed to be 20 years, so IRR is also based on a 20 year period.

6.   There is no policy interference, therefore farmers are only offsetting current electrical costs and are not compensated for any excess generation.

Table 9 highlights the results of this analysis:

Table 9: Feasibility of select turbines for small, medium and large farms in NS, if substituted for electricity

Turbine	Farm Size	Output (annual kWh)	Cost of turbine ($)	Simple Payback (yrs)	IRR (%)
Gaia Wind 133-11	Small	35263	51652	18.02	1
Halus Power System V-17	Medium	122375	110000	19.95	0
Endurance windpower E3120	Large	139995	250000	30.07	-4

Source: Own Calculations

As demonstrated in Table 9, the cost of wind turbines is expensive, and payback periods are extremely long for all farm sizes. Assuming that the lifespan of a turbine is 20 years, only the small turbine has a positive IRR, of only 1%. A negative IRR means that the investor will not make money over the lifespan of the project, making the investment unappealing. Wile and Corscadden (2012) found that a return on investment (ROI) of at least 5% is needed to attract investor interest in wind projects.

The results from Table 9 show that it is not financially feasible to implement any of these turbines on dairy farms. However, there are sometimes factors other than financial gain that influence an investor's decision to implement a renewable energy source. These factors can include environmental, marketing or social determinants, which

vary by individual values. However, other factors that can affect IRRs include inflation of electric prices or decreasing costs of technology. For example, if current trends in electric prices continue, the price of electricity twenty years from now will be much higher than it is currently. In the future, this may make the turbines more feasible and IRRs more attractive. The same would occur if technology costs were to decrease (which typically occurs over time as more suppliers enter the market and newer technologies are created).

Also, there has been a major gap in the literature on energy substitution. Chapter 2 discussed the available literature on energy substitution and all authors considered electricity as fixed proportioned, where only electricity can substitute for renewable energy sources. However, in chapter 3, it was found that both heating fuel and diesel are extremely substitutable for electricity, meaning that if technology (i.e. electric motors for tractors) were readily available, a renewable energy source could be used to offset total farm energy use, not just electrical. Thus, as demonstrated in chapter three, all energy categories (heating, diesel fuel and electricity) are substitutable in the long term. This implies that not only could a wind turbine be installed to offset electrical costs, but in the long run, heating and diesel and auto fuels could be substituted with electricity and then the turbine could also offset these energy costs, increasing the total energy offset. If this were the case, then larger turbines could be installed, making it more feasible.

Using identical costs and assumptions as used for Table 9, feasibility is assessed assuming total farm energy (100%) is substitutable, rather than just the electric portion (approximately 30%). This increases the IRR and simple paybacks (Table 10), making wind turbines much more feasible than if wind energy was solely replacing the electrical portion.

Table 10: Feasibility of select turbines for small, medium and large farms in NS, if substituted for total farm energy

Turbine	Farm Size	Output (annual kWh)	Cost ($)	Simple Payback (yrs)	IRR (total energy)
Gaia Wind 133-11	Small	35263	51652	5.31	6%
Halus Power System V-17	Medium	122375	110000	6.31	15%
Endurance Windpower E3120	Large	139995	250000	6.51	10%

Source: Own calculations

As demonstrated in Table 10, the payback period decreases substantially for all farm sizes when total energy use is substituted by a renewable energy source, as opposed to just electrical energy. IRR's also become more attractive, with 6% IRR for small farms, 15% for medium farms and 10% for large farms. It is thought that the reason medium farms is so attractive is because the Halus turbine chosen for the medium farm is quite large and therefore more energy is produced that what is actually needed for mid-sized farms. Since payment is received for excess generation, this is likely why this option is more attractive than it may be if a medium farm were to implement a slightly smaller turbine that would still meet its electrical needs.

4.5 DISCUSSION AND SUGGESTIONS

Table 9 and Table 10 show the attractiveness of wind turbines for different farm sizes. As shown, from a financial viewpoint, without policy interference, wind turbines are not extremely attractive to meet the needs of dairy farms in the province, unless technology becomes available in the long term which would allow total energy (heating and diesel and auto fuels) to be substituted for electricity. This may be possible in the

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long term since electric cars are becoming more readily available in some places worldwide and have potential to become available in NS in the future. Also, electricity as a heat source is possible, if farmers opted to substitute their current heat source (e.g. wood, oil) for electricity. However, it may be a while for some of these technologies to become readily available to allow farmers to switch all energy into electricity and then use a renewable energy source to produce it. Therefore the current feasible renewable energy technology (wind turbines) will be explored to determine if the province is successfully encouraging renewable energy implementation to dairy farmers within the province.

There are many factors that could affect the feasibility of wind turbines, especially the price of electricity. If electrical costs continue to rise (as has been the trend over the past few years), wind turbines may become more appealing to both consumers and to investors. In addition to this, government policies and programs can affect the feasibility of wind turbines, and may be the simplest means for the province to promote renewable energy generation. The feasibility of the three turbines analyzed could change substantially with effective policy measures. NS has begun to encourage efficient and renewable energy generation, through the farm energy programs and policies mentioned in chapter one and four. In addition to these programs, chapter five will explore the COMFIT policy introduced by the provincial government and demonstrate what effects this policy can has on the feasibility of wind turbines implemented by NS farms.

Parts of this chapter have been accepted to be included in the following manuscript: Agriculture's Contribution to the Renewable Energy Sector: Policy and Economics - Do they add up?" By J.N. Mosher and K.W. Corscadden in Renewable and Sustainable Energy Reviews 16(6): 4157-64.[1]

CHAPTER 5: ENERGY POLICY: THE RENEWABLE ELECTRICITY PLAN AND FITS

5.1 DESCRIPTION OF RENEWABLE ENERGY POLICY IN NS

The NS provincial government have set admirable yet ambitious environmental and energy targets to reduce GHG emissions to 10% below 1990 levels by 2020 (Province of Nova Scotia, 2007) and to have 25% and 40% of electricity produced by renewable sources by 2015 and 2020 respectively (Province of Nova Scotia, 2010). Historically, there has been little support for renewable electricity generation in the province, which has led to modest uptake of projects. Before 2010, the only support mechanism for small scale projects was through a net metering program implemented by Nova Scotia Power Inc. – the province's monopoly electricity supplier. This regulation allowed consumers to implement small renewable energy projects with the electricity generated used to offset energy consumed. Therefore the consumer paid for the "net" (electricity consumed less electricity produced) amount used (Nova Scotia Power Inc., 2009a).

The downfall of this regulation (from a consumer perspective) was that if a consumer produced more electricity than they consumed in a year, the consumer was not compensated for their over production and the surplus electricity went back onto the grid. Therefore, it limited the size of installed systems.

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[1]The student conducted the research and wrote this paper.

However, if a consumer produced less than they required, the extra electricity needed was supplied by NSPI, at a cost to the consumer. The net metering regulation only applied to small projects with a generating capacity of less than 100 kW and did not provide payment for excess power generated. This policy also did not allow excess electricity generated to be supplied to surrounding community members within the net metering framework (Nova Scotia Power Inc., 2009a).

On April 23rd, 2010 the provincial government announced the Renewable Electricity Plan that outlined the methods by which the government will move forward with regards to electricity generation (Province of Nova Scotia, 2010). Three scales of renewable electricity generation were provided in this plan: small scale through enhanced net metering, community scale through a community feed in tariff (COMFIT) and large scale through contracts between NSPI and independent power producers (NSDE, 2011a).

Enhanced net metering applies to projects of less than 1 MW to be connected to the distribution grid, where consumers will be paid for excess generation, but the consumer can only install a generator with sufficient capacity to meet the average expected annual energy consumption at their location. COMFIT addresses medium scale RE generation, and applies to projects ranging from 2 MW to 5 MW in size, with a total program cap of 100 MW, connected to the distribution network; and medium and large scale renewable projects continue as they traditionally have with the Utility and Review Board overseeing NSPI's proposed projects and independent power producers bidding for projects through requests for proposals. The two scales that could be utilized by NS dairy farms are net metering and COMFIT. These two will be discussed further in the following sections.

5.2 NET METERING

As mentioned previously, the enhanced net metering policy permits projects of less than 1 MW connected to the distribution network, and will pay farmers for any excess generation, but the farmer can only install a generator with sufficient capacity to meet the average annual energy consumption at their location. An important aspect of this policy is that it will pay for excess generation, which is needed for variable supply. Wind speeds are not constant over time and electricity is not always generated at the same time a farm may have high demands for it. This is especially true with dairy farms since they have high electrical loads twice a day during the milking period. However the turbine may not be generate electricity during those peak periods. Therefore the electrical grid can be used as a storage system, so that farms can take from the electrical grid during periods of high electrical loads, when the turbine may not generate sufficient electricity and it also allows electricity to be put onto the grid by farms during periods of high wind speeds or low electrical loads when the farm cannot utilize all electricity the turbine is producing. This is the basis of the net metering policy, where either the farm pays for any electricity over and above what the turbine produced for a given time period, or the farm is compensated for any excess generation that was supplied to the electrical grid for a given time period.

Although the concept of the net metering policy was substantially enhanced through the payment for any excess generation, the feasibility of farms to utilize this policy has yet to be determined. Table 11 demonstrates the electrical usage of dairy farms in NS, along with the size of turbine that is required to meet the electrical generation requirements for each farm size. Table 11 also demonstrates the electrical

generation that would be required for both 10% and 25% generation above and beyond what is needed by the farm.

Table 11: Electrical requirements for dairy farms in NS based on farm size

Farm Size	Average Annual Electrical Usage (kWh)	Turbine Capacity required (kW)	Production Requirements (kWh)		
			0%	10%	25%
Small	22,042	11.43	22,042	24,246.2	27,552.5
Medium	42,393	21.99	42,393	46,632.3	52,991.25
Large	63,953	33.18	63,953	70,348.3	79,941.25

Source: Own Calculations

Using the same turbines and assumptions used in the case study presented in Chapter 4.4, an analysis of the net metering policy is presented to determine if excess electrical generation would allow the turbines to become feasible for the province's dairy farms to implement.

Table 12 highlights the feasibility of dairy farmers to utilize the net metering policy to install wind turbines on their farms. As Table 12 recaps from Table 9, with the current cost of wind technologies, it is not feasible for NS dairy farms to implement turbines to only meet their electricity generation requirements, where the farm does not produce any extra generation (0% overproduction). However, Table 12 also demonstrates the feasibility of farmers to participate in the net metering policy, if they produced more electricity than what their own farm required and the excess generation was sold back to

the electrical grid. Overproduction was examined at rates of 10% and 25% greater than what was required at each farm size and it was found that even with excess generation, the implementation of these wind turbines were not feasible for either medium or large farms. For small farms, it was slightly feasible at a 10% overproduction, but the payback period is long at 18.03 years with only a 1% IRR. For small farms with 25% excess generation, the payback period was also long, with a 14.4 year payback and 3% IRR.

Table 12: Feasibility of turbines capable of meeting generation requirements for small, medium and large dairy farms in NS

Farm Size	Possible Turbines	Turbine Output (kWh)	Simple Payback (years)			IRR (%)		
			0%	10%	25%	0%	10%	25%
Small	Gaia Wind	35263	18.03	16.39	14.42	1	2	3
Medium	Halus	122375	19.96	18.15	15.97	0	1	2
Large	Endurance E3120	139955	30.07	27.34	24.06	-4	-3	-2

Source: Own Calculation

Although it is somewhat feasible for small farms to implement a wind turbine, overall the current enhanced net metering policy does not provide much incentive for dairy farmers within the province to implement wind technology. Since IRRs were low and payback periods long, many farmers would not consider this a viable option. Therefore, this enhanced net metering policy is not promoting renewable energy technologies to NS dairy farms.

In the future, however, the enhanced net metering policy may become more encouraging, if electrical prices continue to rise. This would be due to the fact that a higher price would be paid for any excess generation sold back to NSPI from overproduction by a farm. Higher prices have the ability to shorten payback periods and increase IRRs. Yet, a higher electrical price also entails farmers paying more for any electricity they had to purchase to supplement their generation (in the case of underproduction). Therefore higher prices would only make this policy more appealing to farmers if they were producing more electricity than what their farm required (overproducing). Another factor that may allow this policy to become more appealing is the price of the turbines. Prices for any technology tend to decrease over time due to advances in technologies. If this were to occur for wind turbines, it would make the payback periods shorter and would increase the IRRs for farmers, therefore encouraging uptake of this policy. However, as the policy currently stands, it is not sufficient to encourage renewable electrical generation by the province's dairy farmers. The next section will review feed-in tariffs (FITs) to determine if the current FIT in NS is promoting renewable energy implementation to farmers.

5.3 FEED IN TARIFFS

RE policy is often determined by the national values, energy profile and current infrastructure in place in a region. There is an explicit relationship between policy goals, programs and technologies (Komor and Bazilian, 2005). A feed-in tariff (FIT) is a policy mechanism used to stimulate investment in RE technologies and is one of the most successful types of RE policy used in the European Union (Meyer, 2003). FITs encourage RE investment by providing financial incentives at a fixed rate per energy unit

for a fixed period of time. This creates investor confidence by guaranteeing rates and minimizing investor risks (Lipp, 2008; Sawin, 2004; Couture and Gagnon, 2010). Some of the characteristics that can influence the rate of the tariff include: technology type, size or application, resource or site, length of payments, how often the policy is reviewed, inflation, adjustment and degression (Gipe, 2006; Mendonça, 2007; Langniss et al., 2009). Wile and Corscadden (2012) found that successful tariffs must provide a reasonable ROI of at least five percent above the generation costs. Tariff rates can also be chosen to stimulate investment in an individual technology (Sawin, 2004), since a higher rate provides more incentive for investment in certain RE projects, however a tariff that is set too high is costly to society and can be a burden to electrical consumers (Lipp, 2008; Klein et al., 2008). Söderholm and Klaassen (2007) have reported that tariffs which are set too high can actually promote installations in areas of low resources (i.e. low wind speeds), reducing the incentive for investors to minimize project costs.

The concept of a FIT policy is simple, yet developing a FIT policy can be a difficult process due to competing policy objectives such as maximizing renewable energy generation, reducing GHG emissions and encouraging investor uptake while minimizing the cost to the rate payer. Most successful FIT policies tend to base tariffs on generation costs (Lipp, 2008; Couture and Gagnon, 2008). Factors considered when setting rates include capital investment and associated costs (licensing etc.), operating and maintenance costs, inflation, interest rates, profit margins and investor confidence (Klein et al., 2008).

Major challenges associated with determining FIT rates include upfront administrative costs, ensuring rates will not be too high or too low to encourage or

discourage investor development and ensuring the policy is simple enough to encourage investors while at the same time allowing for periodic revisions, inflation and degression within the policy. Degression occurs when tariffs are reduced periodically to account for a decrease in costs over time (Burgie and Crandall, 2009) due to the decrease in technology costs as the technologies mature and implementation increases.

Another challenge with setting FIT rates is controlling the total cost of the tariff to society. The cost of the FIT program is usually weighed against economic benefits and the impact new jobs will have on the economy. Capacity limits can be implemented to mitigate the risks of an expensive FIT policy and policies need to be reviewed and updated regularly to ensure the tariff is meeting the policy's objectives (Klein et al., 2008). Revision is typically performed either periodically or adjusted when capacity targets are reached.

5.4 FIT POLICY AND AGRICULTURE

There has been limited research performed on the impact that FITs have had on individual economic sectors or stakeholder groups. The majority of studies of FIT policies use total installed capacity as a measure of success for the policy. However, it can be beneficial to consider the installed capacity by an individual sector, to determine the effect the policy has on different stakeholders in the economy (i.e. consumers, businesses, farmers etc.). Toke et al. (2008) found that the countries that were most successful in local ownership of wind projects (i.e. Germany, Denmark, the Netherlands) have implemented FITs. This section focuses on the impact FITs can have on the agricultural sector, through on-farm renewable energy implementation.

Germany has one of the longest running FIT policies worldwide. In 2009, farmers owned 9% of the total renewable energy generation capacity in Germany (GREA, 2009), primarily through wind and solar installations. German farmers owned nearly nearly 1000 MW of installed solar photovoltaic (PV) capacity in 2009, representing almost one third of the total solar PV installed in the country (Gipe, 2009). Currently, there is over 22 GW of installed solar PV on barn rooftops (Hambrick et al., 2010). In addition to solar PV, German farmers owned about 75% of the total installed wind capacity, some 6500MW (Bolinger, 2001), and are primarily responsible for land that is leased to investors for wind farm installation. Germany also actively cultivates crops for biogas with almost 2 million acres (12%) of arable land used for energy crops (GREA, 2010). It has been suggested by Hambrick et al. (2010) that the success of farm uptake in Germany has been due to successful policy implementation, support from farm co-ops and lobbying groups, rural community engagement and financial institutions awareness and understanding of RE projects.

Denmark is another country that has successfully implemented a FIT that has substantial agricultural participation, with 64% of wind turbines owned by farmers (Toke et al., 2008) and over 60 small farm biogas plants, in addition to 20 large, jointly owned renewable projects (with farmers and investors) in 2003 (Danish Energy Authority, 2003). Other European countries have experienced similar uptake, for example in Austria 6% of farms were involved in RE production in 2005 (OECD, 2009) with 100 biogas plants in operation in 2002 (Walla and Schneeburger, 2005), and in the Netherlands, farmers owned 60% of the installed wind turbines in 2008 (Toke et al., 2008).

European countries adopted FIT policies many years before they appeared in North America, where neither the USA nor Canada has a national FIT policy. In the USA, Florida, Washington State and California have FIT policies and other states such as Oregon, Vermont and Wisconsin have utility run production based incentives similar to FIT policies (Cory et al., 2009). However, in the USA, farmers and individual land owners owned only 1.8%, or 6,387 MW of the total 35,170MW installed wind capacity (Hambrick et al., 2010). Biogas is however a substantial RE industry in USA, with 30% of domestic corn production is used for ethanol (Earley and McKeown, 2009). There is no substantial farm uptake of solar PV industry in the USA, as incentives for farmers are lacking in this area. In relation to wind energy, there appears to be a preference among farmers to lease land to wind investors in order to mitigate risks, costs and tax implications (US GAO, 2004).

Canada has recently implemented FIT policies in two provinces: Ontario and Nova Scotia. These FITs policies are relatively new and have different tariff rates, with Ontario's policy having the highest rate per kWh for solar PV. What impact these policies in Ontario and NS have had on the agricultural industry is yet to be determined. There is however incentives for farmers to participate in Ontario's FIT through a "community adder" which provides a one cent per kilowatt hour supplement in addition to the current FIT rates (Ontario Power Authority, 2010). There are no specific incentives for agricultural participation in NS, leading to the focus of this section of the paper: to review and analyze the newly implemented FIT policy in NS and to consider the potential impact this will have on the uptake of renewable technology by farms.

This section will focus on the recently announced COMFIT policy, that has been introduced to facilitate the installation of renewable technology and help meet the environmental and energy generation targets of the province. There are two alternative streams, for medium scale renewable energy generation: a tidal array FIT and a community based FIT, better known as the COMFIT. The tidal array tariff applies only to in stream tidal projects greater than 0.5 MW and there are no restrictions on applicants. The focus of this paper, however, is on the COMFIT policy. As the name suggests, COMFIT aims to support community based groups including municipalities, Mi'kmaq band councils, co-operatives, not-for-profit organizations, community economic development investment funds (CEDIFs), universities and combined heat and power biomass facilities. Table 12 displays the current COMFIT rates and guaranteed length for approved technologies in NS.

Table 13: COMFIT rates for approved technologies

Technology	FIT Rate ($/MWh)	Length of tariff (years)
Small Wind (≤50kW)	499	20
Large Wind (≥50kW)	131	20
Biomass	175	20
Small scale in-stream tidal	652	20
In-stream tidal	140	20

Source: NS Department of Energy, 2011b

The rates listed in Table 13 demonstrate the province's encouragement for small wind and small scale in-stream tidal. In-stream tidal technology is in the early development stages and it is thought that the high rate implemented for tidal power is to encourage research for this technology. This paper will focus specifically on small wind and the associated regulations. The province's motive for distinguishing between "large"

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wind and "small wind" was based on technology costs and return on equity for investors (NSDE, 2011a), and small wind is designed to encourage involvement by communities. "Small wind" is considered wind projects with a nameplate capacity of less than 50 kW, with the generation output defined at a standardized wind speed of 11 m/s and a turbine swept area of less than 200 m^2 (NSDE, 2011b). The government have adopted as eligible technology, those turbines that are certified by the New York State Energy Research and Development Authority (NYSERDA, 2011). Eligible turbines include eight turbines rated at less than 10 kW, five turbines rated between 10 kW and 20 kW and only two turbines rated between 20 kW and 50 kW (Appendix D). After June 30, 2012, turbines must be certified through the Small Wind Certification Council (Small Wind Certification Council, 2012), which is an independent certification body used by the American Wind Energy Association (AWEA) to standardize the reporting of turbine performance data in compliance with the AWEA Small Wind Turbine Performance and Safety Standard (NSDE, 2011a).

In addition to turbine eligibility, there is a 5 MW provincial cap on COMFIT small wind projects. COMFIT regulations also state that of the 100 small wind projects eligible within the province, there will be a minimum of four per municipality, and a maximum of eight. Projects will be distributed equally throughout the province (NSDE, 2011b).

The agricultural sector has proven to be a substantial investor in RE projects in European countries. However, with the COMFIT restrictions in Nova Scotia, farmers can only participate in COMFIT through the formation of a cooperative which must include at least 25 members and the members must reside within the same municipality. This imposes a considerable barrier for farmer participation in Nova Scotia. A survey

conducted by the Nova Scotia Federation of Agriculture, however, has identified

significant interest from the farming community with fifty-two farms currently

participating in wind assessment projects (NSFA, 2012). As well, farms have a limited

selection of approved turbines with only two approved turbines over 20 kW.

5.5 METHOD OF ANALYSIS

This section considers the impact of technical and regulatory barriers imposed by

the COMFIT policy on the agricultural sector. The results of the NSFA survey and

subsequent lack of project participation by farms indicate the impact of the restriction

that participants are required to form cooperatives. In order to evaluate the impact of

technical restriction three scenarios which have been developed which will demonstrate

the energy output, cost and potential impact of three different turbines based on the

COMFIT rates. The turbines selected for the scenarios are: the Endurance E3120,

manufactured by Endurance Wind Power, which has a nameplate value of 50 kWs and is

currently not an eligible COMFIT turbine due to the swept area size exceeding 200 m^2;

the AOC 15/50 which has a nameplate value of 50 kW is manufactured by Seaforth

Energy Inc. and is eligible for COMFIT; and the Northwind 100 Turbine, which has a

nameplate value of 100 kW, is manufactured by Northern Power Systems and is currently

not approved for COMFIT small wind projects due the nameplate capacity exceeding the

50kW size limit. The Endurance E3120 and the Northwind 100 are, however, both

eligible for the large wind tariff of $131/MWh. To ensure a common analysis platform, a

renewable energy assessment program developed by Natural Resources Canada is used,

RETScreen Clean Energy Project Analysis Software (Natural resources Canada, 2011).

RETScreen is a decision support tool used to evaluate energy production and savings,

costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs).

The three scenarios have been developed to consider four characteristics:

(1)   The variance between the actual energy output versus nameplate capacity

(2)   To determine COMFIT costs to the consumer for various turbines

(3)   To identify the potential GHG offset from COMFIT installations using different turbines

(4)   To provide an estimate of IRR for each turbine

Three scenarios will be presented to address objectives 2 through 4:

Scenario 1   presents the results using the current COMFIT rates for the three turbines: $499/MWh (the small wind rate) for the AOC 15/50 turbine and $131/MWh (the large wind rate) for the Endurance E3120 and Northwind 100 turbines.

Scenario 2   presents the results assuming all three turbines were eligible for small wind rates ($499/MWh).

Scenario 3   presents an advanced FIT to calculate rates for each turbine that would not create an additional financial burden to the consumer and still be attractive to investors.

An average wind speed of 5.5 m/s is assumed in Truro NS and each scenario uses one of the three turbines to generate the 5 MW of small wind capacity available. The remaining assumptions used for the scenarios can be found in Appendix E.

5.6 RESULTS

The results in Table 14 show the output of each of the three models at the standard evaluation wind speed of 11m/s and the assumed average annual wind speed of 5.5 m/s. The first objective is to demonstrate the variance between the actual energy outputs versus nameplate capacity.

Table 14: Variance in turbine output from the manufacturer's nameplate capacity, rated output at a standardized wind speed of 11 m/s and output for a Nova Scotia wind site of 5.5 m/s for various turbine models

Turbine	Manufacturers nameplate (kW)	Swept Area (m^2)	Manufacturers Rated Output at 11 m/s (kW)	CF at 11m/s (%)	Manufacturers Rated Output at 5.5 m/s (kW)	CF at 5.5 m/s (%)
Endurance E3120	50	289.45	48.8	55.8	11.65	27.1
AOC 15/50	50	176.53	42.4	60.4	6.65	29.8
Northwind 100	100	347.21	77.7	51.3	13.7	18.0

Source: Endurance Wind Power, 2012; Northern Power Systems, 2011; Seaforth Energy Inc., 2011 and own calculations

Currently to be eligible for "small wind", the COMFIT regulations stipulate that turbines must have a generating capacity of 50 kW or less at a wind speed of 11 m/s, with a swept area of less than 200 m^2. As illustrated by Table 14, turbine output at a standardized wind speed of 11 m/s is not always equivalent to the output indicated by the

nameplate capacity of the turbine. This is due to the lack of standardized criteria when manufacturers established nameplate capacity. The Northwind 100 has a nameplate capacity of 100 kW yet it is only generates 77.7 kW at 11 m/s. This is due to the fact that the Northwind 100 has been rated at a wind speed of 14.5 m/s (Northern Power Systems, 2011). The AOC 15/50 turbine is considered a 50 kW turbine but it only generates 42.4 kW at 11 m/s (Seaforth Energy Inc., 2011), and the Endurance E3120 rated at 50 kW produces 48.8 kW at 11 m/s, but has a swept area of 289 m^2 (Endurance Wind Power, 2011). The results in Table 14 demonstrates the variance between manufacturer's nameplate capacity and generation capacity based on a standardized method using a standard wind speed of 11 m/s which is currently being used. In addition, actual generation output at 11 m/s and output at a more typical wind speed, which in this case has been selected at 5.5 m/s vary substantially. Capacity factor (CF) is the term used to provide a measure of expected output for a particular turbine given an average annual wind speed and is sometimes referred to as the efficiency (Gipe, 2009). Capacity factor is defined as the ratio of actual energy output to potential energy output if operating at full capacity, for a given time period, equation 5.1:

Capacity Factor =   Actual Annual Energy Produced (kWh)   (5.1)
                              8760hrs x Rated Capacity (kW)

It should also be noted that using a nameplate capacity at a higher wind speed than 11 m/s will actually result in a lower capacity factor at a given wind speed, which may result in the appearance that a turbine is less efficient.

5.6.1 SCENARIO 1

The second objective of the analysis is to determine the consumer costs for

various technologies under the COMFIT program. Table 15 shows the costs for the three

turbine models used in scenario 1. The It is assumed that the cost to the consumer is the

additional cost above the current residential electrical rate. FIT costs are calculated using

the current COMFIT rates of $0.499/kWh for small wind turbines (Endurance E3120 and

AOC 15/50) and $0.131/kWh for the large Northwind 100 turbine. Since eligibility

requirements are based on nameplate capacity, only fifty Northwind 100 turbines are

required to meet the 5 MW cap, as stipulated by the province. At an average wind speed

of 5.5 m/s, and using the lower rate of $0.131/kWh, it would only cost the consumer

$1.02 million to implement the COMFIT program using this turbine. However it is

questionable whether the rate of $0.131/kWh would be attractive for investors. The

results listed in Table 15 show that a simple payback period for this investment would be

over 40 years. If the E-3120 is used at a nameplate capacity of 50 kW, then 100 turbines

would be required to meet the 5MW cap. As shown in Table 15, it is cheaper to the

consumer to implement large turbines at the lower rate of $0.131/kWh, as it would only

cost the province $1.028 million to implement 5MW of the Northwind 100 turbine and

$1.559 million for the Endurance E3120 turbine, whereas the cost for the AOC 15/50 is

$4.341 million. The additional cost to the consumer is calculated assuming 490000

consumers in the province (NSPI, 2001) and a current electrical rate of $0.119/kWh, with

equation 5.2:

Additional	=	Generation from 5MW installed * (COMFIT rate – Current rate)	(5.2)
Consumer		number of electrical consumers	
Cost			

As shown the annual additional consumer cost for the Endurance E3120 and the Northwind 100 is miniscule at $0.29 and $0.19, respectively. The additional consumer cost for the AOC 15/50 is also very small at only $6.75 per year.

Table 15: Output, cost, offset GHG, additional consumer costs for three turbines implemented in Truro NS at a height of 30 m and average wind speed of 5.5 m/s at CURRENT COMFIT rates

Turbine	Output (GWh from 5 MW of capacity)	FIT cost for 5 MW installed (million $)	Additional Consumer Cost ($ per consumer per year)	Offset GHG for 5MW installed	Simple Payback (years)	IRR at a wind speed of 5 m/s (%)
Endurance E3120	11.9	1.559	0.29	8570	16.1	Negative
AOC15/50	8.7	4.341	6.75	6470	9.5	9.4
Northwind 100	13.7	1.028	0.19	5685	41.8	Negative

Source: Own Calculations

The third objective was to identify the potential GHG offset from the COMFIT installations for each of the three turbines. RETScreen software provides estimates of emission reduction and considers three main GHGs: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The baseline assumption is that the GHGs offset are for the NS region, which has substantial use of coal for electricity generation. Since coal is a significant contributor to GHG emissions, it is a contributing factor to the high renewable targets set for the province, as any electricity generated by wind offsets some electricity generated by coal and results in significant GHG reductions. As demonstrated in Table

15, the Endurance E3120 is more expensive to society, resulting in increased output and more GHG offset with 8750 tCO2 equivalents offset by the Endurance E3120 and only 6470 tCO2 equivalents offset by the AOC 15/50. The Northwind 100 would result in 5685 tCO2 equivalents offset by 5 MW of installed capacity

The fourth objective was to provide an estimated IRR for each technology. IRR are often used to determine the attractiveness of a capital investment to an investor. The higher the IRR, the more attractive the investment is. As shown in Table 15, The AOC 15/50 is the only turbine with a positive IRR at 9.4%, and the Endurance E3120 and Northwind 100 turbines are not attractive to investors with negative IRRs, meaning investors will not make money over the lifetime of this investment. Therefore, although the Endurance E3120 and Northwind 100 turbines are less expensive for the consumer, they are still not attractive to investors as they both have long payback periods and negative IRRs. With this scenario, only the AOC 15/50 turbine is reasonable for both the investor and consumer, with a payback of 9.5 years and an IRR of 9.4% an additional consumer cost of $6.75 per consumer per year.

5.6.2 SCENARIO 2

Scenario 2 addresses the same three objectives but considers the effects if all three turbines were eligible for small wind rates, not just the AOC15/50. This calculates the cost at a rate of $0.499/kWh for all three turbines.

Table 16: Output, cost, offset GHG, additional consumer costs for three turbines implemented in Truro, NS at a height of 30 m and average wind speed of 5.5 m/s at small scale COMFIT rates.

Turbine	Output (GWh from 5 MW)	FIT cost for 5MW installed (million $)	Additional Consumer Cost (annual dollars per consumer)	Offset GHG for 5MW installed	Simple Payback (years)	IRR at a wind speed of 5 m/s (%)
E-3120	11.9	5.938	9.23	8570	4.2	45.0
AOC 15/50	8.7	4.341	6.75	6470	9.5	9.4
Northwind 100	13.7	3.917	6.09	5685	7.0	20.6

Source: Own Calculations

Table 16 demonstrates the effect of alleviating the size restrictions to allow all three turbines be eligible for small wind COMFIT rates of $0.499/kWh. This increased the cost to the province for five megawatts of installed capacity for both the Endurance E3120 and Northwind 100 turbines to $5.938 million and $3.917 million, respectively. The additional consumer costs also increased to $9.23 per consumer per year for the Endurance E3120 and to $6.09 per consumer per year for the Northwind 100, which makes them more than the additional cost for the AOC 15/50. Although the Endurance E3120 and Northwind 100 turbines became more expensive to consumers, they also became more appealing to investors as the Endurance E3120 turbine went from having a 16.1 year payback with a rate of $0.131/kWh to a payback of 4.2 years at $0.499/kWh. The payback for the Northwind 100 turbine also decreased from 41.8 to only 7.0 years. As well, the IRRs for the Endurance E3120 and Northwind 100 turbines are now higher than that of the AOC 15/50 since these turbines have higher generating outputs. Although this scenario is very attractive to investors, it does come at an increased cost to the province of $5.938 million for the Endurance E3120 leading to a slightly increased

additional consumer cost of $9.23 annually versus the $6.75 for the AOC 15/50 annually. The output and offset GHGs have not changed from scenario one. Therefore, this scenario promotes more efficient turbines to investors but is more costly to consumers, and has no effect on the output or GHGs, yet drastic changes with payback and IRRs.

5.6.3 SCENARIO 3

Scenario 3 presents a policy tool that has been used in other areas including Germany, France and Switzerland (Gipe, 2011), called an advanced or sliding scale FIT. This FIT would base rates on output generation and would remove the need to have the size regulations. With this advanced FIT, efficient wind turbines are promoted to investors, at no additional cost to the province or consumer. This is done by differentiating the tariff based on output generated. So as generation increases, tariff rates decrease allowing for overall cost to remain the same. However as generation increases there are additional benefits for investors to implement efficient turbines and the amount of offset GHGs increases. Typically the objective of this type of tariff is to reduce development pressure in the windiest areas, usually with a five year grace period to determine production and FIT rates. This correlates with NS's community approach to their FIT, as it would encourage development in all areas of the province. As well with this method, it could allow for more efficient turbines to be eligible without increasing costs to consumers as investors would receive lower rates for higher production (see Table 17).

Table 17 presents the results for Scenario 3. As shown, the cost to the province is held steady at 4.341 million (the cost of the AOC 15/50 turbine from scenario 1), but the

rates paid vary depending on output generated. The Northwind 100 would receive the highest tariff rate at $0.553/kWh and the Endurance E3120 would receive a rate of $0.365/kWh and the rate for the AOC 15/50 would remain the same at $0.499/kWh. Although the Northwind 100 would receive the highest rate payment, the Endurance E3120 turbine is the best option as it has the lowest payback period of 5.8 years and the highest IRR of 29%. As well it is the most efficient turbine and 8570 tCO2 equivalents would be offset annually. The Northwind 100 would receive the highest FIT rate at $0.553/kWh, but this turbine is not as attractive to investors since this larger turbine is more expensive creating a payback period of 10.7 years and an IRR of 25.3%. With this method the AOC 15/50 is the least attractive option, with no change in output or investment options from scenario 1, but still has more offset GHGs than the Northwind 100.

Table 17: Sliding scale FIT rates to keep COMFIT costs the same to the province

Turbine	Output (GWh from 5 MW)	FIT cost for 5MW installed (million $)	FIT tariff rate ($/kWh)	Offset GHG for 5MW installed	Simple Payback (years)	IRR at a wind speed of 5 m/s (%)
E-3120	11.9	4.341	0.365	8570	5.8	29.0
AOC15/50	8.7	4.341	0.499	6470	9.5	5.3
Northwind 100	13.7	4.341	0.553	5685	6.2	25.3

Source: Own Calculations

5.7 DISCUSSION AND SUGGESTIONS

The implementation of the COMFIT policy has been beneficial for the province in terms of trying to develop and implement a renewable energy policy. Within the Renewable Energy Plan (Province of Nova Scotia, 2010), it has been determined that the policy will be revised in two years after implementation, leading to the discussion of issues to be considered for amendment. The first issue relates to eligibility for ownership and the barriers to entry. Allowing small, private investors the opportunity to partake in wind investments has substantially increased wind power deployment in other countries, especially Denmark (Pettersson et al., 2010), yet with the current COMFIT policy, farmers are not eligible for entry unless they form a cooperative of at least 25 members. Furthermore, it has been determined that farmers typically have the resources needed for renewable energy installations (e.g. land) (Lipp, 2007). It was demonstrated that farmers have been substantial investors in renewable energy in other areas of the world (GREA, 2009; Toke, 2005; Bolinger, 2001) and there are currently fifty-two NS farmers expressing interest to partake in this policy (NSFA, 2012). In 2008, the average net farm income for NS dairy farms was $63,731 (CFFD, 2010). A wind turbine could be a substantial means of extra income for a farmer in NS, if the current FIT rates were used with the AOC 15/50 turbine an annual income of $17,034 could be generated, or 26.7% of current net income could be generated by wind energy. This could be a significant mode of extra earnings for NS dairy farmers to aid in the viability and sustainability in an industry with a trend of rising input costs. By excluding farmers from easily taking part in this policy, the province may be losing an important group of potential investors and an

opportunity to help an important economic industry. It is recommended that the COMFIT policy be amended to allow farmers to be individually eligible for COMFIT.

The second issue arising from the analysis relates to balancing competing policy objectives. Three major objectives have been considered in the scenarios: maximizing renewable energy generation and GHG emissions offset, while at the same time providing a decent IRR for investors and doing so at the lowest cost to the province and consumer (see Figure 8).
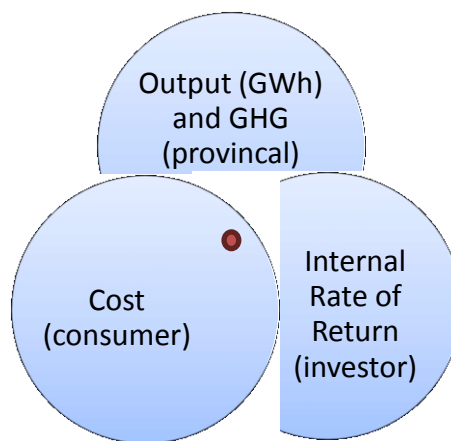
Figure 8: Advanced FIT balance of policy objectives

Figure 8 highlights the competing policy objectives, with a very small window for variance within this model, because if not found in the overlapping area, not all three of these objectives will be maximized to their full potential.

To balance these objectives, the criteria for approving wind turbines should be reassessed to allow more efficient turbines based on output at a standardized wind speed (not nameplate value) and rated capacity based on capacity factor and the manufacturer's

output specification. This will allow for increased output per turbine which will maximize offset GHG emissions. As well this minimizes locations needed for turbine installations which allow more prime wind speed areas to be remain for future use.

The second FIT policy objective to balance relates IRR received by investors. A ROI of at least 5% is needed to attract investor interest (Wile and Corscadden, 2012). The IRR has to be balanced to ensure that it is not over priced which can cause too great of a financial burden to consumers, yet it must be large enough to encourage investment. The current COMFIT rates appear to achieve this balance for the only turbine analyzed that is eligible, the AOC 15/50. However if other turbines were eligible for COMFIT there is potential for them to be even more attractive to investors, increasing the competition between wind turbine suppliers.

The third policy objective to balance is to minimize the cost to the province and consumer. As discussed with the sliding scale FIT, the cost to the province can be kept the same, yet alternative turbines can be promoted. This would allow costs to remain the same, regardless of the turbine output capacity, yet it promotes a range of turbines to investors, increasing the attractiveness of projects and increasing the amount of offset GHGs. It is highly recommended that a sliding scale FIT be considered when revising the current COMFIT policy.

5.0 CONCLUSIONS

This section reviews the enhanced net metering and COMFIT policy in NS as implemented through the renewable electricity plan (Province of Nova Scotia, 2010). It also provides comparison between three turbines to demonstrate the variance in

nameplate values and actual turbine performance which highlights the need for a standardization of eligible turbines. When the COMFIT policy is to be reviewed, areas of improvement are suggested for consideration when amending the policy. As shown, the enhanced net metering policy is not currently useful for dairy farms. Therefore, areas for policy improvement include the requirements for COMFIT eligibility, where it was found farmers are only eligible through the formation of a co-operative, which is a barrier to farmer participation. As well, a review of COMFIT policy objectives could allow for a more balanced approach which could include simultaneously maximizing generation and offset GHG emissions while encouraging investor uptake yet minimizing costs to consumers. This can prove to be tricky and it is suggested that an advanced FIT (Gipe, 2011) may be needed to encourage efficient turbine use and continue to keep consumer costs minimized.

CHAPTER 6: GENERAL CONCLUSIONS

Overall it has been determined, using a translog cost function as a means to calculate the Allen/Uzawa and Morishima elasticities of substitution, that there is substitutability between energy sources on NS dairy farms at both the upper and lower levels. Upper level substitution implies that the different energy categories that make up the overall farm energy use (electricity, heating and diesel fuel) can be substituted for each other. Heating fuel was found to be extremely substitutable for all farm sizes and it is thought that this is because the technologies are currently available to allow farmers to switch out of (into) heating fuel from (out of) electricity or diesel and auto fuels. In addition it was found that in the long run, since all energy sub-groups were substitutes, if or when technologies become available, farmers could easily switch out of (into) any other energy source, and that management decisions could be based on prices of these energy sources (rather than depend on available technology).

Wind energy technologies were the only technologies examined, due to the fact that currently renewable technologies for heating and diesel and auto fuel are not readily available for NS dairy farm use. As well, it was determined that in NS, wind turbines are currently the only technology that is somewhat viable (depending on policy mechanisms in place) to replace conventionally generated electricity. Therefore wind turbines were thoroughly examined in relation to current policy tools.

Implementation of wind turbines on dairy farms in NS using the net metering policy was found to be non-viable for all farm sizes. This was due to long payback periods and low IRRs. The small dairy farm was the only sized farm that had a positive IRR, but it was only of 1%. Positive outcomes are that in the long term all energy sources

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are substitutable, indicating that if farms were to switch all energy on farm into electric energy and use renewable energy technologies to supply their total farm energy, it made the enhanced net metering policy much more appealing as it substantially lowered payback periods and increased IRRs. Therefore, energy substitutability could become very important in the future as the shift from oil based products (e.g. diesel) into electricity becomes more apparent. This highlights potential for the development of electric batteries and storage systems that would be able to run farm machinery and equipment such as tractors, tillage and haying equipment.

Other policy mechanisms in place in the province were also examined to determine if they are useful to NS dairy farms. It was found that the COMFIT policy is also not very appealing to dairy farmers, even though it is farms that tend to have the resources necessary for renewable energy implementation. This policy was found to be unattractive since farmers are only eligible if they are part of a co-operative of at least 25 members, all of which must reside within the same municipality, which proves to be a substantial deterrent to farm eligibility. As well, the eligibility of turbines needs to be re-examined, since few turbines are eligible, and more efficient turbines increased the feasibility of farm implementation. In general, the COMFIT policy objectives should be reviewed to better balance the policy objectives of minimizing cost to the consumer, while maximizing output generation and offset GHGs for the province while providing a decent IRR for the investor. A sliding scale FIT is presented as an alternative to the current FIT policy, which would encourage efficient turbine use, while continuing to keep consumer costs minimized.

It is recommended that the net metering policy continue to compensate participants for any excess generation, to allow for variable generation. Also, to encourage farm uptake of this policy, it is recommended that turbines larger than what is required by the farm be eligible to install, provided the turbine is under the 1 MW capacity limit. This would allow individual farms to participate in this program and be compensated for their excess generation (at a rate much under that of the COMFIT policy), and it would encourage farm implementation of wind turbines.

It is recommended for the COMFIT policy, that eligibility requirements for farmers be re-examined to allow individual farms to be eligible, since farms tend to be located in rural communities and often have resources available to install renewable energy technologies. As well, turbine eligibility should be reassessed to promote efficient turbine installations. It is suggested that a sliding scale FIT would promote efficient turbine use, minimize cost to consumers all while encouraging investor uptake. This type of policy should be considered during the revision stages of the COMFIT policy.

Future research in this field could include a sensitivity analysis for the elasticities of substitution on NS dairy farms. This would allow determination of exactly what sized dairy farm is required to make wind turbines feasible, with current technology and electicity rates. Also, a sensitivity analysis with respect to the price of wind turbines could be performed to determine at what technology price wind turbines would become feasible for each size of dairy farm in NS to implement. As well, farm types other than dairy could be assessed to determine if substitution rates are similar across all farm types within the province and to determine if the feasibility of wind technologies varies based on farm type. Also, policy analysis could be performed on other farm sectors to

determine if all NS agricultural sectors are facing similar policy influences. This would

provide a more broad view of the feasibility of wind turbines within the entire NS

agricultural sector, which would allow policy makers to base renewable energy policy

initiatives towards the agricultural sector, rather than solely the dairy sector, as suggested

in this research.

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APPENDIX A: ALLEN/UZAWA AND MORISHIMA ELASTICITY OF SUBSTITUTION MATRIX FOR SMALL DAIRY FARMS IN NS

Allen/Uzawa Elasticity of Substitution Matrix - Small farms							
Quantity	Price ($)						
	Diesel and Auto Fuel	Electricity	Heating	Fertilizer	Feed	Machinery	Salaries
Diesel and Auto Fuel	-9.92	-0.79	-14.49	0.63	3.22	0.91	3.64
Electricity	-0.79	-20.93	-0.83	-3.66	8.20	1.65	3.11
Heating	-14.49	-0.83	-1004.39	-4.57	5.93	5.36	7.68
Fertilizer	0.63	-3.66	-4.57	-7.65	1.26	1.40	3.13
Feed	3.22	8.20	5.93	1.26	-213.73	1.50	-2.15
Machinery	0.91	1.65	5.36	1.40	1.50	-5.46	1.35
Salaries	3.64	3.11	7.68	3.13	-2.15	1.35	-13.57

Morishima Elasticity of Substitution Matrix - Small Farms							
	Price ($)						
Quantity	Diesel and Auto Fuel	Electricity	Heating	Fertilizer	Feed	Machinery	Salaries
Diesel and Auto Fuel	0.00	3.26	-0.36	1.94	3.11	0.50	0.26
Electricity	1.58	0.00	1.59	3.18	6.88	1.05	0.45
Heating	77.56	358.17	0.00	184.19	238.80	46.74	19.03
Fertilizer	0.65	1.42	0.24	0.00	2.11	0.42	0.20
Feed	17.00	79.21	17.37	39.61	0.00	9.96	3.98
Machinery	0.50	2.54	0.86	1.26	1.64	0.00	0.13
Salaries	1.35	5.96	1.68	3.08	2.70	0.69	0.00

Source: Own calculations

APPENDIX B: ALLEN/UZAWA AND MORISHIMA ELASTICITY OF SUBSTITUTION MATRIX FOR MEDIUM SIZED DAIRY FARMS IN NS

Allen/Uzawa Elasticity of Substitution Matrix - Medium farms

Quantity	Price ($)						
	Diesel and Auto Fuel	Electricity	Heating	Fertilizer	Feed	Machinery	Salaries
Diesel and Auto Fuel	-13.58	-2.44	-23.86	0.18	3.30	0.89	3.95
Electricity	-2.44	-34.23	-6.25	-6.54	7.95	1.99	3.88
Heating	-23.86	-6.25	-70430.26	-7.12	7.79	7.23	10.03
Fertilizer	0.18	-6.54	-7.12	-10.97	1.83	1.68	3.86
Feed	3.30	7.95	7.79	1.83	-7.38	1.21	-1.09
Machinery	0.89	1.99	7.23	1.68	1.21	-6.29	1.20
Salaries	3.95	3.88	10.03	3.86	-1.09	1.20	-6.62

Morishima Elasticity of Substitution Matrix - Medium farms

Quantity	Price ($)						
	Diesel and Auto Fuel	Electricity	Heating	Fertilizer	Feed	Machinery	Salaries
Diesel and Auto Fuel	0.00	4.49	-0.63	2.24	4.43	0.49	0.18
Electricity	2.13	0.00	1.70	4.52	11.07	1.22	0.38
Heating	4714.41	28362.28	0.00	11482.77	18493.16	2380.43	705.28
Fertilizer	0.75	1.78	0.23	0.00	3.36	0.43	0.15
Feed	0.72	6.17	0.92	1.50	0.00	0.29	0.06
Machinery	0.48	3.33	0.82	1.30	1.97	0.00	0.07
Salaries	0.71	4.23	1.01	1.71	1.45	0.26	0.00

Source: Own calculations

APPENDIX C: ALLEN/UZAWA AND MORISHIMA ELASTICITY OF SUBSTITUTION MATRIX FOR LARGE DAIRY FARMS IN NS

Allen/Uzawa Elasticity of Substitution Matrix - Large farms

Quantity	Price ($)						
	Diesel and Auto Fuel	Electricity	Heating	Fertilizer	Feed	Machinery	Salaries
Diesel and Auto Fuel	-14.75	-3.07	-32.53	-0.06	3.46	0.89	4.12
Electricity	-3.07	-37.99	-9.94	-7.49	8.23	2.09	4.17
Heating	-32.53	-9.94	-4054.67	-14.76	9.99	9.72	13.46
Fertilizer	-0.06	-7.49	-14.76	-12.02	2.01	1.75	4.08
Feed	3.46	8.23	9.99	2.01	-6.31	1.19	-1.09
Machinery	0.89	2.09	9.72	1.75	1.19	-6.45	1.18
Salaries	4.12	4.17	13.46	4.08	-1.09	1.18	-6.51

Morishima Elasticity of Substitution Matrix for large farms

Quantity	Price ($)						
	Diesel and Auto Fuel	Electricity	Heating	Fertilizer	Feed	Machinery	Salaries
Diesel and Auto Fuel	0.00	4.40	-1.04	2.24	5.55	0.45	0.16
Electricity	2.44	0.00	1.64	4.66	14.08	1.15	0.36
Heating	281.15	1524.70	0.00	617.60	1238.26	117.12	34.32
Fertilizer	0.84	1.71	-0.16	0.00	4.28	0.40	0.14
Feed	0.68	5.48	0.95	1.27	0.00	0.22	0.04
Machinery	0.51	3.22	0.94	1.25	2.33	0.00	0.06
Salaries	0.74	4.03	1.17	1.62	1.65	0.22	0.00

APPENDIX D: NYSERDA APPROVED TURBINES FOR COMFIT ELIGIBILITY BEFORE JUNE 30, 2012

Manufacturer	Model	Rated power (kW at 11 m/s)	Swept Area (m^2)	NS COMFIT Approved
ACSA	A 27	181.00	572.49	
Aerostar	6 meter	7.49	28.30	√
Bergey Windpower	BWC XL.1	1.00	4.90	
Bergey Windpower	BWC EXCEL-S	8.86	38.58	√
Cascade Renewable Energy	Swift Mark II	0.92	3.57	
Endurance Wind Power	S-343	5.20	31.86	√
Endurance Wind Power	E-3120 (Three phase)	54.80	289.45	
Endurance Window Power	E-3120 (single phase)	48.00	289.45	
Enertech	E13	34.00	141.19	√
Eoltec	Scirocco E5.6-6	5.72	24.69	√
Fortis	Montana 3.1m	2.46	7.59	
Fortis	Alize 7.1m	8.59	39.59	√
Gaia-Wind	11kW Wind Turbine	11.80	132.35	√
Northern Power Systems	North Wind 100	77.70	347.21	
Proven Energy	Proven 7	2.50	9.64	
Proven Energy	Proven 11	6.00	23.63	√
Proven Energy	Proven 35	12.80	56.77	√
REDriven, Inc.	FD 6.4-5000	5.50	33.09	√
REDriven, Inc.	FD 8.0-10K	11.00	50.83	√
REDriven, Inc.	FD 10.0-20K	14.00	119.62	√
Seaforth Energy	AOC 15/50	42.40	176.53	√
Southwest Windpower	Whisper 200	0.98	5.91	
Southwest Windpower	Skystream 3.7	2.24	10.50	
Southwest Windpower	Whisper 500	3.00	16.41	√
Vergnet	GEV	243.00	804.04	
Wind Energy Solutions	Tulipo	2.63	19.61	
Wind Energy Solutions	WES 18	63.80	253.87	

Manufacturer	Model	Rated power (kW at 11 m/s)	Swept Area (m²)	NS COMFIT Approved
Wind Energy Solutions	WES 30	179.00	706.14	
Wind Turbine Industries	Jacobs 31.20	16.97	70.08	√
Xzeres Wind	110	2.50	10.15	
Xzeres Wind	442	9.17	40.62	

Source: NYSERDA, 2011.

APPENDIX E: RETSCREEN ASSUMPTIONS

(1)   Location is in Truro, N.S. with an annual wind speed of 5.5 m/s at a height of 30 meters.

(2)   Losses included array losses of 7%, airfoil losses of 3%, miscellaneous losses of 5% and 94% availability.

(3)   Turbine costs were assumed to be the following, and estimates are from each of the manufacturers:
        Endurance E3120: $270,000
        AOC 15/50: $351,000
        Northwind 100: $513,000

Included in these turbine costs were a connection cost of 8% and maintenance cost of 2%.

(4)   Fuel cost escalation rate, inflation rate and discount rate of 2% each.

(5)   Project lifetime is assumed to be 20 years.

(6)   Projects are assumed to have a debt ratio of 60%, at an interest rate of 7% for a term of 20 years.

(7)   It is assumed there are 490000 electrical consumers in the province of NS.

(8)   Additional consumer cost is calculated assuming a current electrical rate of $0.119 per kilowatt hour.

APPENDIX F: COPYRIGHT PERMISSION LETTER

January 27, 2012

Renewable & Sustainable Energy Reviews,

Re: Agriculture Contribution to Renewable Energy Sector: Policy and Economics - Do they add up?

    I am preparing my Master of Science in Agriculture thesis for submission to the Faculty of Graduate Studies at Dalhousie University, Halifax, Nova Scotia, Canada. If published, I am seeking your permission to include a manuscript version of the following paper as a chapter in the thesis:

    "Agriculture's Contribution to the Renewable Energy Sector: Policy and Economics - Do they add up?" By J.N. Mosher and K.W. Corscadden in Renewable and Sustainable Energy Reviews 16(6): 4157-64.

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Yours sincerely,
Jaclyn Mosher

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Name: Lawrence L. Kazmerski
Title: Editor in Chief, Renewable and Sustainable Energy Reviews
Signature: [cid:C8084129-113F-4E04-BBEC-08547D86B52D]
Date: February 8, 2011